NORTH CAROLINA INTERAGENCY LEADERSHIP TEAM

MOBILITY
ECONOMIC VITALITY
ENVIRONMENTAL PROTECTION

CLIMATE READY NORTH CAROLINA
Building a Resilient Future

2012

Statement of Support

Since 2009, the North Carolina Interagency Leadership Team (ILT) has been looking at how multiple government agencies could consider potential climate and extreme weather event impacts on their areas of responsibility. In March, 2010, the ILT hosted a workshop "Planning for North Carolina's Future: Ask the Climate Question." Four hundred-forty individuals participated in this workshop.

To consider risks and vulnerabilities related to changes in the climate and to build resilience, the ILT promotes collaborative and integrated planning at the federal, state and local levels. Planners, engineers and policy-makers will need to have the best information, as it evolves, to consider and evaluate strategies to ensure limited funding is used cost effectively to achieve overall site, locality, resources and infrastructure goals and objectives. When making decisions, it will be essential to have the best information available to help practitioners as they "ask the climate question" in all planning areas.

Because this ILT project focuses on North Carolina, the effort has been led by the state agencies, while being supported by the federal agencies. Participating state agencies are the North Carolina Departments of Environment and Natural Resources, Transportation, Commerce, Cultural Resources, Agriculture and Consumer Services, and the Wildlife Resources Commission. The report also includes contributions from the Division of Emergency Management (N.C. Department of Public Safety), Division of Public Health (N.C. Department of Health and Human Services), and the N.C. Department of Insurance. Federal agencies who participated in our collaborative process and who contributed to the report include the U.S. Environmental Protection Agency, Federal Highway Administration, U.S. Department of Commerce/NOAA Fisheries, and U.S. Fish and Wildlife Service; although not authorized to officially endorse such a report on behalf of the U.S. Army, a Wilmington District, U.S. Army Corps of Engineers liaison participated in ILT meetings in an advisory capacity during the development of the report.

The Climate-Ready North Carolina strategy discusses how our state can proactively prepare for projected impacts of climate variability and weather extremes on our economy, infrastructure and natural resources. The strategy outlined in this report provides a framework for collaboratively planning an integrated climate adaptation response for North Carolina. While further effort will be needed, it represents a step toward protecting our state from climate-related hazards.

This strategy neither deals with greenhouse gas reduction efforts nor recommends any new regulations. Further, by supporting this report, the ILT agencies are in no way executing any authorities, approvals, or allowances with which their agencies are charged. Nothing in this report is intended to diminish, modify or otherwise affect the statutory or regulatory authorities of the agencies involved.

Through the strategies outlined in this report, the N.C. Interagency Leadership Team will continue to work together in support of resilient communities across North Carolina.

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To learn more about the NC Interagency Leadership Team or for more information about this report, please visit **www.NCILT.org**.

Executive Summary

This report was developed by the North Carolina Interagency Leadership Team (ILT), a group of eleven state and federal agencies, to communicate to planners and engineers, working for the public and private sectors, about the potential effects and risks due to changes in climate and extreme weather events, as well as strategies for considering those effects and risks in planning, design and implementation of projects.

As Ryan Boyles, North Carolina's state climatologist with the State Climate Office of North Carolina, explains, "Since North Carolina already experiences almost every kind of severe weather and climate, and that our best science suggests these events will not become less severe (and may become worse), our State can do a lot to manage future risk by taking steps to reduce our vulnerability to current hazards." Obviously, we cannot predict the future with 100% certainty in any area of human concern, but we can plan so we can avoid unpleasant outcomes whenever possible. If the weather forecaster says it may rain, we grab our umbrella. If we live in a floodplain, we take out a flood insurance policy on our home. It is simply prudent to evaluate our risk and plan accordingly.

Each of the most likely climate impacts—increased drought, increased and more intense precipitation, heat waves, hurricanes, and rising sea level—are expected to have substantial consequences for our state's coastal and cultural resources, transportation and other infrastructure, water supplies, agriculture, natural systems, public health, and our citizens' homes and livelihoods. (U.S. Global Change Research Program, 2009)

The ILT agencies and their partners examined how multiple government agencies could consider potential climate- and weather-related impacts to their areas of responsibility, and developed a coordinated climate adaptation framework. The emphasis is on practical, economically feasible options that can be undertaken by state agencies, working with willing partners at local, regional and federal levels. These possible actions could be integrated into existing planning processes, priorities and standard operating procedures.

The strategies are intended to address common concerns across sectors and regions, and to serve as a resource to support decisions. Early efforts concentrate on adaptive responses that build on existing momentum using current resources, focus on "no-regrets" actions that are good to do for other reasons beyond climate adaptation, and show tangible results and responsible use of tax dollars.

Overarching cross-sector strategies were recommended by the ILT for implementation. These are:

1. Promote comprehensive adaptation planning among state agencies.
2. Facilitate communication and education to support local, regional and state planning efforts.
3. Collaborate with partners to provide relevant information for decision making.
4. Encourage broad collaboration and partnerships to leverage resources.
5. Partner with communities to facilitate local climate adaptation efforts.

6. Refine adaptation strategies as information becomes available and tools improve.

These broad strategies will enable our state to be better prepared as we build North Carolina's resilience to potential threats. By implementing a strategic and well-considered approach to prepare and plan for adverse weather events, we can help safeguard both human systems and natural resources to support the citizens and communities across our state. Proactively addressing these vulnerabilities could substantially reduce the financial costs of responding to climate-related natural disasters.

Chapter 1: Introduction

North Carolinians are at risk from increasing climate-related hazards. In recent years, our state has experienced a number of extreme weather and climate events, as well as noteworthy variability across seasons. North Carolina experiences all possible severe weather categories (with the exception of monsoons), and is reported by the National Climatic Data Center as one of the states experiencing the most billion-dollar weather/climate disasters. While uncertainty exists about how much our climate may change in the future, these trends provide good reasons to be concerned about how well prepared we may be to respond to disruptions caused by severe weather events.

According to the U.S. Global Change Research Program, the major climate-related challenges projected for North Carolina include increased air and water temperature, inundation from rising sea levels, more frequent and intense heat waves, increased hurricane intensity, and altered rainfall patterns resulting in both more droughts and more flooding. These natural hazards are not new, but over time they are expected to increase in severity or frequency.

These projected challenges from extreme weather and climate events are expected to have substantial consequences to our state's coastal and cultural resources, transportation and other infrastructure, water supplies, agriculture, natural systems, public health, and our citizens' homes and livelihoods.

Because these challenges could have significant impacts on our state, it is important that North Carolina develop a strategy to reduce its vulnerability and enhance its resilience. North Carolina's people and economic assets already experience significant economic losses from weather- and climate-related disasters. Although our vulnerability cannot be eliminated completely, climate adaptation and disaster risk management can reduce exposure and vulnerability to the potential adverse impacts of climate disruption.

By implementing a strategic and well-considered approach to prepare and plan for adverse events, we can help safeguard both human systems and natural resources to support the citizens of our state. Proactively addressing these vulnerabilities could substantially reduce both the financial costs and emotional strain of responding to climate-related natural disasters.

Recommendations for Climate Adaptation Planning in North Carolina

Since the turn of the 21st century, there has been a growing awareness of the need to address the climate-related threats to our state's health and safety. North Carolina's state government and elected officials have undertaken a series of efforts over the last few years to address these concerns.

These include:

- Climate Action Plan Advisory Group (CAPAG) http://www.ncclimatechange.us/capag.cfm
- Legislative Commission on Global Climate Change http://www.ncleg.net/gascripts/DocumentSites/browseDocSite.asp?nID=14
- Department of Environment and Natural Resources http://www.climatechange.nc.gov/

More information about each of these is included in Appendix H: Earlier Climate Efforts.

Developing the Climate-Ready North Carolina Strategy

Building on these previous endeavors, the North Carolina Interagency Leadership Team (ILT) began looking at how multiple government agencies could consider potential climate- and weather-related impacts to their areas of responsibility. The N.C. Interagency Leadership Team [see Table 1] is a group made up of five federal and six state agencies that are committed to integrating planning for the state's transportation system with natural and cultural resource protection, along with economic development.

NOTE: While some of these earlier endeavors looked at reduction of greenhouse gases in the atmosphere, the Climate-Ready North Carolina Strategy does not focus on greenhouse gas reduction efforts, or recommend imposing new regulations. This strategy only considers how our state could proactively prepare for potential adverse impacts of climate variability and weather extremes.

This effort is simply the beginning of the work to collaboratively plan an integrated climate adaptation response for North Carolina. While further work will be needed, this initial strategy represents a major step toward protecting our state from climate-related hazards. The strategy outlined in this report is the product of that collaborative effort whose process and product was advised by numerous state and federal agencies.

Table 1*

NORTH CAROLINA INTERAGENCY LEADERSHIP TEAM		OTHER PARTNERS
State Agencies	**Federal Agencies**	**Non-ILT State Agencies**
Agriculture and Consumer Services	Environmental Protection Agency	DHHS-Public Health
Commerce	Federal Highway Administration	Emergency Management
Cultural Resources	National Oceanic and Atmospheric Administration	Insurance
Environment and Natural Resources	U.S. Army Corps of Engineers**	
Transportation	U.S. Fish and Wildlife Service	
Wildlife Resources Commission		

Key Advisors and Stakeholders also provided input.

North Carolina State Climate Office	Duke University-Nicholas Institute
University of North Carolina-Chapel Hill	University of North Carolina-Asheville
East Carolina University	North Carolina State University
Local and county governments	Regional Councils of Government

**The Climate-Ready North Carolina Strategy was collaboratively developed by a working group with representatives from these entities.*

***Participates in an advisory capacity.*

Within the Interagency Leadership Team's broader strategic plan, there are two climate change strategies.

1. In the first strategy, the ILT agencies committed to communicate with local governments and other stakeholders in order to raise awareness of the challenges created by climate change.

To accomplish this, a working group was established with staff from the N.C. Interagency Leadership Team agencies, and additional key partners. This team hosted a statewide workshop, "Planning for North Carolina's Future: Ask the Climate Question," to provide tools to enable decision makers to plan adaptation responses in their communities. More than 400 individuals from across North Carolina attended the two-day workshop on March 2–3, 2010, representing those responsible for planning in the areas of land use, transportation, infrastructure, natural resources, cultural resources, public health, economic development, tourism, real estate, insurance, and emergency management. Participants expressed support for the development of a coordinated state adaptation strategy.

2. The second ILT climate change strategy involves working with stakeholders in vulnerable areas of the state to develop strategies for adaptation to climate change.

Building on the success of the "Planning for North Carolina's Future: Ask the Climate Question" workshop, the working group began the process of developing a coordinated adaptation strategy framework through collaboration among the participating state agencies. This effort to develop a North Carolina strategy was led by the state agencies and supported by the federal partners, with active participation by other collaborators [see Table 1].

The adaptation strategy framework was developed over the course of two years, as the team brought in key advisors and stakeholders to consider these questions:

- What are the key climate vulnerabilities?
- What current efforts could help to address these vulnerabilities?
- How can we address these threats within current programs?
- How can we collaborate with other partners to leverage limited resources?

Appendix A provides more detail about the process that the N.C. Interagency Leadership Team used to assess vulnerability and develop a coordinated adaptation strategy framework.

Overview of the Strategy Report

The main focus of this document is on the broad strategies that enable our state to become climate-ready as we build North Carolina's resilience to potential threats. This report documents the progress made in 2010–2012, and outlines near-term adaptive response options that can be undertaken by state agencies, working with partners at local, regional and federal levels. It is intended to address common concerns across sectors and regions, and to be a resource to support decisions.

Chapter 2: Climate and Weather-Related Trends
Summarizes climate trends beginning with the global scale, and progressing to trends in the Southeast region, before looking at trends that have been observed in North Carolina.

Chapter 3: Climate-Related Impacts, Risks and Vulnerabilities for North Carolina
The vulnerability assessments revealed five climate conditions that are most likely to impact North Carolina: drought, sea-level rise, tropical cyclones, heavy precipitation, and increased heat. This chapter summarizes how each of these conditions could impact our state, across all the sectors that are examined in more detail in Appendices B through E.

Chapter 4: Cross-Sector Strategies Provides information about the collaborative strategies that were recommended by the ILT for implementation. This initial effort concentrates on collaborative activities that can be accomplished in the next 3–5 years. The emphasis is on practical, economically feasible options that can coordinated across branches and levels of governments. These possible actions could be integrated into existing planning processes, priorities and standard operating procedures. To leverage limited resources, initial strategies will focus on low cost / no regrets actions that address multiple systems or particularly vulnerable areas.

Appendices

Appendix A: Vulnerability Assessment and Strategy Development Process The ILT Working Group worked with consultants to develop an assessment prototype that would reveal North Carolina's vulnerability to climate change impacts. This assessment method uses a qualitative approach and was completed by a group of selected practitioners based on their professional experience and expert judgment. These assessment results were used to inform adaptive strategies designed to reduce risk and increase resilience to projected future changes that could affect North Carolina's people, economy, built environment, and natural environment.

Appendices B through E: Sector-Specific Adaptive Response Options In addition to considering how to collaboratively address common concerns, the participants in the working group considered the climate-related impacts to their specific areas of responsibility. These planning sectors were grouped into broad categories based on common issues that are of concern to North Carolinians: our people, our economy, our built environment, and our natural environment. An Appendix is devoted to each of these four categories, in which the authors reviewed relevant vulnerabilities, current efforts, and adaptive response options for each specified sector. Specific adaptive response options were developed that address the needs of individual

sectors, which provides a menu of possible actions that individual agencies or other entities could choose to implement.

Details about these considerations are shared in the following Appendices:

Appendix B: North Carolina's People Climate impacts could impact North Carolina's people in the areas of public health, emergency management, and cultural resources.

Appendix C: North Carolina's Economy Climate-related hazards can affect the state's economy, particularly in the areas of agriculture and forestry, tourism and insurance.

Appendix D: North Carolina's Built Environment Our built environment may be impacted, including transportation, water resources, energy production, and coastal resources and structures.

Appendix E: North Carolina's Natural Environment Shifts in climate trends could impact our state's wildlife habitats, including aquatic, terrestrial, and upland ecosystems.

Appendix F: Earlier Efforts to Address Climate-Related Threats in North Carolina North Carolina's state government and elected officials have undertaken a series of efforts over the last few years to address these concerns.

Appendix G: Climate Sensitivity Assessment Packet This template was developed with NEMAC to assess the likely climate impacts to various sectors.

Appendix H: References Literature cited throughout report is consolidated into a single list.

Appendix I: Glossary Climate-related terminology is defined.

Chapter 2: Climate and Weather-Related Trends

NOTE: This chapter has been reviewed for accuracy and approved by North Carolina's climate experts (State Climate Office of North Carolina, Southeast Regional Climate Center). These climate experts provided this data from peer-reviewed research.

Overview

This chapter summarizes climate trends beginning with the global scale, and progressing to trends in the Southeast region, before looking at trends that have been observed in North Carolina. Also identified are the suite of climate-related risks that are likely to produce significant consequences by the mid- to late- 21st century.

In order to assess the kinds of climate-related impacts North Carolina might experience, the adaptation strategy development team relied on a number of different sources of scientific information. The primary sources of peer-reviewed scientific literature include:

- The 2009 report, *Global Climate Change Impacts in the United States*, published by the U.S. Global Change Research Program, a joint effort of 13 federal agencies and the White House, provided global and regional climate information. http://www.globalchange.gov/publications/reports/scientificassessments/us-impacts/full-report
- The Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report*, is a collaborative effort by the world's top scientists, economists and other experts to synthesize peer-reviewed scientific literature to produce assessments of the current state of knowledge about climate change. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm
- The Southeast Regional Climate Center (SERCC) at the University of North Carolina at Chapel Hill provided data on North Carolina's recent extreme weather and climate events, as well as the Southeast observed trends and projected future changes. http://www.sercc.com/
- The State Climate Office of North Carolina is the primary source for N.C. weather and climate information. North Carolina's state climatologist, the Director of the State Climate Office, assessed climate trends and severe weather events in our state. http://www.nc-climate.ncsu.edu/

Global Climate Trends

This 2012 statement from the American Meteorological Society is based on the peer-reviewed scientific literature and is consistent with the weight of current scientific understanding as expressed in assessments and reports from the Intergovernmental Panel on Climate Change, the U.S. National Academy of Sciences, and the U.S. Global Change Research Program.

"Warming of the climate system now is unequivocal, according to many different kinds of evidence. Observations show increases in globally averaged air and ocean temperatures, as well as widespread melting of snow and ice and rising globally averaged sea level. Surface temperature data for Earth as a whole, including readings over both land and ocean, show an increase of about 0.8°C (1.4°F) over the period

1901–2010 and about 0.5°C (0.9°F) over the period 1979–2010 (the era for which satellite-based temperature data are routinely available)."

"Due to natural variability, not every year is warmer than the preceding year globally. Nevertheless, all of the 10 warmest years in the global temperature records up to 2011 have occurred since 1997, with 2005 and 2010 being the warmest two years in more than a century of global records. Weather patterns will continue to vary from day to day and from season to season, but the frequency of particular patterns and extreme weather and climate events may change as a result of global warming." (American Meteorological Society, 2012)

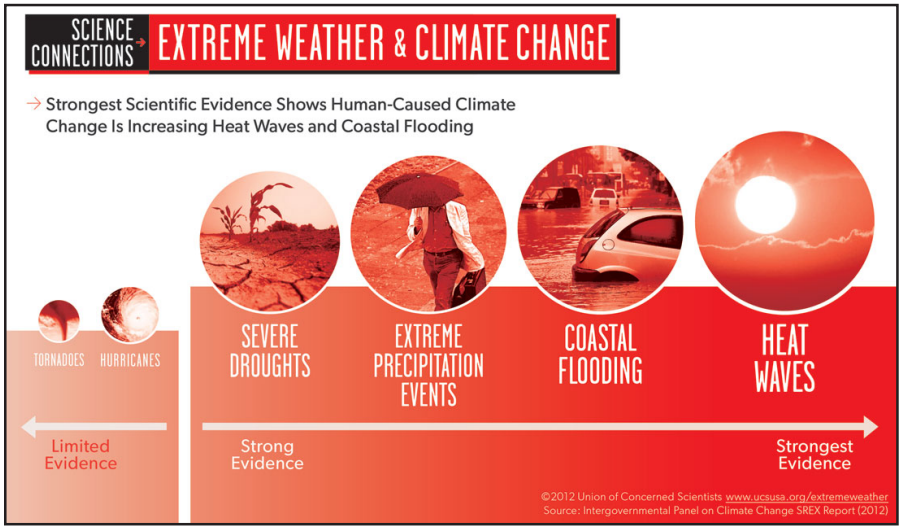
Likelihood: IPCC reports characterize the confidence in the validity of findings in relative terms (such as "low," "medium," and "high"), based on the assessment of underlying scientific evidence and agreement. The reports use common terms to quantify the probability of various outcomes, because without precise definitions, these terms could mean different things to different people. So when we say:

- Virtually certain we mean 99–100% probability
- Very likely we mean 90–100% probability
- Likely we mean 66–100% probability
- About as likely as not we mean 33 to 66% probability
- Unlikely we mean 0–33% probability
- Very unlikely we mean 0–10% probability
- Exceptionally unlikely we mean 0–1% probability

IPCC Global Weather Projections

The Intergovernmental Panel on Climate Change (IPCC) released a *Special Report: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* in 2012. In this report, the IPCC indicates that we can expect more of these 5 types of extreme events, ordered by likelihood of occurrence:

- It is virtually certain that increases in the frequency of warm daily **temperature** extremes and decreases in cold extremes will occur through the 21st century on a global scale.
- It is very likely that **heat waves** will increase in length, frequency, and/or intensity over most land areas.
- It is very likely that average **sea-level rise** will contribute to upward trends in extreme coastal high water levels.
- It is likely that the average maximum wind speed of **tropical cyclones** will increase throughout the coming century, although possibly not in every ocean basin.
- It is likely that the frequency of **heavy precipitation** or the proportion of total rainfall from heavy falls will increase in the 21st century over many areas of the globe.



Climate of the Southeast United States: Past, Present, and Future

Detailed climate records allow us to track rainfall, temperature, storms, and other climate factors. Analyzing weather observations provides a picture of what we have already experienced, and a good indication of the trends and severe events that will continue to occur. Downscaled climate information is not yet available for individual states, but historical extreme events in the Southeast give a good indication of what we may expect in North Carolina's future climate.

The 2009 National Climate Assessment report, *Global Climate Change Impacts in the United States*, published by the U.S. Global Change Research Program, detailed the current and future impacts of climate change on the nation. An updated evaluation of climate impacts on the Southeast region, which includes North Carolina, will be published in the Southeast Regional Technical Report created for the 2013 National Climate Assessment (Konrad et al. in press). ***Highlights from this most recent Southeast Regional Technical Report regarding relevant observed trends and projected future changes are summarized below.***

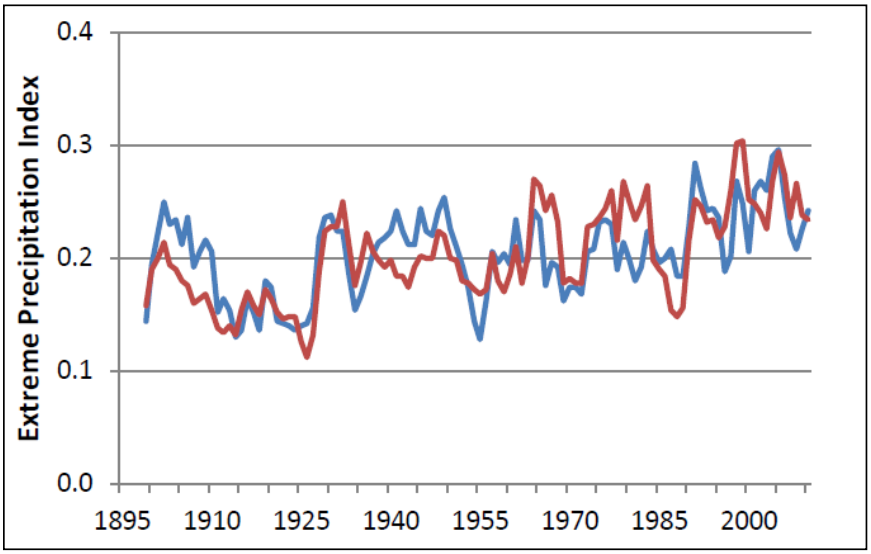
NOTE:

- Observed trends data is based on cooperative observer data from the National Climatic Data Center and updated from Kunkel et al (2003). The National Weather Service Cooperative Observer Program is a network of 11,000 volunteers who collect weather observations on farms, in urban and suburban areas, National Parks, seashores, and mountaintops. These daily maximum and minimum temperatures, snowfall, and 24-hour precipitation totals, are required to define the climate of the United States and to help measure long-term climate changes.
- The projections are based on the analysis of multiple climate scenarios and models, and data has been peer-reviewed.

PRECIPITATION

Observed Trends

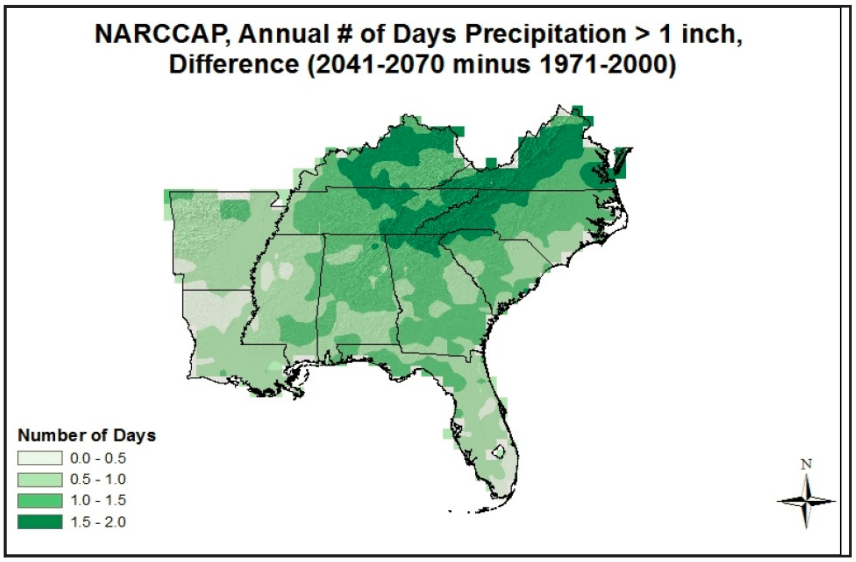
- Inter-annual variability in precipitation has increased over the last several decades, with more exceptionally wet and dry summers having been observed compared to the mid-20th century.
- Increased frequency of extreme precipitation events have occurred, particularly over the last two decades.
- No long-term annual trend in precipitation is seen across North Carolina since 1895, though there has been a slight upward trend in fall season precipitation and a slight downward trend in summer season precipitation.



Time series of the extreme precipitation index (using a precipitation 5-year running average) for the SE for the occurrence of 1-day, 1 in 5 year extreme events (red) and 5-day, 1 in 5 year events (blue). Based on cooperative observer data from the National Climatic Data Center and updated from Kunkel et al. (2003).

Projections

- There is much uncertainty in precipitation projections because models are often unable to resolve regional and local-scale processes, like sea breezes and the location of the Bermuda High.
- Average annual precipitation is projected to decrease by 2% to 4% over South Florida, while increases up to 6% are expected in North Carolina.
- Mean annual precipitation is projected to increase across most of the Southeast region in all seasons except summer, in some areas over 10%.

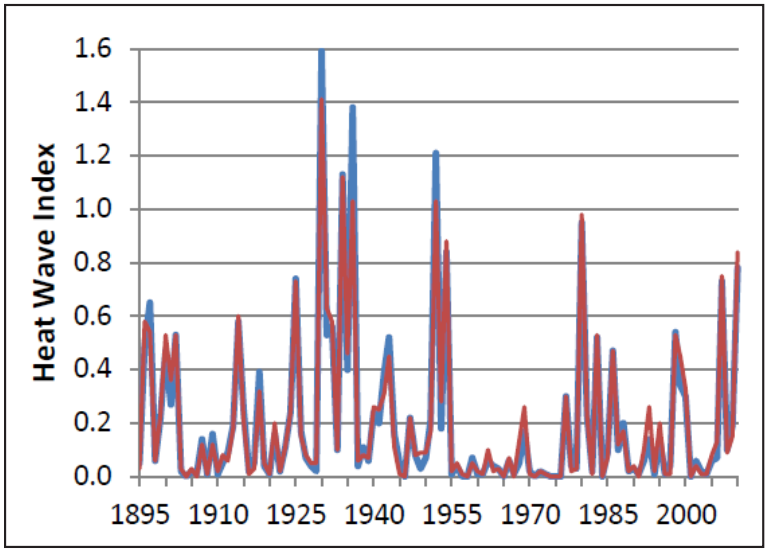


Mean change in annual number of days with Heavy Precipitation (exceeding 1 inch) between 2041–2070 and 1971–2000.

TEMPERATURE

Observed Trends

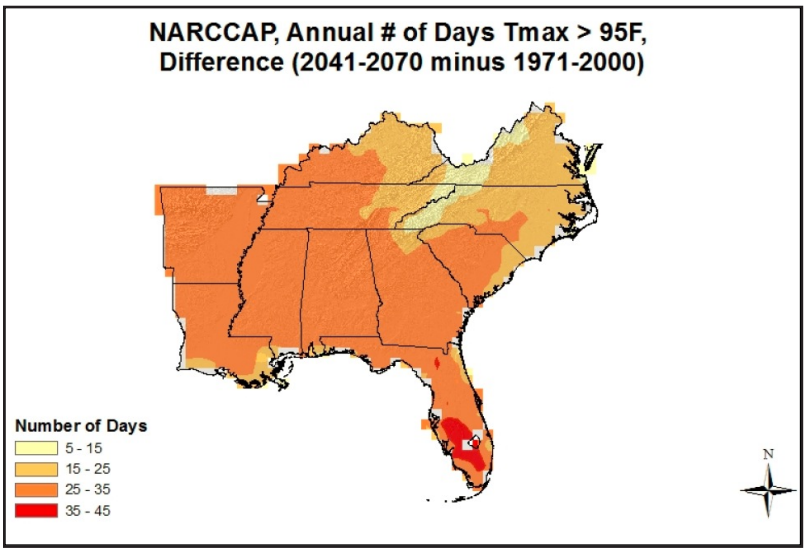
- The Southeast region did not exhibit an overall warming trend in surface temperature during the 20th century.
- Since the 1970s, temperatures have increased with 2001–2010 being the warmest decade on record.
- Increasing temperatures for the period beginning in the 1960s are most apparent in the summer season, which can be linked to increasing daily minimum temperatures and human development of the land surface.



Time series of an index for the occurrence of heat waves defined as 4-day periods and 7-day periods that are hotter than the threshold for a 1-in-5 year recurrence. Constructed by K. Kunkel

Projections

- Mean annual temperatures are projected to increase throughout the 21st century.
- Maximum number of days with temperatures at least 95° F are expected to increase by the mid-21st century.
- Warming in the northern tier of the Southeast region expected to increase the length of the freeze-free season (as much as 30 days by mid-21st century).



Mean change in annual number of days with a maximum temperature exceeding 95˚F between 2041–2070 and 1971–2000.

FLOODING / SEVERE THUNDERSTORMS / TORNADOES

Observed Trends

- Increased risk of flooding in urban areas is due to the increase of extreme precipitation events coupled with the expansion of impervious surfaces and urbanization.
- In the last 50 years, there has been a significant increase in the number of severe thunderstorm reports, including tornadoes. This trend could be due to improved ability to identify and record storm damage.

Road washout from heavy rainfall event.

Projections

- Climate models are not designed to resolve such localized storms, and so projected intensity and frequency is uncertain and associated with theoretical simulations.

EXTREME HEAT / COLD

Observed Trends

- The frequency of minimum temperatures exceeding 75˚F has generally increased across most of the Southeast region. This is related in part to land cover changes, such as urbanization.
- The frequency of days with maximum temperatures exceeding 95˚F declined across most of the early 20th century, but began an upward trend in the past three decades.

Projections

- The number of days with maximum temperatures over 95˚F are projected to increase by 15–35 days over most of the Southeast region by mid-century.

DROUGHT

Observed Trends

- Droughts are typically shorter in duration in the Southeast region than the Western U.S.
- Climate reconstructions suggest that decade-long droughts have occurred periodically over the past 1000 years in the region. In this larger context, the prominent droughts of the 20th and 21st century are not unusual.

Dry lake bed during 2008 drought.

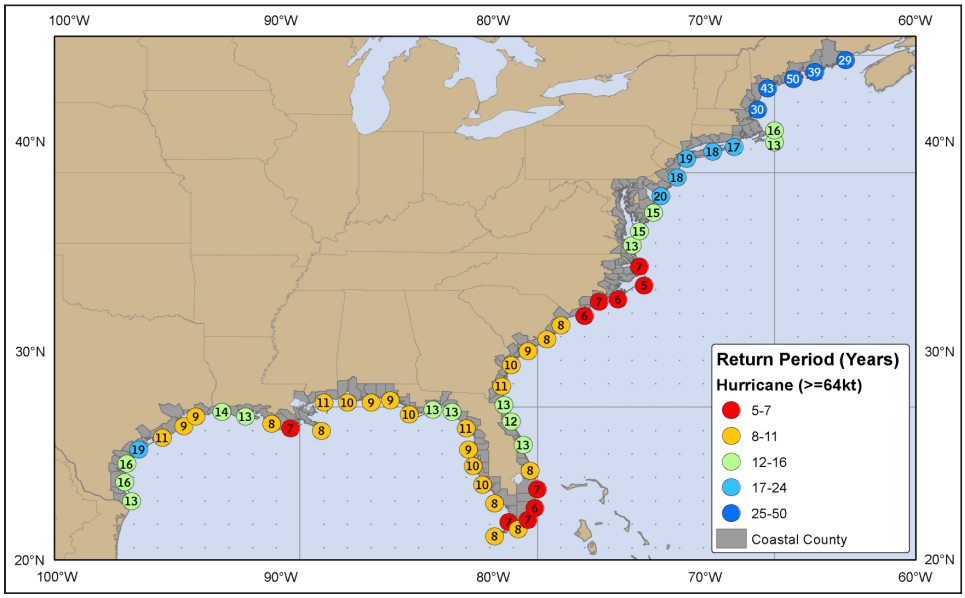
Projections

- There is much uncertainty regarding future drought frequency and intensity for the Southeast region resulting from a range of projections of future precipitation patterns and evaporation rates.
- Hydrological drought is expected to increase across most of the country until at least 2050.

TROPICAL STORMS/HURRICANES

Observed Trends

- Hurricane activity and landfall frequencies are typically lower during El Nino years.
- The Atlantic Multidecadal Oscillation (AMO) phase strongly correlates to hurricane frequency:
    - Positive AMO = increase in hurricanes making landfall
    - Negative AMO = decrease in hurricanes making landfall
- Hurricane activity across the Atlantic basin has remained high over the past two decades, although, beginning in 2006, global hurricane activity has been at its lowest level since the 1970s.



Estimated return period (in years) for hurricanes passing within 50 nautical miles of various locations on the U.S. Coast in the last 100 years.
Source: National Hurricane Center

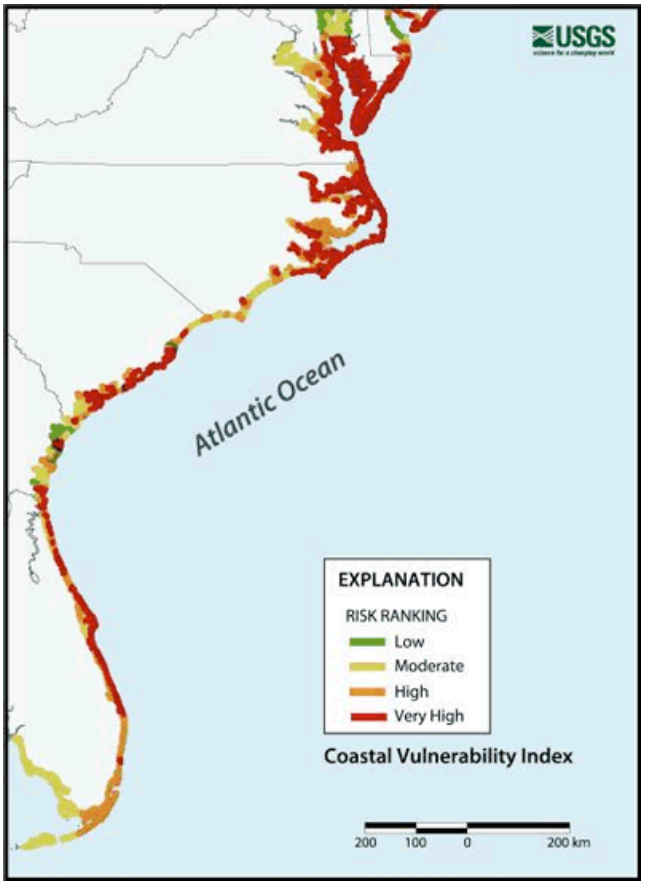
Projections

- Frequency of major hurricanes (categories 3 to 5) will increase.
- The overall frequency of tropical storms and hurricanes will decrease.

SEA-LEVEL RISE

Observed Trends

- Variations in sea level since the mid-19th century have been assessed using tidal gauge records, which show that average sea level has risen at 1.7mm/year for most of the 20th century and accelerated to 3mm/year in the last 20 years.
- The relative rate of sea-level rise varies along the coast.



The Coastal Vulnerability Index developed by the NOAA and USGS ranks the sea-level rise risk to North Carolina's coast as very high.

Projections

- Models project sea-level rise of between 0.2 and 2.0 meters by the end of the century.
- Increases in sea level are likely to result in greater magnitude of storm surge and coastal erosion.

Climate
Average Temperature

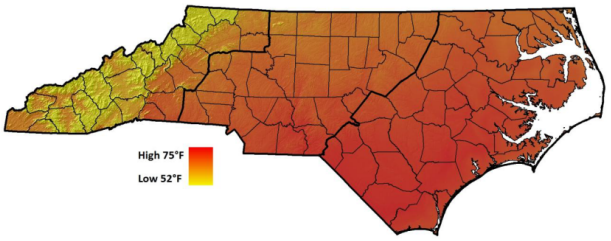
The diverse terrain of North Carolina creates a range of average temperatures, which generally decrease with increases in elevation. On any given day, temperatures can range more than 20°F from the Mountains to the Coast. The cool temperatures in the high elevations result in short growing seasons for crops, high energy demand in the winter, and, ecologically, serve as refuges for rare forest types and species. Temperatures in the central and eastern part of the state provide long growing seasons for agricultural production.

The maps to the right show the average maximum and average minimum temperatures (°F) across the state over a 30-year period. The normal monthly temperatures in the table below show normal maximum and minimum temperatures for January and July at specific weather stations over a 30-year period.

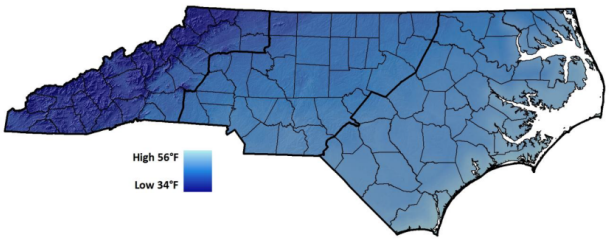
Monthly Normal Temperatures (1971-2000)

	January		July	
Weather Station, County	Normal Max. Temp.	Normal Min. Temp.	Normal Max. Temp.	Normal Min. Temp.
Mountains Mt. Mitchell, Yancey Co.	34	17	68	53
Asheville, Buncombe Co.	46	27	84	64
Piedmont Charlotte, Mecklenburg Co.	51	32	90	71
Burlington, Alamance Co.	50	28	91	68
Coastal Plain Wilmington, New Hanover Co.	56	36	90	72
Greenville, Pitt Co.	52	31	89	70

Average Maximum Temperature 1971–2000

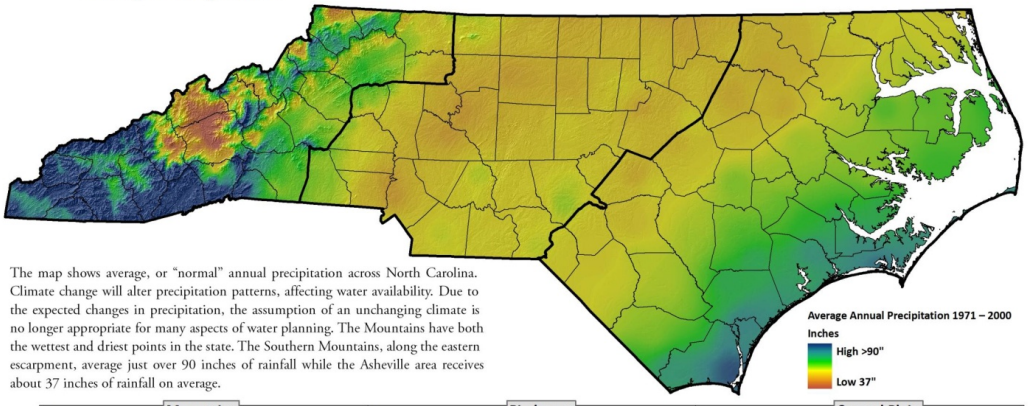


Average Minimum Temperature 1971–2000



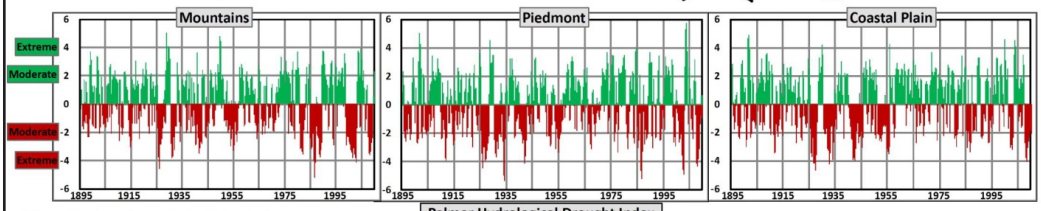
Sources: State Climate Office of North Carolina; Oregon State University, PRISM Group

Climate
Average Precipitation



The map shows average, or "normal" annual precipitation across North Carolina. Climate change will alter precipitation patterns, affecting water availability. Due to the expected changes in precipitation, the assumption of an unchanging climate is no longer appropriate for many aspects of water planning. The Mountains have both the wettest and driest points in the state. The Southern Mountains, along the eastern escarpment, average just over 90 inches of rainfall while the Asheville area receives about 37 inches of rainfall on average.

Average Annual Precipitation 1971 – 2000
Inches
High >90"
Low 37"



Palmer Hydrological Drought Index
(Monthly 1895-2009)

The graphs above show an index indicating long-term impacts to water resources, such as reservoirs and groundwater levels. On the graphs above, red indicates dry conditions whereas green indicates wet conditions. Any value above 2 or below -2 indicates moderate wet/dry conditions, respectively, while any value above 4 or below -4 indicates extreme wet/dry. The graphs reflect historical wet and dry periods, showing that precipitation variability is a major component of the climate in North Carolina. The frequency and severity of wet and dry periods are likely to change; therefore, understanding how this variability changes and impacts water resources will be important in adapting to climate change.

Sources: State Climate Office of North Carolina; Oregon State University, PRISM Group

Climate Trends in North Carolina

The State Climate Office of North Carolina is the primary source for N.C. weather and climate information and is involved in all aspects of climate research, education, and extension services. The State Climate Office is a public-service center, part of the UNC system, housed at North Carolina State University. North Carolina's state climatologist is the Director of the State Climate Office.

According to Ryan Boyles, the state climatologist and director of the State Climate Office for North Carolina, even with the extensive records kept by his office, there are challenges involved in making predictions about our state's future climate. "While one can observe a pattern that is somewhat similar between the global and North Carolina averages, the N.C. temperatures are far more variable from year to year. The variability in precipitation is also high. This highlights one of the primary challenges with climate change analysis at local and even statewide scales: local climate variability is so high in North Carolina that significant trends are difficult to deduce." (State Climate Office of North Carolina, 2012)

"One meaningful trend we can observe is that minimum temperatures (morning lows) are increasing in many urban areas. The changes we're making to our land use patterns are much more closely linked to local-scale changes in minimum temperatures than any broader global warming." (State Climate Office for North Carolina, 2012)

Boyles continues, "While analysis of general temperature and precipitation patterns in North Carolina allows us to investigate broader climate changes, our economy and communities are most sensitive to severe weather and climate events. Indeed, North Carolina experiences almost every kind of severe weather pattern in existence. Our best science suggests these events will not become less severe (and may become worse). So to provide a more comprehensive assessment of climate change and impacts to N.C., one must include an analysis of severe events." (State Climate Office for North Carolina, 2012)

Billion dollar disasters
2011 was a year of unparalleled extremes: 12 disastrous weather events in the U.S. each resulted in over a billion dollars in property damage—an all-time record breaking number—with an estimated $53 billion price tag. Several of the 2011 extreme events are the type expected to worsen due to climate change. North Carolina is one of the states that has experienced the most Billion Dollar Weather/Climate Disasters (1980–2011). http://www.noaa.gov/extreme2011/index.html research.

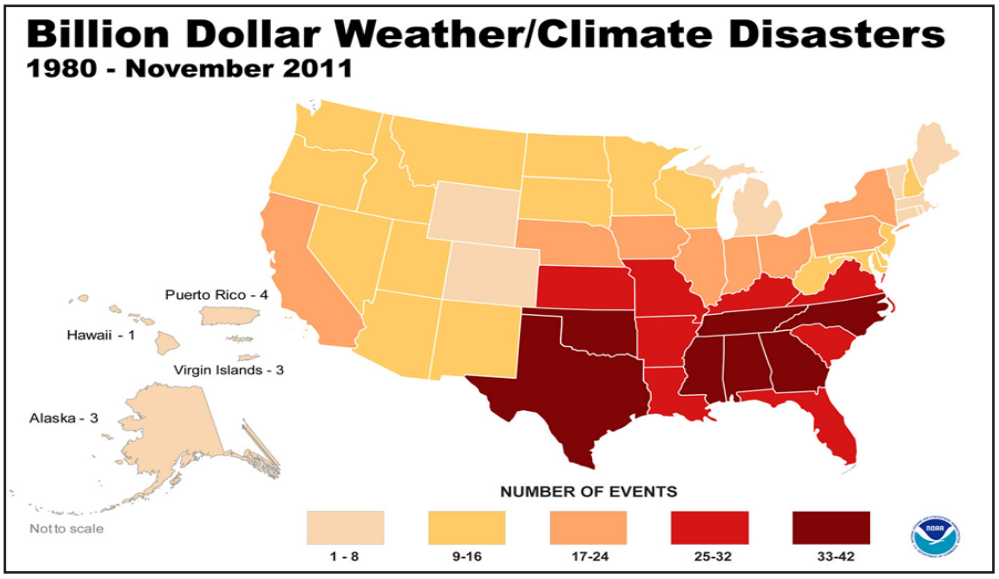
Recent Severe Weather Events in North Carolina

Most of our society's sensitivities to climate are not seen with annual averages. Instead we see our sensitivities in the climate extremes (State Climate Office for North Carolina, 2012). While uncertainty exists about how much the climate may change in the future, recent North Carolina severe weather events indicate that there is reason to be concerned.

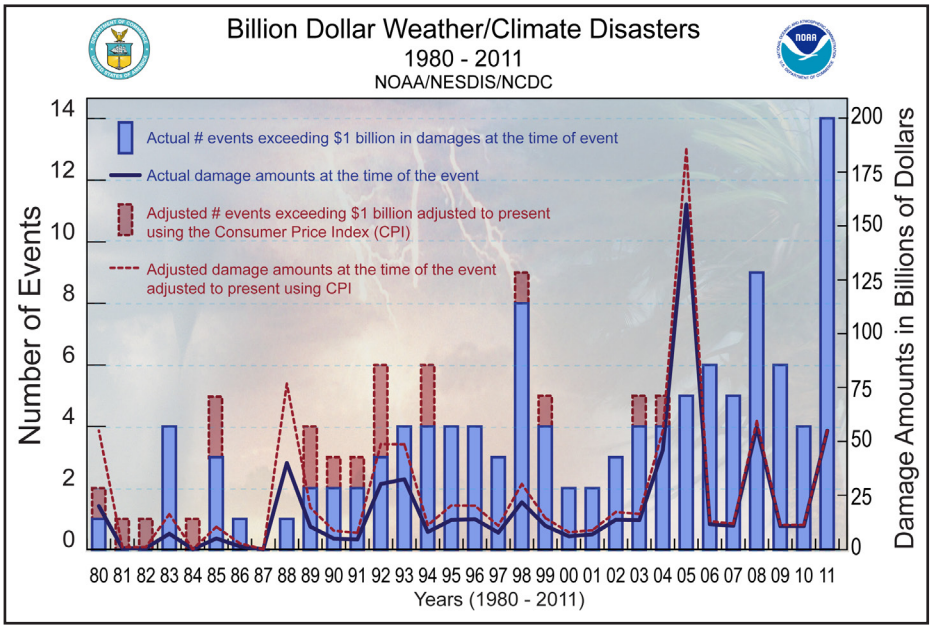
North Carolina experiences all possible major weather events (with the exception of monsoons). In a given year, North Carolinians may witness any of the following extremes: hurricanes, floods, droughts, heat waves, winter storms, cold spells, hail, high winds, lightning, and tornadoes.

The Southeast Regional Climate Center (SERCC) at the University of North Carolina at Chapel Hill is one of six regional climate centers in the United States. The SERCC program responds to user needs for regional climate services in the Southeast, and

provided the following data on North Carolina's recent extreme weather and climate events. Charles Konrad and Chris Furhrmann of the SERCC wrote the Southeast Regional Technical Report created for the 2013 National Climate Assessment (excerpted in Climate of the Southeast United States: Past, Present, and Future section above).



Disaster Type: Tropical Storms/Hurricanes; Severe Weather; Heatwaves/Droughts; Non-Tropical Floods; Fires; Freezes; Blizzards; Ice Storms; Noreaster



Extreme Events: In recent years, North Carolina has experienced an exceptional number of extreme weather and climate events. Since 2006, the state has:

- set statewide records for the all-time warmest month (August 2007), warmest summer (2010), and second warmest summer (2011);
- suffered its worst drought in more than 100 years (summer-winter 2007);
- experienced its worst tornado outbreak in the modern record (April 2011);
- been impacted by eight tropical cyclones (hurricanes, tropical storms, or tropical depressions); and
- recorded at least one extreme precipitation event (3" or more in 24 hours) at half the state's weather stations.

Seasonal Variability: In addition to extreme events, in 2011 North Carolina experienced noteworthy variability across seasons:

- Winter brought below-average temperatures with several snowstorms;
- Spring produced a record number of tornadoes; and
- Summer included a major heat wave, drought and a land-falling hurricane (Irene).

Record-Setting Heat

- The summer of 2010 (June–August) was the warmest on record (1895–2010) across the state of North Carolina, with the statewide mean summer temperature more than 2˚F higher than the previous warmest summer of 2007.
- For the year 2010, Raleigh-Durham recorded 91 days of 90˚F temperatures or greater, breaking the previous record of 83 days set back in 2007. Charlotte recorded 87 days and Greensboro recorded 67 days of 90˚F temperatures and greater.
- A year after experiencing its warmest summer on record, in 2011 North Carolina experienced its second warmest summer. Raleigh-Durham recorded five consecutive days of 100˚F and higher temperatures from July 20–24, breaking the previous record of four consecutive days set in June 2008.

References

American Meteorological Society, Climate Change: An Information Statement of the American Meteorological Society, adopted by AMS Council on August 20, 2012

Boyles, Ryan. State Climate Office of North Carolina, Climate Change in North Carolina, downloaded from http://www.nc-climate.ncsu.edu/climate/climate_change August 28, 2012

IPCC Fourth Assessment Report (AR4)—Climate Change 2007: Working Group I—The Physical Science Basis, Chapter 3, Table 3.7, pg 314)

IPCC, 2012. IPCC Special Report: Managing the Risks of Extreme Events and

Disasters to Advance Climate Change Adaptation(SREX), IPCC Working Groups I and II, http://ipcc-wg2.gov/SREX/report/

Karl, T.R., J.M. Melillo, and T.C. Peterson (Eds.). 2009. *Global Climate Change Impacts in the United States*. Cambridge University Press, New York.

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U.S. Environmental Protection Agency, "Assessment of the Impacts of Global Climate Change on Regional U.S. Air Quality: A Synthesis of Climate Change Impacts on Ground Level Ozone", April, 2009

U.S. Environmental Protection Agency, Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region, 2009

Chapter 3: Climate-Related Impacts, Risks and Vulnerabilities for North Carolina

Five climate conditions most likely to impact North Carolina:

1. More frequent drought
2. Rising sea-level and accompanying storm surge
3. More intense hurricanes
4. Increased heavy precipitation events
5. More extreme heat

Introduction

A change in climate and associated weather patterns over the course of this century may lead to an increase in mean sea level, severe damage to or destruction of the barrier islands, an increase in the frequency of drought and heat waves, more powerful tropical storms, severe flooding, and increased intense weather episodes across the state.

North Carolina already experiences significant climate variability, but there is concern about the potential of changes in our future climate that could make bad situations worse. Climate disruption could multiply the risks from a common problem like periodic dry spells, which could then increase the severity into an extended drought that affects all segments of society. Meeting the needs for energy, water, and transportation can be difficult when dealing with non-climate challenges, such as population growth, rapid development and urbanization. Addressing these existing challenges becomes more complicated when climate-related stressors are added to the mix.

Climate-related impacts do not occur only in isolation, but can be interconnected, so that changes to one climate condition may induce impacts in other areas. In one example, drought conditions increase the risk of wildfire. In another pairing of impacts, rising sea levels allow storm surge to move further inland than it did before, thus changing the salinity of ecosystems and possibly the available habitat. Further, this intrusion of salt water can degrade drinking water wells and flood septic fields.

> The greatest potential for harm from climate change may come from its ability to make bad situations worse. It can act as a risk multiplier for almost any situation, taking a potential problem and increasing its risk and severity. ...Climate change has the ability to affect many resources essential to human civilization. Areas facing issues with water, energy, available land or economic growth have the potential to see the issues magnified by climate change. Also, because many of our most important resources are connected, problems with one resource may quickly lead to problems in other areas. *Defense, National Security & Climate Change: Building Resilience and Identifying Opportunities Related to Water, Energy and Extreme Events (2012)*

Participants in the working group considered a dozen global climate conditions that

had been identified in the IPCC Fourth Assessment report. These fall into four major categories: temperature-related, precipitation-related, tropical/severe weather-related, and sea-level rise-related. (See Appendix A for more details on the assessment process.)

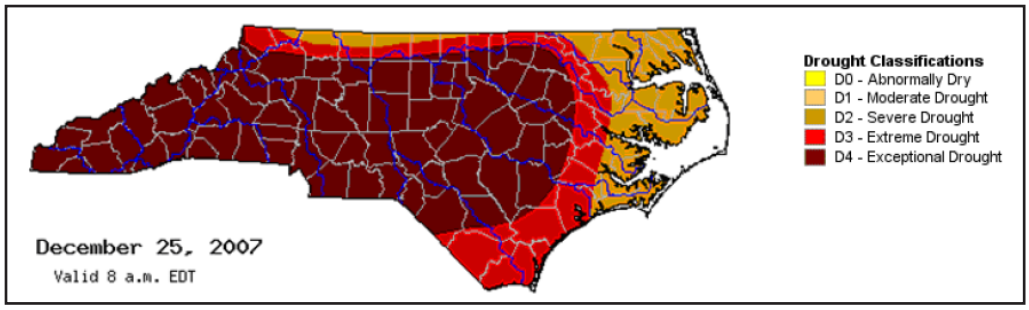
This chapter summarizes the five climate-related impacts, risks and vulnerabilities that are most likely to impact North Carolina. See Appendices B through E for more details on sector-specific impacts.)

NOTE: The primary peer-reviewed scientific sources used include: The U.S. Global Change Research Program, *Global Climate Change Impacts in the United States* (2009) and The Intergovernmental Panel on Climate Change Fourth Assessment Report (2007). See Appendix G: References for additional source material used for this assessment.

Drought is defined by the State Climate Office of North Carolina as a deficit in normal precipitation for a region over a period of time sufficient to cause impacts.

1. MORE FREQUENT DROUGHT

Despite an abundance of moisture, North Carolina does experience drought when precipitation deficits lead to impacts such as reduced agricultural production and/or shortages of freshwater supplies. Rapid population growth and development have greatly increased the region's demand for water and our vulnerability to variability in precipitation.



North Carolina has historically experienced periodic droughts that are within the range of natural climate variability. During the 1998–2002 drought, the Carolinas experienced new records for low lake, reservoir, and groundwater levels, which are the lowest since written records have been kept. If the frequency or duration of extreme and exceptional droughts increase, the impacts are likely to be more disruptive. Such droughts have the potential to result in widespread economic damage, caused by exceptional and widespread crop and pasture losses, as well as water emergencies triggered by water shortages in reservoirs, streams, and wells. With the potential for changes to the range of climate conditions, determining how to plan for more frequent and/or more intense droughts becomes more important.

Droughts impact many sectors of North Carolina's economy and therefore many of the state's residents. Reduced public and industrial water supplies can threaten public health, business continuity and employment. Reduced stream flows can reduce electric generation from hydropower projects. Declining water levels and increasing water temperatures can reduce or curtail generation from thermoelectric

plants because of reduced cooling capabilities and existing permit requirements. Drought conditions during critical periods in the growing season will increase stress on water resources as farmers provide supplemental water to maintain production of food and fiber crops and livestock. Structures located along the boundaries of forests, pastures and other undeveloped lands face increased susceptibility to damage and loss from wild fires during droughts. Reduced precipitation could negatively impact several profitable recreational sectors, such as the ski industry and wildlife-associated recreation.

The state's agricultural sector, a major economic engine, is at risk from droughts if sufficient water supplies are not available to support agriculture, energy production, industrial users, and consumers, which could have a significant economic impact. Increased drought will lead to a greater demand for water for irrigation and livestock. The Piedmont and Coastal Plain regions will be more vulnerable to this impact due to the large amount of agriculture performed in these regions. Drought can cause severe reductions in crop yields. Impact of to cold water aquaculture is severe because clean, plentiful, cold water is a critical input for commercial trout production.

Lack of water has a very large impact on natural systems. Projections of longer and more severe droughts, coupled with higher temperatures, could mean that many species will not be able to adapt. This could lead to large changes in both aquatic and terrestrial ecosystems across the state. Drought also influences the forest ecosystem to be more vulnerable to wildfire and pest damage, which lead to human health and economic impacts. Changes in input of fresh water may be significant to tidal wetlands, particularly in the northern part of the state. Changes in salinity associated with recent droughts may have had effects on existing vegetation. An increase in drought frequency or severity would make such effects more important.

Falls Lake during 2008 drought.

The largest sector of freshwater use for North Carolina is cooling of power plants (more than 80%). Drought reduces the amount water available for energy plants to generate electricity and dispose of the heated cooling water safely.

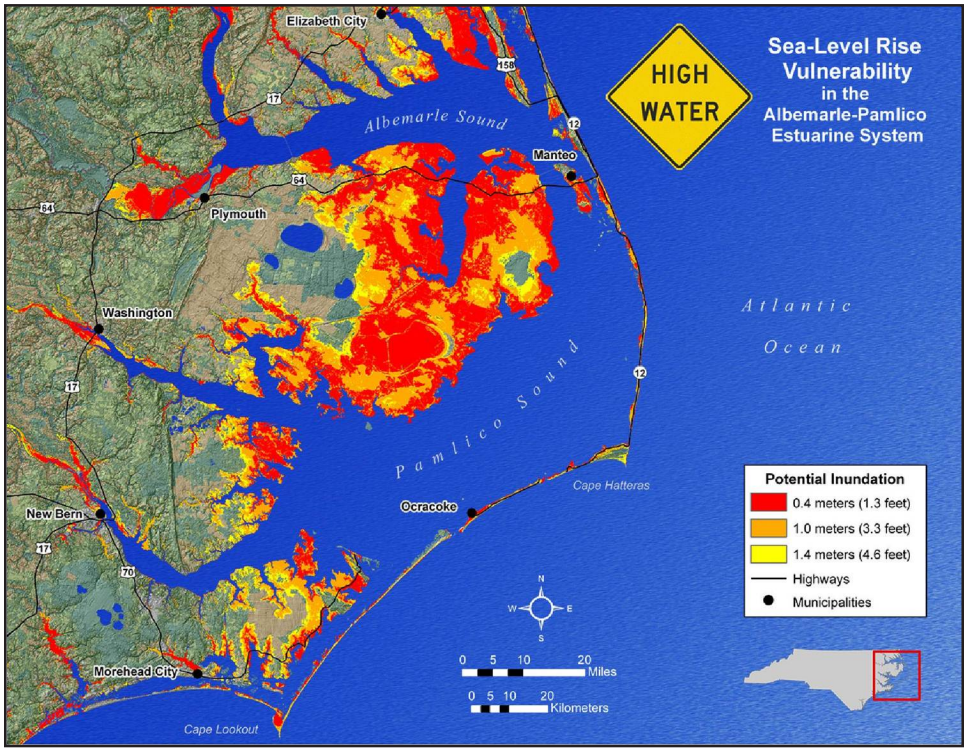
Drought also affects community and individual water supplies. During drought, contaminants may build up on the ground, and subsequent rainfall generates flash floods that may overwhelm stormwater systems. As a result, communities may see a reduction in water quality and an increase in waterborne disease during drought.

Drought can also reduce air quality by increasing concentrations of particulate matter, which can cause respiratory distress in human and animal populations. During periods of drought, there is much less rainfall to clean particulates from the air. At the same time, there is an increase in particulates generated from both manmade and natural sources, such as construction, agriculture, road travel, quarrying, dust and wildfires. This impact is especially important in metropolitan areas or in areas that are not in attainment of the national ambient air quality standards for particulate matter.

Rising sea level can be the result of the warming-induced expansion of the oceans, accelerated melting of glaciers, and/or loss of ice in Greenland and Antarctica, leading to a rise in sea-level. The future climate concern is the rate at which this may increase.

2. RISING SEA LEVEL WITH ACCOMPANYING STORM SURGE

According to the Environmental Protection Agency's 2009 report, *Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region*, North Carolina has the third highest land area vulnerable to sea-level rise of all U.S. states. Tide gauges have shown a steady increase in sea level, and it is very likely that sea level will continue to rise over time. Even if the pace does not increase significantly, North Carolina's shoreline will be altered. The state has thousands of square miles of land at low elevation that would be at risk of inundation. Much of the land in the state's northeastern coastal plain lies very close to sea level and has very little slope, meaning that even small increases in sea level could result in a wide expanse of coastal land being temporarily or permanently inundated over time.



Low-lying areas in the northeast part of the state are at risk of being inundated by sea level rise.

Rates of sea level rise are increasing three-to-four times faster along portions of the U.S. Atlantic Coast than globally, according to a new U.S. Geological Survey report published in *Nature Climate Change*.

Many variables, including the coastal slope, geological makeup, erosion rates, and the shape of the coastline, combine to make N.C.'s coastline vulnerable to higher sea level. In combination with tropical storms that may increase in intensity, sea-level rise magnifies existing coastal hazards such as flooding and storm surge. Many homes and businesses are in low-lying areas, where they already face the risk of storm-related damage. Already, shoreline erosion has threatened homes along the beach and increased demand for structural defense.

Inundation may evolve over a long time frame and will vary based on the contours and geography of the coast. Land in low-lying areas will be affected by all types of storms that affect the coast and become increasingly vulnerable to loss. Inundation may not happen only gradually; it can be accelerate rapidly during tropical cyclones as storm surge pushes flooding further inland. These events often lead to coastal erosion. With both rising seas and more intense storms, large disruptions to the barrier island systems are likely. As the sea rises and coastal erosion occurs, what is currently land could be in the middle of a channel or several hundred yards offshore.

As salt water displaces fresh water, large impacts to natural and manmade systems could occur. Salt water intrusion can affect not only marshes, bays and lakes, but also

the groundwater system and shallow aquifers that are common in the outer Coastal Plain. Freshwater tidal wetlands are likely to be among the most severely affected by rising sea level and increased intensity of storms. Permanent inundation and shoreline erosion are already occurring due to gradual sinking of the land in some areas and can be expected to continue; where the land is already sinking, the rising water would be deeper. Salt intrusion into freshwater peat lands accelerates their collapse, particularly in the Albemarle Pamlico peninsula.

In marine and estuarine coastal habitats, increasing water temperatures combined with sea-level rise are thought to influence aquatic community structure. Changes in barrier islands and wetlands could reduce the productivity of estuarine nursery areas, negatively impacting N.C. fisheries. Fish species distribution could change, especially species that are already at their southern or northern distribution limits.

As the coastline changes, increased storm intensity combined with rising sea level would affect properties that occupy the coastal area of our state. Our coastal communities could face significant losses of residential and commercial properties, as well as costly damage to transportation, energy, water/sewer and communications infrastructure. Extreme inundation and wind damage could result in population displacement and property losses.

Any significant rise in mean sea level may pose direct threats to lowland historic towns and districts in the Coastal Plain, which draw thousands of visitors each year and generate significant economic benefit. There are nearly 5,800 prehistoric and historic archaeological sites in the Coastal Plain of North Carolina within 30 feet of mean sea level.

Sea-level rise due to climate change could have a significant economic effect on North Carolina agriculture and forestry. Increased frequency of flooding in coastal areas due to sea-level rise has the potential to cause crop losses and damage to buildings and equipment. As sea levels continue to rise, coastal forests will be displaced as shorelines retreat.

Rising sea level can negatively impact water supplies for municipalities and industries. The degree of impact may vary, depending on whether it is caused by temporary flooding during storm surge or extreme high tides, or because a low-lying area becomes permanently inundated. Infrastructure failure may occur due to coastal inundation of water and wastewater components, like septic tanks, sewer lines, and pump stations. Septic tank failure in poorly drained coastal soils creates a need for alternative waste treatment. When pump stations, sewer lines, and wastewater treatment plants are inundated, the environment is contaminated, and the infrastructure must be replaced.

The impacts of sea-level rise could potentially affect the infrastructure and operations of both land and marine transportation systems in the coastal areas of North Carolina. Transportation infrastructure may be impacted by the inundation of roads, more frequent or severe flooding of low-lying infrastructure, the erosion of road base and bridge supports, and the loss of barrier shoreline due to sea-level rise. More severe storm surges may also cause more frequent interruptions in travel on coastal and low-lying roadways and rail service, and may also require evacuation of vulnerable areas. Rising sea levels may require some changes in port and ferry facilities to accommodate higher tides and storm surges. More severe storm surges may also result in interruptions to ferry services, shipping services, and port operations.

Tropical cyclones are measured by their strength (frequency, intensity, track, peak wind speed, precipitation, and storm surge). **Hurricanes** are classified as a category 1–5, based on their strength. The future climate concern is that hurricane strength may increase.

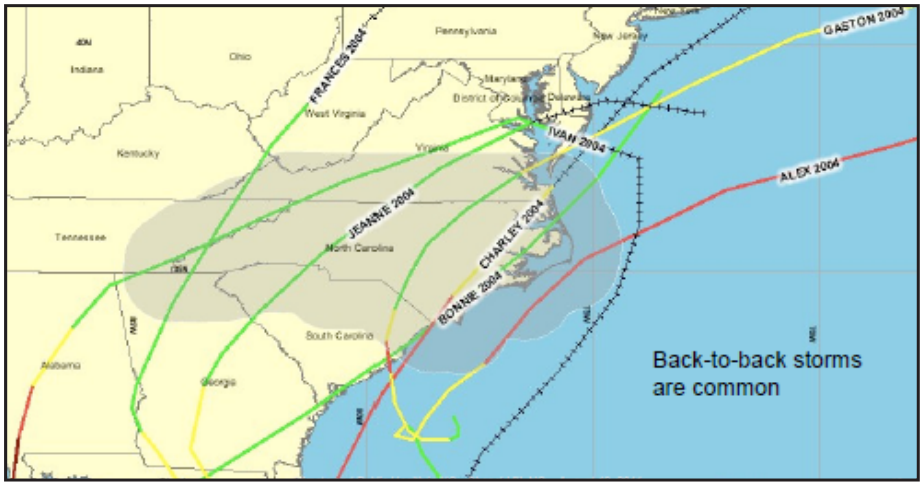
3. MORE INTENSE HURRICANES

Major tropical cyclones, which include hurricanes, tropical storms, and tropical depressions, can cause a number of devastating impacts to manmade and natural land features. North Carolina has a long history of destructive hurricanes. The coast of North Carolina can expect to receive a tropical storm or a hurricane once every 4 years. The state's protruding coastline makes it vulnerable to tropical cyclones that curve northward in the western Atlantic Ocean. Cape Fear and Cape Lookout are also favored areas for tropical cyclones to make landfall. Between 1886 and 1996, North Carolina experienced 28 direct landfalls.

Tropical storms and hurricanes are projected to increase in intensity, with more of them becoming major hurricanes (category 3 to 5). (IPCC, 2012) North Carolina already experiences billion-dollar disaster events on a frequent basis from a variety of severe weather. If our state receives a direct hit from a major hurricane, we could anticipate that significant damage would occur.

The entire state of North Carolina is subject to the effects of tropical storms and

hurricanes, which are characterized by heavy rain accompanied by strong winds. Although their impact is the most intense in the Coastal Plain region, the wind and flooding events linked to these tropical systems cause high amounts of damage and flooding across the state. Increased storm intensity is expected to produce higher storm surges along our coast. Combined with rising sea level, storm surge damage would reach farther inland and be more destructive.



A direct hit by a strong hurricane would be expected to damage and/or destroy many coastal structures. Wind, flooding, and storm surge are all likely to cause major harm. Damage to tourist infrastructure, including attractions, services, and accommodations, could have a significant impact on the coastal economy. Depending on the magnitude and severity of the storm, there could be large uninsured losses that may qualify for state or federal disaster declaration and aid. The cost of insurance would rise to cover the increased risks and claims will rise because of increased property losses.

N.C. Highway 12 after Superstorm Sandy wrecked sandbag structures built to protect it.
Photo courtesy N.C. Deparment of Transportation

High winds increase the possibility for damage to buildings, trees, other infrastructure, and contamination of drinking water supplies. In coastal areas, high winds can increase tidal levels, creating even more water damage to buildings, docks, bulkheads and other coastal development, as well as increasing shoreline erosion. Damage from such storms can have severe impacts to transportation facilities, utility distribution and communication lines, sewer and water infrastructure, thereby threatening human health and public safety. Such damage produces negative economic impacts to communities in the region.

Hurricane impacts to agriculture may be severe depending on the severity of the storm and the time of year in which it occurs. Crop and livestock damage and productivity loss are likely from such storms, as well as damage to buildings and equipment. Forestry losses from high winds associated with tropical cyclones can be severe. Without adequate planning and disaster assistance, agricultural interests can be devastated.

The Outer Banks are likely to be impacted significantly due to increased storm intensity, which can cause inlets to open and close. Such changes could occur gradually, as barrier islands narrow and disappear. However, these processes could also happen more rapidly, if a large storm opens substantial portions of barrier islands at one time.

Tropical storms have a tremendous impact on health services infrastructure. When North Carolina experiences emergencies, state and local health departments may be required to divert critical resources.

The destructive power of hurricanes will likely be enhanced by sea-level rise and higher storm surges on the cultural resources within the Coastal Plain. More intense tropical cyclones will pose a major risk to museums, archival records, historic districts and other National Register properties, state historic sites, cemeteries, and archaeological sites.

4. INCREASED HEAVY PRECIPITATION EVENTS

Heavy precipitation events can cause substantial impacts to manmade and natural land features. This is caused mainly from flooding, and would especially impact infrastructure located within floodplains. Heavy rainfall can produce short-lived flash floods and longer-duration river floods that can have tremendous impacts on property and human life. A variety of weather systems occur in the Southeast during different seasons. In winter, slow-moving systems produce large areas of very heavy rainfall, followed in spring and summer by thunderstorms that produce heavy rainfall in localized areas. In late summer and fall, tropical storms and hurricanes can produce extremely heavy rainfall, both locally and regionally. All rivers are susceptible to

flooding, which can affect people through increased incidence of waterborne disease, contamination of water supplies, and both property and agricultural losses. Most flood-related deaths occur as a result of flash floods produced by tropical cyclones; these storms can also cause landslides on the steep slopes of the southern Appalachians.

Increased storm intensity or frequency may lead to increased stormwater runoff, with an increase in sediments, nutrients and contaminants in streams, rivers and reservoirs, resulting in negative effects on aquatic species and their habitats. Changes in rainfall intensity and variability will also affect stream flow patterns, channel hydrodynamics, lake levels, and the volume of groundwater recharge from aquifers, which could upset the physical, chemical, and biological structure of streams. An increase in heavy precipitation events would also increase the frequency that water with low oxygen levels is flushed from coastal wetlands into coastal rivers; this which would result in an increased occurrence of fish kills.

Transportation infrastructure, whether land, air or water, can be inundated and/or damaged, disrupting the mobility of people and goods. Buildings and homes can also be damaged or destroyed. Emergency access can be impeded, creating threats to human safety if transportation corridors become impassable.

More intense rainfall events can produce higher flood heights, possibly causing dams and flood control structures to the point of overtopping and/or failure, as well as impacting reservoirs and intakes structures that provide municipal drinking water. The uncontrolled release of stored water will produce a cascading series of damaging impacts downstream, including the possibility of compromising the integrity of downstream dams. Increased debris carried by the floodwaters can interfere with hydro-power generation and create other hazards. In addition, the destruction of the dam results in the loss of the fresh water stored in the reservoir for municipal drinking water, increasing the threats to public health from the lack of potable water delivery.

Landslides and sinkholes can be triggered by intense precipitation, creating public safety concerns, loss of roadways and buildings, and significant economic impacts. Increased heavy rainfall in vulnerable steep slope areas make it likely that landslides could increase, causing catastrophic property damage.

Flooding resulting from heavy rainfall events will also pose a major threat to various cultural resources such as archaeological sites, state historic sites, historic structures and districts, and archival records.

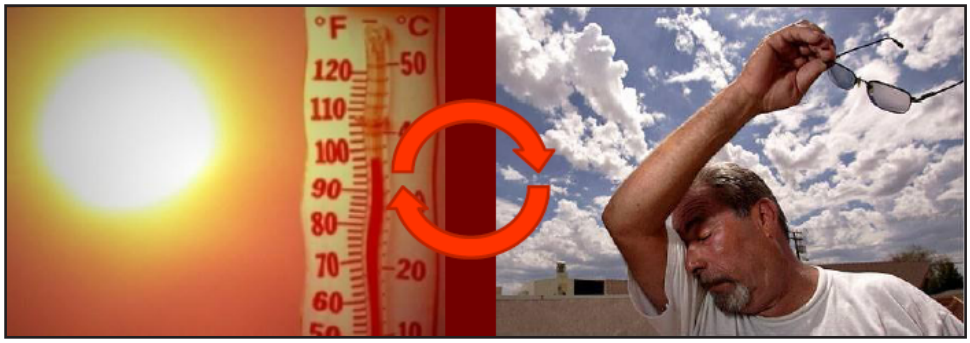
In agriculture and forestry, increased soil erosion may occur as a result of more frequent heavy rainfall events. Crop productivity may decrease as a result of more

frequent flooding of fields and delays to planting and harvesting. Forest productivity could be affected because flooding affects trees at every stage of their development, from seed germination and flowering to sprouting and vegetative growth.

Increased and more intense precipitation can affect the quality and quantity of clean water available to North Carolinians, when heavy rainfall events cause inundation of storm-water and sewage systems, toxic waste facilities, or livestock waste lagoons. Heavy rain events can cause untreated waste from waste treatment plants or animal operations to be released into drinking water sources.

Other significant health impacts that result from heavy precipitation events are also a concern. Contamination of irrigation water can contribute to food-borne disease. Vector-borne diseases that are transmitted primarily by ticks and mosquitoes can cause serious illness or even death. These vector-borne diseases may become newly established or endemic diseases may increase as a result of changing climatic patterns.

5. MORE EXTREME HEAT



It is likely that extreme heat events will become more frequent, longer lasting and more intense. Under these conditions, competing demands for water (human consumption, industrial use, agricultural irrigation, energy generation) will increase. Water supplies may already be at risk due to drought, further compounding the issues of heat waves.

Heat waves are expected to increase with future climate variability all across North Carolina. The impact of the temperature extremes may have the greatest impact in the Piedmont due to the projected high population relative to available water supply. The Piedmont will have a very strong link between heat stress and drought due to the large number of people living in the region and their energy needs.

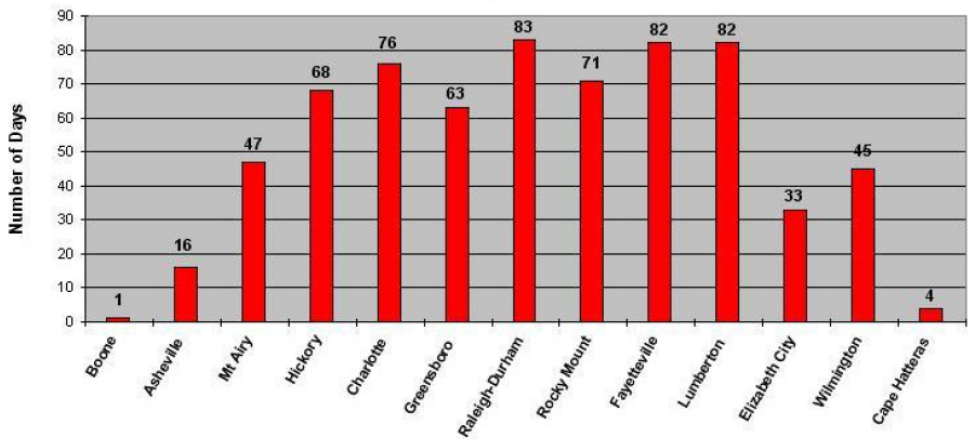
Heat waves are a combination of both elevated temperature and its impact on our lives. Heat stress for people is a direct result of an increase in temperatures, typically associated with heat waves, and may be accompanied by high humidity levels as well, leading to high heat index values. With high temperature days and nights, people face direct heat exposure. When hot spells occur early in the year we experience especially significant impacts, since people are not yet acclimated to the heat. Higher night-time temperatures that follow hot days do not allow complete recovery from the effects of heat. Residents who do not have access to air-conditioned facilities face increased threat to their health, especially those in

Extreme heat impacts take more than one form, with slightly different concerns:

- **Heat waves** are an episode of several consecutive high-temperature days and nights, when the temperatures never really cool down. The future climate concern is an increase in the frequency and intensity of these events.
- Extreme heat can also include an increased **number of very hot days**. The future climate concern is an increase of this occurrence, both locally and regionally.
- **Seasonal average temperatures** (as opposed to daily temperatures) could exceed historic averages. The future climate concern is shorter cool seasons and longer warm seasons, with an increase in average temperatures during both.

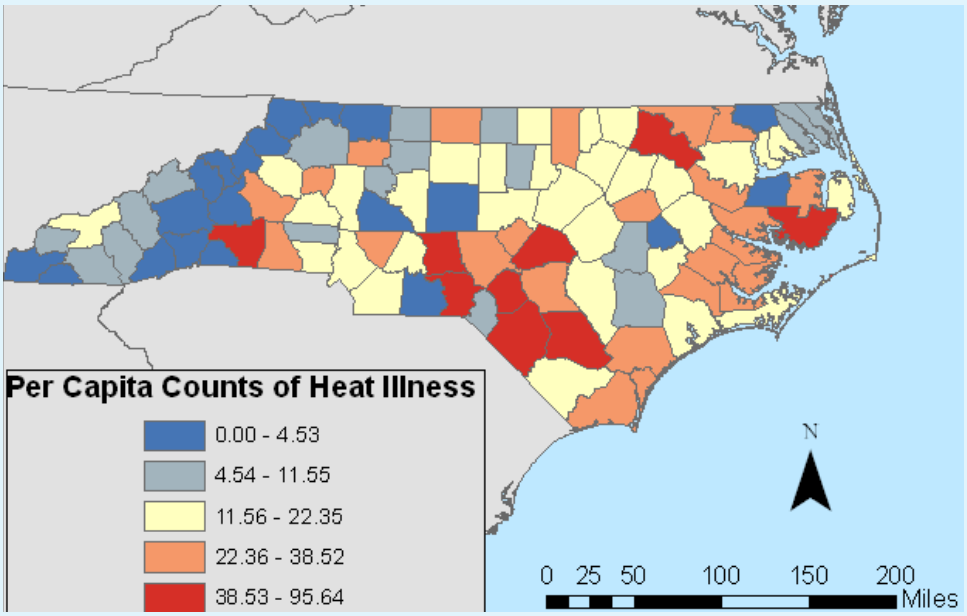
susceptible groups such as the elderly and infirm. Heat stress will impact human health and can increase morbidity and mortality, even among younger people who work or play outside in the heat.

Figure 2 - Days at 90 Degrees or Greater in NC



Heat waves that cause heat stress will have a compounding impact in that they will lead to increases in energy and water demands, as well as a decrease in air quality. Energy demands, in particular, will be impacted by heat waves as heat stress on humans lead to an increase in air conditioning needs, which is the primary mechanism to reduce heat stress. The increased water temperatures can impact the cooling capabilities for thermo-electric power generation facilities. Residents who do not have access to air-conditioned facilities face increased threat to their health, especially those in susceptible groups such as the elderly and infirm.

Air pollution levels, specifically the peak ozone levels on high temperature days are expected to increase significantly. The impacts will be regional in nature and more severe in metropolitan areas and areas that are already in nonattainment for ozone. In addition, a longer warm season will increase the length of the ozone season, currently from May 1 to September 30, with potentially more days of the year with high ozone levels. Ground level ozone can cause respiratory distress in sensitive human populations and also can have a negative impact on plant growth.



Rate of emergency department visits (per capita) for heat-related illness by county from 2007–2008

Total Visits:

Urban	1186
Rural	1404 (+218)

Annual Visit Rate (per 100,000):

Urban	13.0
Rural	15.6 (+2.6)

However, heat stress will not only affect human life, but crops as well. Water demands will also increase as farmers are forced to rely more on irrigation to water their crops. Plants will exhibit decreases in yield as temperatures increase above their optimum range. Virtually all types of aquaculture are severely stressed during sustained periods of high temperatures. As water demands increase, water supplies will decrease. Increased heat could negatively impact several profitable recreational sectors, such as the ski industry and wildlife-associated recreation.

In aquatic ecosystems, increased air temperatures will lead to increased water temperatures and lower dissolved oxygen levels for most streams and rivers. Increases in water temperature could also cause aquatic species to experience shifts in their range or distribution, and sensitive species may experience decline or extirpation. Species such as trout, that are already at the edge of their natural range, are likely to be affected by temperature increases. Algal blooms are more likely in the larger, slower-flowing rivers. This reduces the amount of dissolved in-stream oxygen,

increasing the likelihood of larger and more frequent fish kills, especially when combined with human-caused factors such as pollution. The prevalence of warmer water temperatures may increase the likelihood of additional exotic species that were previously considered to be non-threatening when the winters were too cold for survival.

Plant and animal communities associated with high elevation northern hardwood forests and spruce-fir forests are all highly likely to be affected by changes in temperature and moisture associated with climate change. There is concern and uncertainty about whether these shifts will "push communities off the top of the mountains." Changes might be either gradual (resulting from shifts in reproductive success, or impacts from disease and insect infestation) or may be abrupt (tied to severe weather or fire).

As levels of carbon dioxide have increased in the atmosphere, more of the gas has been absorbed by the ocean, leading to higher concentrations of carbonic acid in ocean water. This "ocean acidification" is expected to harm a range of marine life, but especially corals and creatures with shells, such as oysters, shrimp, scallops, lobsters.

Chapter 4: Overarching Cross-Sector Strategies

The N.C. Interagency Leadership Team, a group of state and federal agencies, is collaborating on climate adaptation strategies integrated across various sectors. The ILT agencies and their partners are concentrating early efforts on adaptive responses that:

- build on existing momentum using current resources,
- focus on "no-regrets" actions that are good to do for other reasons beyond climate adaptation, and
- show tangible results and responsible use of tax dollars.

Introduction

The North Carolina Interagency Leadership Team (ILT) examined how multiple government agencies could consider potential climate- and weather-related impacts on their areas of responsibility. The ILT tasked the Climate Change Working Group with developing a coordinated climate adaptation framework that would work across the various sectors represented by the individual agencies.

This initial effort by the ILT agencies and their partners concentrates on collaborative activities that can be accomplished in the next 2 to 5 years. To leverage limited resources, initial strategies focus on no-cost or low cost actions that can address multiple or particularly vulnerable systems. Efforts will be undertaken to integrate these adaptive responses with other ongoing local and regional government planning initiatives, where appropriate.

Two kinds of adaptation strategies are described in this report: *Overarching cross-sector strategies and Sector-specific adaptive response options.* Both kinds of strategies can be undertaken by state agencies, working with willing partners at local, regional and federal levels. Collectively, the strategies are intended to address common concerns across sectors and regions, and to serve as a resource to support decisions.

Overarching cross-sector strategies, which were recommended by the ILT for implementation, are the focus of this chapter. The emphasis is on practical, economically feasible options that can be coordinated across branches and levels of governments. These possible actions could be integrated into existing planning processes, priorities and standard operating procedures.

Sector-specific adaptive response options were developed that address the needs of individual sectors, providing a menu of possible actions that individual agencies or other entities could choose to implement. In addition to collaboratively addressing common concerns through broader cross-sector strategies, the participants in the working group considered the climate-related impacts to their specific areas of responsibility. Participants reviewed relevant vulnerabilities, current efforts, and adaptive response options for each specified sector. Details about these sector-specific adaptive response options are provided in Appendices B through E, which are organized into four categories: our people, our economy, our built environment,

and our natural environment.

The following overarching, cross-sector strategies have been recommended by the North Carolina Interagency Leadership Team for implementation. These broad strategies can enable our state to become climate-ready as we build North Carolina's resilience to potential threats.

Overarching Cross-Sector Strategies

1. PROMOTE COMPREHENSIVE ADAPTATION PLANNING AMONG STATE AGENCIES.

Encourage agencies to incorporate climate adaptation into existing planning programs, designs and policies, and integrate consideration of changing climate conditions into relevant decisions with long planning horizons.

Consideration of potential impacts should be given when investing funds to develop public infrastructure, such as transportation, water supplies, or sewage treatment systems, in areas where future drought, flooding or inundation is likely to occur within the lifespan of that structure.

In response to Session Law 2010-180, most state agencies reviewed their planning and regulatory programs. Some programs reported that they currently consider the impacts of climate change, while many others indicated that this could be considered in the future. Assessment of these programs allowed the departments to evaluate when and how certain programs might be modified to respond to changing climate conditions.

Facilitate linkages between climate adaptation, pre-disaster planning, natural hazard mitigation planning, and long-term disaster recovery planning.

North Carolina Emergency Management works with the Federal Emergency Management Agency to respond to disasters, when natural hazards cause damage to the built environment. Through the federal Disaster Mitigation Act of 2000, states develop hazard mitigation plans (similar to climate adaptation plans) and may apply for pre-disaster hazard mitigation grants, which North Carolina has done. UNC Chapel Hill's Hazards Center recommends this as an effective means to proactively plan ahead to prevent climate-related disasters.

Prioritize "no-regrets" adaptation actions that yield mutual benefits with other efforts.

Early efforts may focus on "no-regrets" actions that are good to take for other reasons beyond climate adaptation, and provide multiple benefits. For example, maintaining coastal wetlands provides nursery habitat for commercial and recreational fish, while enhancing water quality; these marshes can also absorb some of the force of hurricane-driven storm surges, and limit storm damage.

Establish an ongoing process that ensures state agencies are collaboratively planning for adaptation.

State agencies can consider how similar climate impacts could affect multiple sectors, and then coordinate development of solutions within and across agencies. Stronger lines of communication and information sharing would enhance this collaboration.

2. FACILITATE COMMUNICATION AND EDUCATION TO SUPPORT LOCAL, REGIONAL AND STATE ADAPTATION PLANNING EFFORTS.

Work to enable decision makers, stakeholders and the general public to be well informed of potential climate impacts and vulnerabilities, as well as the state's efforts to address these concerns.

As up-to-date information about potential climate impacts and vulnerabilities becomes available, it can be made accessible through an online climate adaptation clearinghouse that will be developed with partners.

Collaborate on communication planning and outreach with partners such as universities, extension agencies, federal agencies, local governments, Councils of Governments, and nongovernmental organizations.

It will require a team effort among partners to develop communication planning and outreach methods to support planning efforts. Many of these groups have the capacity to support state efforts, can convene meetings of interested participants, and can provide expertise in specific areas of concern. We will coordinate with willing organizations to facilitate working with interested local communities. Partners like N.C. Sea Grant, NOAA, and various universities have expressed interest in supporting this effort.

Include local or state-wide concerns with specific climate adaptation options as part of outreach and education efforts.

Within the State of North Carolina, climate impacts are expected to vary significantly by region, so region-specific response options would be needed. Education efforts could include potential strategies and guidance on selecting appropriate alternatives. Opportunities to inform the public about climate impacts could be provided through DENR attractions, such as the new Nature Research Center, or other public facilities.

3. COLLABORATE WITH PARTNERS TO PROVIDE RELEVANT INFORMATION FOR DECISION MAKING.

Collaborate with partners to access climate-related information that informs decisions.

North Carolina is fortunate to have climate science expertise to assist state government agencies in interpreting the data and assessing the possible risks.

- NOAA's National Climatic Data Center and Coastal Services Center provide the technology, information, and management strategies used by local, state, and national organizations to address complex issues.
- The Southeast Regional Climate Center at the University of North Carolina at Chapel Hill, the Carolinas Integrated Science and Assessments program at the

University of South Carolina, and the State Climate Office of North Carolina at North Carolina State University provide relevant North Carolina data, that is included in the National Climate Assessment.

Develop a North Carolina clearinghouse for climate adaptation with links to relevant localized and state climate information and a toolbox with adaptive response options.

One of the obstacles to adaptation planning is that insufficient information is currently available to support decisions at the state and local level. Working with internal and external partners could move our state toward a robust decision support system to address climate-related risks. Having a central repository that provides critical data would support the decision-making process. With a menu of options, communities can reach their own conclusions about the options best suited to a particular region.

Improve understanding of various climate–related risks and systems vulnerabilities.

The ILT agencies will have access to up-to-date, detailed information about the risks and vulnerabilities of our state's natural and built environments provided by trusted sources of information. For example:

- North Carolina Emergency Management received funding from the Federal Emergency Management Agency (FEMA) to develop two powerful assessment tools that will be provided online for communities to analyze climate-related and other natural hazards: the North Carolina Sea Level Rise Risk Management Study and the iRisk Tool for N.C. Integrated Hazard Risk Management.
- The U.S. Department of the Interior placed both the Southeast Regional Climate Science Center and the South Atlantic Landscape Conservation Cooperative at N.C. State University. The scientists will create climate models to forecast wildlife habitat and population changes, and assess species vulnerability to climate change.

4. ENCOURAGE BROAD COLLABORATION AND PARTNERSHIPS TO LEVERAGE RESOURCES.

Partner with organizations, private industry, professional associations and institutions to reduce duplication of effort and leverage resources.

Effective and efficient coordination of resources will make information available for citizens, community developers and local support agencies to reduce or mitigate various risks. North Carolina can seek opportunities to partner with other organizations that are already looking at the need for climate adaptation strategies. Some examples include:

- The insurance industry (e.g., Swiss Re),
- Energy organizations (e.g., The Energy Foundation),
- Trade representatives (e.g. , American Association of State Highway and Transportation Officials), and

- Professional organizations (e.g., the American Planning Association).

Encourage partnerships at a regional level to ensure coordination.

North Carolina government agencies participate in a number of partnerships that support coordinated climate adaptation efforts. Some examples include:

- The Governor's South Atlantic Alliance (SAA) is collaborating on implementation of science-based policies and solutions to support disaster-resilient communities in the face of hurricanes and sea-level rise.
- The Southeast Regional Partnership for Planning and Sustainability (SERPPAS) is considering how to best adapt to climate change in the Southeast.
- The Piedmont Triad Sustainable Communities Project, which covers 12 counties, has a climate adaptation working group.
- The Southeast Aquatic Resource Partnership is a regional collaboration of natural resource and science agencies, conservation organizations and private interests developed to strengthen the management and conservation of aquatic resources in the southeast.

5. PARTNER WITH COMMUNITIES TO FACILITATE LOCAL CLIMATE ADAPTATION EFFORTS.

Provide technical assistance and information for interested communities to ensure their success in working toward climate adaptation goals.

As communities recognize the need to begin planning how to adapt to climate impacts, knowing where to find the resources and information will be important. Various adaptation partners can provide online resources, training opportunities, and stakeholder meeting facilitation to assist these communities. For example:

- USEPA and FEMA are partnering to provide technical assistance for climate change adaptation and local planning to two N.C. coastal communities facing impacts from sea-level rise and more intense coastal storms.

Build local capacity to develop solutions that manage risk from extreme weather and other climate change impacts in order to reduce losses.

Resilience to disasters must be built at the community level, to ensure that unpredictable extreme events do not exceed the community's ability to recover. Area residents and leaders can choose appropriate response options that address the specific risks they face. For example:

- The Division of Emergency Management is working with UNC-CH School of City and Regional Planning to develop a planning resource handbook for local government stakeholders and planners who are interested in incorporating climate change issues into planning processes. The handbook should be complete in fall of 2013, to be followed by training if funding is available.
- The North Carolina Sea Grant Program has formed the N.C. Coastal Community Climate Adaptation Network to coordinate an outreach and communication process that can help coastal communities adapt to climate impacts, including sea-level rise.

6. REFINE ADAPTATION STRATEGIES AS INFORMATION BECOMES AVAILABLE AND TOOLS IMPROVE.

Use the best available science to inform flexible strategies, which will evolve over time.

Climate scientists are working to bring the global climate model simulations down to a more local level and incorporate weather data specific to a particular area. More locally relevant projections of long-term weather patterns for North Carolina and its regions would be invaluable for adaptation planning.

Monitor, evaluate, and adjust to support adaptive management of resources.

Adaptation planning needs to be a cyclical, iterative process that includes monitoring the effectiveness of response options and modifying these as needed over time. As the climate continues to change in the coming decades, different adaptation strategies may be required.

Ensure that expert advice and stakeholder input are a continued part of the long-term ongoing process of climate adaptation.

Keeping up with the latest research and recommendations will support the state's evolving climate adaptation strategy. As these options are identified, it will also be important to seek input from representatives from communities, NGOs, elected officials, scientists, and policymakers.

Appendix A: Vulnerability Assessment and Strategy Development Process

Introduction

In keeping with their focus on an integrated planning process, the N.C. Interagency Leadership Team (ILT), representing 11 state and federal agencies, thought about how multiple government agencies could consider potential climate- and weather-related impacts on their areas of responsibility. The ILT began looking at the need for planning ways to adapt to projected impacts of climate change. Even though the ILT includes both state and federal agencies, from the beginning it was decided that the strategy development effort would need to be State-led and federally supported. The strategy outlined in this report is the product of that collaborative effort whose process and product was advised by numerous state and federal agencies.

In 2010, the ILT sponsored a well-attended workshop, "Planning for North Carolina's Future: Ask the Climate Question," to provide tools to enable decision makers to plan adaptation responses in their communities. To keep the momentum going, the ILT tasked the Climate Change Working Group with developing a coordinated set of strategies that would work across the various sectors represented by the participating state agencies. This integrated framework for common action would guide state agencies and other organizations to better understand what the future climate and its associated impacts will mean for North Carolina.

To provide well-rounded input, the ILT Climate Change Working Group was expanded to include more agencies beyond the ILT. Additional representatives were included who could provide expertise in specific areas. In the first phase, this team worked with consultants to develop an assessment prototype that would reveal North Carolina's vulnerability to climate change impacts. This assessment method uses a qualitative approach and was completed by selected practitioners based on their professional experience.

In the second phase, these assessment results were used to inform adaptive strategies designed to reduce risk and increase resilience to projected future changes. The focus was on developing practical, economically feasible options that would be coordinated across branches and levels of governments. These possible actions could be integrated into existing planning processes, priorities and standard operating procedures.

Process Used to Develop the Strategy Framework

VULNERABILITY ASSESSMENTS

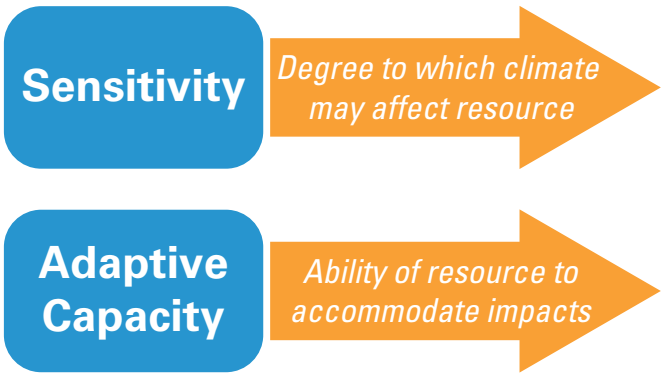
A method was developed to assess the degree of vulnerability that North Carolina's built, natural, human and economic systems might have to specific climate-related impacts. Vulnerability is a function of a system's sensitivity to changes in climate and its ability to adapt to those changes. The vulnerability assessment process looked at both climate sensitivity and adaptive capacity.

- Sensitivity is the degree to which a built, natural, or human system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased

water temperature).

- Adaptive capacity is the ability of the built, natural, and human systems within a given system or planning area to accommodate changes in climate with minimal disruption or cost.

The vulnerability assessment process took place in two overlapping phases: 1) Climate Sensitivity assessment, and 2) Adaptive Capacity assessment.



1. Climate Sensitivity Assessment

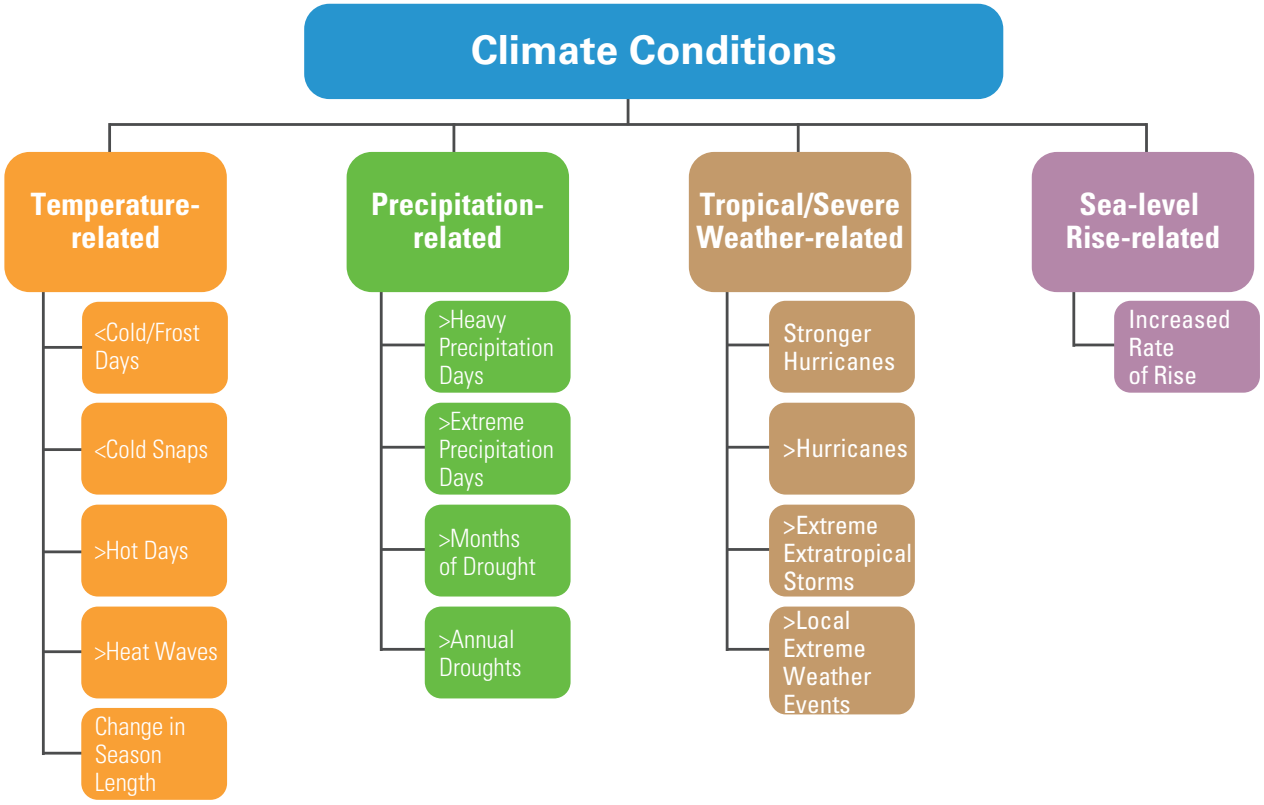
To develop the climate sensitivity assessment, the working group was supported by the National Environmental Modeling and Analysis Center (NEMAC) and the Renaissance Computing Institute (RENCI) at University of North Carolina at Asheville. NEMAC used funding from NOAA's National Climatic Data Center (NCDC) to develop a way to apply the National Climate Assessment at a local, regional, or state scale. North Carolina's assessment process demonstrated how local information can be collected using a bottom-up approach, which will be included in the National Climate Assessment scheduled for 2013.

The participants in the working group considered how these climate-related impacts could impact various areas of responsibility that are managed by various state agencies. The climate assessment process was conducted with fifteen small groups of agency experts knowledgeable about the specific sectors. Agency participants coordinated responses to questionnaires to identify and evaluate how changes in climate conditions might have consequences to the resources that their agencies are responsible for managing.

A number of factors were considered for each sensitivity assessment:

Climate conditions: Participants in the working group considered a dozen global climate conditions that had been identified in the IPCC Fourth Assessment report. These fall into four major categories: temperature-related, precipitation-related, tropical/severe weather-related, and sea-level rise-related. Climate conditions include such things as warm and cold spells, heavy precipitation, drought, tropical cyclones, high and low temperature days, cool and warm seasons, and sea-level rise, among

others. See Appendix I, Climate Assessment Packet, for the IPCC detailed definitions of the climate conditions.



Consideration was given to the specific climate conditions as defined by the IPCC.

Sector: Eleven major Sector categories were designated by NOAA for the National Climate Assessment. Each of these sectors was sub-divided; a total of 34 sub-sectors aligned with the state agencies involved in the process (See table below.) Individual assessments were conducted for all planning areas identified by participating agencies. (For more information about how the changing climate conditions are expected to impact each of these sectors, refer to Appendices B through E.)

NOAA-Designated Sectors	North Carolina Sub-sectors (i.e. Planning Areas)
Transportation	Land Transportation Operations Land Transportation Maintenance Marine Transportation Operations Marine Transportation Maintenance Air Transportation Operations Air Transportation Maintenance
Natural Environments	Ecosystems (aquatic and terrestrial)
Water Resources	Public water supply Industrial water supply Agricultural water use Water quality (including infrastructure, water/wastewater)
Coastal Resources	Public trust resources (use and access) Natural buffers—wetlands and barrier islands Public property and infrastructure Private property and development Marine and estuarine coastal habitats
Human Health and Welfare	Heat-related /weather-related morbidity and mortality Vectorborne/zoonotic, foodborne, and waterborne diseases Asthma, respiratory allergies, and airway disease Mental health and stress-related disorders Other diseases (cancer, cardiovascular disease and stroke, neurological diseases and disorders, human development effects)
Agriculture and Forestry	Agriculture Forest Resources
Energy Production and Use	Utilities—Power Generation (coal, gas, hydro, etc.) Utilities—Use (electricity, gas, liquid fuels) Energy Resources Development and Marketing Energy Conservation and Efficiency
Human Social Systems	Cultural resources (cultural landscape resources, cultural archival resources) Insurance Emergency management (mitigation, preparedness, planning, response, recovery) Economic vitality (business and industry, tourism recreation, community development)
Land Resources	Dams Mining Erosion and Sedimentation Control

Systems: Systems are the built, natural, and human networks that provide important services or activities within a community or region. People value the resources, services or assets that are normally available for their use. Examples include transportation corridors, water supply and reservoirs, wetlands, human health, clean air, or wildlife habitats.

Scale: Two main spatial scales were used in the North Carolina assessment, state and state-regional (within the state). North Carolina was broken into three regions: coast, mountains, and piedmont. For the water resources sector, a multi-state regional scale was considered, because some river basins extend past state borders.

Non-climate factors: Non-climate factors include such things as population, topography, land use, soil type, governing policies, and the economy, among others. These could interact with climate conditions to intensify an impact.

Climate impacts: Together, the climate conditions and non-climate factors may combine to cause a climate impact to a system. Examples of these impacts are flooding, reduced water availability, inundation, reduced agriculture production, increased wildfire, or salt infiltration. Climate impacts may affect a system positively, or more often, negatively.

Systems: Systems are the built, natural, and human networks that provide important services or activities within a community or region. People value the resources, services or assets that are normally available for their use. Examples include transportation corridors, water supply and reservoirs, wetlands, human health, clean air, or wildlife habitats.

Consequences: When systems are affected by climate impacts, a consequence will result. For example, the consequence of drought stress on agricultural crops is measured by the amount of decrease in average crop yield.

Stakeholders: Each separate assessment listed the key stakeholder or decision makers who would be involved in assessing vulnerability and/or implementing adaptation strategies. For example in planning how to address sea-level rise inundating infrastructure such as sewer lines, wastewater treatment plants, and septic tanks, stakeholders might include the county health department, state water quality officials, and homeowners.

Sensitivity Rating: Each of the resources was rated as having high, medium or low sensitivity, based to the degree to which it might be directly or indirectly affected by the climate impacts being assessed. For example, coastal freshwater wetlands would be rated as having a high sensitivity to coastal erosion associated with sea level rise.

SENSITIVITY RATING

S3 (high)	System will be greatly exposed to and/or affected by the impact.
S2 (moderate)	System will be somewhat exposed to and/or affected by the impact.
S1 (low)	System will not be greatly exposed to and/or affected by the impact.

2. Adaptive Capacity Assessment

After a year of supporting the Climate Change Working Group to develop the assessment prototype and assess multiple sectors, NEMAC had completed their commitment. For the next phase, the team worked with another facilitator, Warren Miller of FountainWorks, who is well-versed in North Carolina state policy and strategic planning. His guidance was critical during the next year as the Climate Change Working Group developed state recommendations for policy and adaptation strategies that would coordinate with local, regional, and federal governments, as well as nongovernmental partners.

To adequately inform development of appropriate strategies, the working group decided that assessment of adaptive capacity in combination with climate sensitivity, would allow for more complete evaluation of the state's vulnerability to climate impacts.

Adaptive capacity is the ability of the built, natural, and human systems within a given planning area to accommodate changes in climate with minimal disruption or cost.

- Systems that can accommodate changes can either

  1) absorb impacts and still be resilient, or

  2) make necessary adjustments that will remove the vulnerability.
- Systems that cannot absorb impacts or encounter barriers to adaptation efforts have low adaptive capacity.

The adaptive capacity ratings developed for this report considered the ability of each resource to accommodate that climate impact with minimal disruption or cost. Each of the following questions was considered for each system:

1. What processes already exist and what efforts are currently underway to help improve the system's preparedness to changing climate conditions?
2. Is the system flexible, or will the rate of climate change overwhelm the system's ability to adjust?
3. What is the cost ($) associated with accommodating or adjusting to the impact (if known)?

Adaptive Capacity Rating: Each of the resources was rated as having high, medium or low sensitivity, based to the degree to which it might accommodate changes in climate with minimal disruption or cost. For example, coastal freshwater wetlands would be rated as having a low adaptive capacity to coastal erosion associated with sea level rise.

ADAPTIVE CAPACITY RATING

A3 (low)	System will not be able to accommodate or adjust to impact.
A2 (moderate)	System will be somewhat able to accommodate or adjust to impact.
A1 (high)	System will be able to accommodate or adjust to impact in a beneficial way.

3. Sensitivity + Adaptive Capacity = Vulnerability

Vulnerability is a function of a system's sensitivity to changes in climate and its ability to adapt to those changes. Sensitivity and adaptive capacity for a specific resource were separately rated as having low, moderate or high degrees. The Sensitivity and Adaptive Capacity scores were added to generate a relative Vulnerability score for risk from climate impacts. To follow through on the freshwater wetlands example, S3 Sensitivity rating + A3 Adaptive Capacity rating = 6 points = High vulnerability rating.

VULNERABILITY RATING

2 points = Low vulnerability

3 points = Moderate-low vulnerability

4 points = Moderate vulnerability

5 points = Moderate-high vulnerability

6 points = High vulnerability

NORTH CAROLINA IS VULNERABLE TO FIVE MAJOR CLIMATE CONDITIONS

The vulnerability assessment process revealed that five climate conditions are the most likely to impact North Carolina: drought, sea-level rise, tropical cyclones, heavy precipitation, and increased heat. (See Chapter 3 for more detail on these climate-related impacts, risks and vulnerabilities.)

In the sections that follow, basic examples are provided of systems that rated moderate-high to high on the vulnerability scale. More detailed information about climate-related vulnerability is provided in Chapter 3. Appendices B through E consideration adaptation strategies that could help specific sectors become more resilient to these impacts.

1. More Frequent Drought

Drought is defined by the State Climate Office of North Carolina as a deficit in normal precipitation for a region over a period of time sufficient to cause impacts.

Reduced water availability shows up as changes in:

- Stream flow
- Base flow
- Soil moisture
- Groundwater recharge
- Salt wedge migration
- Air pollution increase

Despite an abundance of moisture, North Carolina does experience drought when precipitation deficits lead to impacts such as reduced agricultural production and/or shortages of freshwater supplies. Rapid population growth and development have greatly increased the region's demand for water and our vulnerability to variability in precipitation.

North Carolina has historically experienced periodic droughts that are within the range of natural climate variability. During the 1998–2002 drought, the Carolinas experienced new records for low lake, reservoir, and groundwater levels, which are the lowest since written records have been kept. If the frequency or duration of extreme and exceptional droughts increase, the impacts are likely to be more disruptive. Such droughts have the potential to result in widespread economic damage, caused by exceptional and widespread crop and pasture losses, as well as water emergencies triggered by water shortages in reservoirs, streams, and wells. With the potential for changes to the range of climate conditions, determining how to plan for more frequent and/or more intense droughts becomes more important.

Droughts impact many sectors of North Carolina's economy and therefore many of the state's residents. Reduced public and industrial water supplies can threaten public health, business continuity and employment. Reduced stream flows can reduce electric generation from hydropower projects. Declining water levels and increasing water temperatures can reduce or curtail generation from thermoelectric plants because of reduced cooling capabilities and existing permit requirements. Drought conditions during critical periods in the growing season will increase stress on water resources as farmers provide supplemental water to maintain production of food and fiber crops and livestock. Structures located along the boundaries of forests, pastures and other undeveloped lands face increased susceptibility to damage and loss from wild fires during droughts. Reduced precipitation could negatively impact several profitable recreational sectors, such as the ski industry and wildlife-associated recreation. In addition, droughts lead to decreased air quality. Reduced precipitation results in more particulate matter in the air. Drier soil and roadways also generates more airborne particulate matter.

The state's agricultural sector, a major economic engine, is at risk from droughts. If sufficient water supplies are not available to support agriculture, energy production, industrial uses, and consumer demands, it could have a significant economic impact. Increased drought will lead to a greater demand for water for irrigation and livestock. The Piedmont and Coastal Plain regions will be more vulnerable to this impact due to the large amount of agriculture performed in these regions. Drought can cause severe reductions in crop yields. Impact of to cold water aquaculture is severe; clean, plentiful, cold water is a critical input for commercial trout production.

Lack of water has a very large impact on natural systems. Projections of longer and more severe droughts, coupled with higher temperatures, could mean that many species will not be able to adapt. This could lead to large changes in both aquatic and terrestrial ecosystems across the state. Drought also influences the forest ecosystem to be more vulnerable to wildfire and pest damage, which lead to human health and economic impacts. Changes in input of fresh water may be significant to tidal wetlands, particularly in the northern part of the state. Changes in salinity associated with recent droughts may have had effects on existing vegetation. An

increase in drought frequency or severity would make such effects more important.

The largest sector of freshwater use for North Carolina is cooling of power plants (more than 80%). Drought reduces the amount water available for energy plants to generate electricity and dispose of the heated cooling water safely.

Drought also affects community and individual water supplies. During drought, contaminants may build up on the ground, and subsequent rainfall generates flash floods that may overwhelm stormwater systems. As a result, communities may see a reduction in water quality and an increase in waterborne disease during drought.

Drought can also affect air quality, by increasing concentrations of particulate matter can cause respiratory distress in human and animal populations. During periods of drought, there is much less rainfall to clean particulates from the air. At the same time, there is an increase in particulates generated from both manmade and natural sources, such as construction, agriculture, road travel, quarrying, dust and wildfires. This impact is especially important in metropolitan areas or in areas that are not in attainment of the national ambient air quality standards for particulate matter.

2. Rising sea-level with accompanying storm surge

Rising sea level can be the result of the warming-induced expansion of the oceans, accelerated melting of glaciers, and/or loss of ice in Greenland and Antarctica leading to a rise in sea-level. The future climate concern is the rate at which this may increase.

Sea-level rise could bring about changes such as:

- Inundation
- Increased coastal erosion
- Breach of barrier Islands
- Saltwater intrusion
- Rising water table

According to the Environmental Protection Agency's 2009 report, Coastal Sensitivity to Sea Level Rise: A Focus on the Mid-Atlantic Region, North Carolina has the third highest land area vulnerable to sea-level rise of all U.S. states. Tide gauges have shown a steady increase in sea level, and it is very likely that sea level will continue to rise over time. Even if the pace does not increase significantly, North Carolina's shoreline will be altered. The state has thousands of square miles of land at low elevation that would be at risk of inundation. Much of the land in the state's northeastern coastal plain lies very close to sea level and has very little slope, meaning that even small increases in sea level could result in a wide expanse of coastal land being temporarily or permanently inundated over time.

Many variables, including the coastal slope, geological makeup, erosion rates, and the shape of the coastline, combine to make N.C.'s coastline vulnerable to higher sea level. In combination with tropical storms that may increase in intensity, sea-level rise magnifies existing coastal hazards such as flooding and storm surge. Many homes

and businesses are in low-lying areas, where they already face the risk of storm-related damage. Already, shoreline erosion has required structural defense and loss of homes along the beach.

Inundation may evolve over a long time frame and will vary based on the contours and geography of the coast. Land in low-lying areas will be affected by all types of storms that affect the coast and become increasingly vulnerable to loss. Inundation may not happen only gradually; it can be accelerated during tropical cyclones as storm surge pushes flooding further inland. These events often lead to coastal erosion. With both rising seas and more intense storms, large disruptions to the barrier island systems are likely. As the sea rises and coastal erosion occurs, what is currently land could be in the middle of a channel or several hundred yards offshore.

As salt water displaces fresh water, large impacts to natural and manmade systems could occur. Salt water intrusion can affect not only marshes, bays and lakes, but also the groundwater system and shallow aquifers that are common in the outer Coastal Plain. Freshwater tidal wetlands are likely to be among the most severely affected by rising sea level and increased intensity of storms. Permanent inundation and shoreline erosion are already occurring due to gradual sinking of the land in some areas and can be expected to continue. Salt intrusion into freshwater peat lands accelerates their collapse, particularly in the Albemarle Pamlico peninsula.

In marine and estuarine coastal habitats, increasing water temperatures combined with sea-level rise are thought to influence aquatic community structure. Changes in barrier islands and wetlands could reduce the productivity of estuarine nursery areas, negatively impacting N.C. fisheries. Fish species distribution could change, especially species that are already at their southern or northern distribution limits.

As the coastline changes, increased storm intensity combined with rising sea level would affect properties that occupy the coastal area of our state. Our coastal communities could face significant losses of residential and commercial properties, as well as costly damage to transportation, energy, water/sewer and communications infrastructure. Extreme inundation and wind damage could result in population displacement and property losses.

Any significant rise in mean sea level may pose direct threats to lowland historic towns and districts in the Coastal Plain, which draw thousands of visitors each year and generate significant economic benefit. There are nearly 5,800 prehistoric and historic archaeological sites in the Coastal Plain of North Carolina within 30 feet of mean sea level.

Sea-level rise due to climate change could have a major economic effect on North Carolina agriculture and forestry. Increased frequency of flooding in coastal areas due to sea-level rise has the potential to cause crop losses and damage to buildings and equipment. As sea levels continue to rise, coastal forests will be displaced as shorelines retreat.

Rising sea level can negatively impact water supplies for municipalities and industries. The degree of impact may vary, depending on whether it is caused by temporary flooding during storm surge or extreme high tides, or because a low-

lying area becomes permanently inundated. Infrastructure failure may occur due to coastal inundation of water and wastewater components, like septic tanks, sewer lines, and pump stations. Septic tank failure in poorly drained coastal soils creates a need for alternative waste treatment. When pump stations, sewer lines, and wastewater treatment plants are inundated, the environment is contaminated, and the infrastructure must be replaced.

The impacts of sea-level rise could potentially affect the infrastructure and operations of both land and marine transportation systems in the coastal areas of North Carolina. Transportation infrastructure may be impacted by the inundation of roads, more frequent or severe flooding of low-lying infrastructure, the erosion of road base and bridge supports, and the loss of barrier shoreline due to sea-level rise. More severe storm surges may also cause more frequent interruptions in travel on coastal and low-lying roadways and rail service, and may also require evacuation of vulnerable areas. Rising sea levels may require some changes in port and ferry facilities to accommodate higher tides and storm surges. More severe storm surges may also result in interruptions to ferry services, shipping services, and port operations.

3. More Intense Hurricanes

Tropical cyclones include hurricanes, tropical storms, and tropical depressions. Tropical cyclones are measured by their strength (frequency, intensity, track, peak wind speed, precipitation, and storm surge). Hurricanes are classified as a category 1–5, based on their strength .The future climate concern is that hurricane strength may increase.

Powerful storms often produce these impacts:

- Increased Storm Damage
- Shoreline erosion
- Storm surge
- Flooding
- Wind

Major tropical cyclones, which include hurricanes, tropical storms, and tropical depressions, can cause a number of devastating impacts to manmade and natural land features. North Carolina has a long history of destructive hurricanes. The coast of North Carolina can expect to receive a tropical storm or a hurricane once every 4 years. The state's protruding coastline makes it vulnerable to tropical cyclones that curve northward in the western Atlantic Ocean. Cape Fear and Cape Lookout are also favored areas for tropical cyclones to make landfall. Between 1886 and 1996, North Carolina experienced 28 direct landfalls.

Tropical storms and hurricanes are predicted to increase in intensity, with more of them becoming major hurricanes (category 3 to 5). North Carolina already experiences billion-dollar disaster events on a frequent basis from a variety of severe weather. If our state receives a direct hit from a major hurricane, we could anticipate even more significant damage than from the less intense storms we have experienced in the past.

The entire state of North Carolina is subject to the effects of tropical storms and hurricanes, which are characterized by heavy rain accompanied by strong winds. Although their impact is the most intense in the Coastal Plain region, the wind and flooding events linked to these tropical systems cause high amounts of damage and flooding across the state. Increased storm intensity is expected to produce higher storm surges along our coast. Combined with rising sea level, storm surge damage would reach farther inland and be more destructive.

A direct hit by a strong hurricane would be expected to damage and/or destroy many coastal structures. Wind, flooding, and storm surge are all likely to cause major harm. Damage to tourist infrastructure, including attractions, services, and accommodations, could have a significant impact on the coastal economy. Depending on the magnitude and severity of the storm, there could be large uninsured losses that may qualify for state or federal disaster declaration and aid. The cost of insurance would rise to cover the increased risks and claims will rise because of increased property losses.

High winds increase the possibility for damage to buildings, trees, other infrastructure, and contamination of drinking water supplies. In coastal areas, high winds can increase tidal levels, creating even more water damage to buildings, docks, bulkheads and other coastal development, as well as increasing shoreline erosion. Damage from such storms can have severe impacts to transportation facilities, utility distribution and communication lines, sewer and water infrastructure, thereby threatening human health and public safety. Such damage produces negative economic impacts to communities in the region.

Hurricane impacts to agriculture may be severe depending on the severity of the storm and the time of year in which it occurs. Crop and livestock damage and productivity loss are likely from such storms, as well as damage to buildings and equipment. Forestry losses from high winds associated with tropical cyclones can be severe. Without adequate planning and disaster assistance, agricultural interests can be devastated.

The Outer Banks are likely to be impacted significantly due to increased storm intensity, which can cause inlets to open and close. Such changes could occur gradually, as barrier islands narrow and disappear. However, these processes could also happen more rapidly, if a large storm opens substantial portions of barrier islands at one time.

Tropical storms have a tremendous impact on health services infrastructure. When North Carolina experiences emergencies, state and local health departments may be required to divert critical resources.

The destructive power of hurricanes will likely be enhanced by sea-level rise and higher storm surges on the cultural resources within the Coastal Plain. More intense tropical cyclones will pose a major risk to museums, archival records, historic districts and other National Register properties, state historic sites, cemeteries, and archaeological sites.

4. Increased heavy precipitation events

Heavy precipitation events include:

- Increase in the number of days with heavy precipitation
- Increase in the amount and rate of precipitation during events

The future climate concern is that the amount and rate at which precipitation occurs during an event may increase significantly.

Heavy precipitation often results in:

- Flooding
- Increased stream flows
- Erosion
- Landslides

Heavy precipitation events can cause substantial impacts to manmade and natural land features. This can be caused mainly from flooding, and would especially impact infrastructure located within floodplains. Heavy rainfall can produce short-lived flash floods and longer-duration river floods that can have tremendous impacts on property and human life. A variety of weather systems occur in the Southeast during different seasons. In winter, slow-moving systems produce large areas of very heavy rainfall, followed in spring and summer by thunderstorms that produce heavy rainfall in localized areas. In late summer and fall, tropical storms and hurricanes can produce extremely heavy rainfall, both locally and regionally. All rivers are susceptible to flooding, which can affect people through increased incidence of waterborne disease, contamination of water supplies, and both property and agricultural losses. Most flood-related deaths occur as a result of flash floods produced by tropical cyclones; these storms can also cause landslides on the steep slopes of the southern Appalachians.

Increased storm intensity or frequency may lead to increased stormwater runoff, with an increase in sediments, nutrients and contaminants in streams, rivers and reservoirs, resulting in negative effects on aquatic species and their habitats. Changes in rainfall intensity and variability will also affect stream flow patterns, channel hydrodynamics, lake levels, and the volume of groundwater recharge from aquifers, which could upset the physical, chemical, and biological structure of streams. An increase in heavy precipitation events would also increase the frequency that anoxic water is flushed from coastal wetlands into coastal rivers, which would result in an increase in fish kills.

Transportation infrastructure, whether land, air or water, can be inundated and/or damaged, disrupting the mobility of people and goods. Buildings and homes can also be damaged or destroyed. Emergency access can be impeded, creating threats to human safety if transportation corridors become impassable.

More intense rainfall events can produce higher flood heights, possibly causing dams and flood control structures to the point of overtopping and/or failure, as well

as impacting reservoirs and intakes structures that provide municipal drinking water. The uncontrolled release of stored water will produce a cascading series of damaging impacts downstream, including the possibility of compromising the integrity of downstream dams. Increased debris carried by the floodwaters can interfere with hydro-power generation and create other hazards. In addition, the destruction of the dam results in the loss of the fresh water stored in the reservoir for municipal drinking water, increasing the threats to public health from the lack of potable water delivery.

Landslides and sinkholes can be triggered by intense precipitation, creating public safety concerns, loss of roadways and buildings, and significant economic impacts. Increased heavy rainfall in vulnerable steep slope areas make it likely that landslides could increase, causing catastrophic property damage.

Flooding resulting from heavy rainfall events will also pose a major threat to various cultural resources such as archaeological sites, state historic sites, historic structures and districts, and archival records.

In agriculture and forestry, increased soil erosion may occur as a result of more frequent heavy rainfall events. Crop productivity may decrease as a result of more frequent flooding of fields and delays to planting and harvesting. Forest productivity could be affected because flooding affects trees at every stage of their development, from seed germination and flowering to sprouting and vegetative growth.

Increased and more intense precipitation can affect the quality and quantity of clean water available to North Carolinians, when heavy rainfall events cause inundation of storm-water and sewage systems, toxic waste facilities, or livestock waste lagoons. Heavy rain events can cause untreated waste from waste treatment plants or animal operations to be released into drinking water sources.

Other significant health impacts that result from heavy precipitation events are also a concern. Contamination of irrigation water can contribute to food-borne disease. Vector-borne diseases that are transmitted primarily by ticks and mosquitoes can cause serious illness or even death. These vector-borne diseases may become newly established or endemic diseases may increase as a result of changing climatic patterns.

5. More Extreme Heat

Extreme heat impacts take more than one form, with slightly different concerns:

- Heat waves are an episode of several consecutive high-temperature days and nights, when the temperatures never really cool down. The future climate concern is an increase in the frequency and intensity of these events.
- Extreme heat can also include an increased number of very hot days. The future climate concern is an increase of this occurrence, both locally and regionally.
- Seasonal average temperatures (as opposed to daily temperatures) could exceed historic averages. The future climate concern is shorter cool seasons

and longer warm seasons, with an increase in average temperatures during both.

Extreme heat impacts, including both heat waves and high temperature days/ nights, can produce:

- Heat Stress
- Water demand increase
- Energy demand increase
- Air pollution increase
- Ocean acidification

It is likely that extreme heat events will become more frequent, longer lasting and more intense. Water demands for drinking water, cooling water, and irrigation would be greater. Water supplies may already be at risk due to drought, further compounding the issues of heat waves.

Heat waves are expected to increase with future climate variability all across North Carolina, but are predicted to be most noticeable across the Piedmont. The impact of the temperature extremes may have the greatest impact in the Piedmont due to the projected high population. The Piedmont will have a very strong link between heat stress and drought due to the large number of people living in the region and their energy needs.

Heat waves are a combination of both elevated temperature and its impact on our lives. Heat stress for people is a direct result of an increase in temperatures, typically associated with heat waves, and may be accompanied by high humidity levels as well, leading to high heat index values. With high temperature days and nights, people face direct heat exposure, and hot spells early in the year have especially significant impacts, since people are not yet acclimated to the heat. Higher night-time temperatures do not allow complete recovery after hot days. Residents who do not have access to air-conditioned facilities face increased threat to their health, especially those in susceptible groups such as the elderly and infirm. Heat stress will impact human health and can increase morbidity and mortality, even among younger people who work or play outside in the heat.

Heat waves that cause heat stress will have a compounding impact in that they will lead to increases in energy and water demands, as well as a decrease in air quality. Energy demands, in particular, will be impacted by heat waves as heat stress on humans lead to an increase in air conditioning needs, which is the primary mechanism to reduce heat stress. The increased water temperatures can impact the cooling capabilities for thermo-electric power generation facilities. Residents who do not have access to air-conditioned facilities face increased threat to their health, especially those in susceptible groups such as the elderly and infirm.

Air pollution levels, specifically the peak ozone levels on high temperature days are expected to increase significantly. The impacts will be regional in nature and more severe in metropolitan areas and areas that are already in nonattainment for ozone. In addition, a longer warm season will increase the length of the ozone season,

currently from May 1 to September 30, with potentially more days of the year with high ozone levels. Ground level ozone can cause respiratory distress in sensitive human populations and also can impact plant growth.

However, heat stress will not only affect human life, but crops as well. Water demands will also increase as farmers are forced to rely more on irrigation to water their crops. Plants will exhibit decreases in yield as temperatures increase above their optimum range. Virtually all types of aquaculture are severely stressed during sustained periods of high temperatures. As water demands increase, water supplies will decrease. Increased heat could negatively impact several profitable recreational sectors, such as the ski industry and wildlife-associated recreation.

In aquatic ecosystems, increased air temperatures will lead to increased water temperatures and lower dissolved oxygen levels for most streams and rivers. Increases in water temperature could also cause aquatic species to experience shifts in their range or distribution, and sensitive species may experience decline or extirpation. Species such as trout, that are already at the edge of their natural range, are likely to be affected by temperature increases. Algal blooms are more likely in the larger, slower rivers and these can exacerbate dissolved oxygen problems, will likely result in increased number and size of fish kills, especially when combined with human-caused factors such as pollution. The prevalence of warmer water temperatures may increase the likelihood of additional exotic species that were previously considered to be non-threatening when the winters were too cold for survival.

Plant and animal communities associated with high elevation northern hardwood forests and spruce-fir forests are all highly likely to be affected by changes in temperature and moisture associated with climate change. There is concern and uncertainty about whether these shifts will "push communities off the top of the mountains." Changes might be either gradual (resulting from shifts in reproductive success, or impacts from disease and insect infestation) or may be abrupt (tied to severe weather or fire).

As the ocean temperature increases and more CO2 is dissolved in ocean waters, there is a decline in pH. This ocean acidification can adversely affect calcifying organisms, such as oysters, affecting their shells, and reducing shell bottom habitat.

Strategy Development Process

Using these vulnerability assessment results to inform adaptive strategies, the working group began developing practical, economically feasible options that would be coordinated across branches and levels of governments. Realistically, possible actions would need to integrate into existing planning processes, priorities and standard operating procedures. The following principles were applied as filters as suggested response options were considered.

ORGANIZING PRINCIPLES GUIDING THE STRATEGY DEVELOPMENT PROCESS

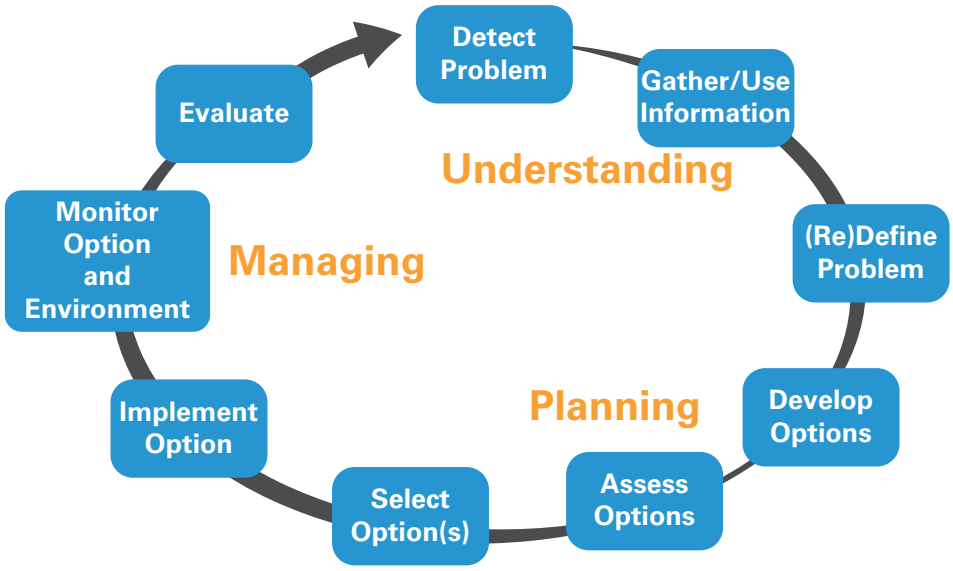
- The ILT agencies and their partners are concentrating early efforts on adaptive

responses that can make progress within 3 to 5 years.

- The open-ended framework outlined below will enable us to 'adapt' as new science emerges and new tools become available.
- To leverage limited resources, initial strategies will focus on no- or low cost actions that can address multiple or particularly vulnerable systems.
- Early efforts may focus on "no-regrets" actions that are good to take for other reasons beyond climate adaptation, and provide multiple benefits.
- Importantly, efforts will be undertaken to integrate these adaptive responses with other ongoing local and regional government planning initiatives.

A FLEXIBLE CLIMATE ADAPTATION STRATEGY FRAMEWORK

It is not realistic to think that a static plan will be able to address changes in the climate over time. Instead, a cyclical approach allows flexibility to adjust the strategy as more information becomes available. The model below shows how most other states, as well as federal agencies, are approaching adaptation strategy planning.



We can anticipate, plan ahead, and act…OR we can react.

North Carolina's resiliency framework is based on this cyclical approach.

Phase 1: Assess vulnerability of specific systems in order to understand the problem.

Phase 2: Develop, assess, and select appropriate options.

Phase 3: As adaptive options are implemented, manage by monitoring and adjusting as needed as circumstances change.

TWO KINDS OF ADAPTATION STRATEGIES

Cross-Sector Strategies

The main focus of this interagency effort was on developing broad cross-sector strategies that enable our state to become climate-ready as we build North Carolina's resilience to potential threats. These overarching strategies, which were recommended by the ILT for implementation, are provided in Chapter Four of this report.

Sector-Specific Adaptive Response Options

Additionally, this assessment process helped with identification of appropriate adaptive response options that deal with more narrowly defined planning areas. More detailed information about sector-specific adaptation strategies is provided in Appendices B through E, as consideration was given to adaptation strategies that could address specific areas of responsibility.

Because the State of North Carolina is only in the beginning stages of adaptation planning, the strategies included in this report are preliminary. Efforts will focus on getting ready for the next phase, by getting reliable information to support decisions and developing collaborative partnerships. Recommendations for rules or regulations are not part of this framework, but careful planning can make sure that the state's financial resources are used wisely.

Appendix B: North Carolina's People

This chapter on North Carolina's People includes these sectors:

1. Public Health
2. Public Safety: Hazard Mitigation Planning and Emergency Response
3. Cultural Heritage

Introduction

The environmental consequences of climate change, both those already observed and those that are anticipated, such as sea-level rise, changes in precipitation resulting in flooding and drought, heat waves, more intense hurricanes and storms, and degraded air quality, will affect human health both directly and indirectly. *A Human Health Perspective on Climate Change, published by Environmental Health Perspectives and the National Institute of Environmental Health Sciences.*

One of North Carolina's greatest resources is its people, and the people of the state will be directly affected by climate-related impacts. North Carolina experiences all possible major weather events (with the exception of monsoons). In an average year, North Carolinians can expect to witness hurricanes, floods, droughts, heat waves, winter storms, cold spells, hail, high winds, lightning, and tornadoes. Each event impacts human health and safety, as well as the state's cultural resources.

Health, safety, and cultural heritage are at the core of why people live, visit, and relocate to North Carolina. These values form the basis for the high quality of life that many North Carolinians enjoy. Both public health and public safety are so elemental, so fundamental to life and human well-being, that they need no justification for consideration. A basic understanding of one's cultural heritage is essential to a sense of personal history, identity, and belonging to the community at large. While this sense of cultural heritage may not be absolutely necessary for physical survival, a combination of the three provides a personal balance which enhances the quality of life and overall health for each individual in the entire state.

1. PUBLIC HEALTH

In 2010, the North Carolina Division of Public Health received funding through the Centers for Disease Control and Prevention for the Climate-Ready Cities and States Initiative, for the purpose of initiating at a climate change adaptation program. The goal of the Climate Ready N.C. program is to develop a strategic plan to address the health impacts of climate change for North Carolinians.

Impacts, Risks, and Vulnerabilities

Climate Ready N.C. focuses on the following public health outcomes: asthma, respiratory allergies, airway disease, heat-related illness, human development, water-carried disease, and extreme weather-related injury.

All climate patterns affect human health and well-being. This section focuses on the effect of the following climate scenarios on the health of North Carolinians: increased drought, increased and more intense precipitation, heat waves, tropical cyclones, and sea-level rise. The public health impacts from these climate conditions are extremely complex, and so this section provides a few examples of some of the major adverse outcomes.

Water Quality and Quantity

Each of the most likely climate impacts—increased drought, increased and more intense precipitation, heat waves, tropical cyclones, and rising sea level—would affect the quality and quantity of clean water available to North Carolinians. Increased and more intense precipitation, along with more intense tropical cyclones or rising sea level, could cause inundation of storm-water and sewage systems, toxic waste facilities, or livestock waste lagoons. These facilities, which may be at risk to fail or overflow, may release hazards such as sewage-related pathogens, storm-water,

animal wastes, and toxic materials. When recreational and drinking water quality is compromised due to demands on stormwater systems that exceed capacity, North Carolina communities may issue boil water advisories or experience violations of drinking water standards, waterborne disease outbreaks, beach and public use water closures, and skin infections among first responders to disasters. Additionally, during heavy precipitation events or tropical cyclones, contamination of irrigation water can contribute to food-borne disease. The occupational health of shellfish harvesters and others who work closely with contaminated water may be threatened.

Drought also affects community and individual water supplies. During drought, contaminants may build up on the ground, and subsequent rainfall generates flash floods that may overwhelm stormwater systems. As a result, communities may see a reduction in water quality and an increase in waterborne disease during drought. Harmful algal blooms (HABs) in NC are closely related to high temperatures and reduced precipitation; they carry toxins that may be harmful when ingested. During droughts, more harmful algal blooms occur, increasing the potential for exposure to HAB toxins, which vulnerable groups such as children and family pets may ingest. Swimming areas would be closed to reduce exposure, decreasing recreational opportunities.

During summer, the water- and food-borne disease incidence increases due to a combination of bacterial activity and human behavior. With more high temperature days and nights or heat waves, water- and food-borne illness events in North Carolina may increase.

Vector-borne Disease and Pest Management
Vector-borne diseases in North Carolina are transmitted primarily by ticks and mosquitoes and include such diseases as spotted fever Rickettsiosis, LaCrosse encephalitis, West Nile virus, eastern equine encephalitis, and tularemia. Several of these diseases can cause serious illness or even death. These vector-borne diseases may become newly established or endemic diseases may increase as a result of changing climatic patterns.

Drought and UV exposure may affect vector-borne disease by influencing the reproductive cycle and behavior of ticks and mosquitoes. For example, ticks may burrow deeper into the ground cover when humidity is low. Furthermore, drought may weaken trees, plants, and agriculture and make them more vulnerable to pests.

Mosquito populations can skyrocket after a tropical cyclone or periods of intense precipitation. For example, following Hurricane Irene in 2011, mosquito landings on a person in one minute became 'too numerous to count' in some coastal counties. An increased number of mosquitoes and increased biting frequency may lead to more disease.

Vector-borne disease increases during summer months due to a combination of vector activity and increased exposure to the insects as people increase their outside activity. Therefore, high temperatures may affect vector-borne disease.

Respiratory Health
Reduced precipitation during prolonged drought results in more particulate matter in

the air, since precipitation is not regularly removing it; drier soil and roadways then generate more dust. Poor air quality during droughts may result in a greater number of air quality alert days, an increased impact on people with asthma, or a higher number of respiratory-related emergency department (ED) visits. Further, wildfires made worse by drought conditions, may contribute smoke and particulate matter to the air. For example, the 2008 and 2011 wildfires in Person County resulted in an increase in respiratory and cardiovascular-related ED visits in surrounding areas.

Climate change has the potential to produce significant increases in ground-level ozone in North Carolina, particularly for the highest-ozone events. More areas/municipalities may experience high ozone events and an increase in the number of days with high ozone. More areas/municipalities may experience high ozone events and an increase in the number of days with high ozone. Sunlight and high temperatures, combined with other pollutants such as nitrogen oxides and volatile organic compounds, can cause ground-level ozone to increase. (USEPA, 2009) As stated above, the resulting poor air quality can increase the number of hospitalizations for individuals with respiratory or cardiovascular disease. The impact is expected to be large in environmental justice communities whose residents have limited means to adapt to warming temperatures, and which already experience a large respiratory and cardiovascular disease burden. (USEPA, 2009)

Injuries

Climatic conditions that may contribute to heat-related injury in North Carolina include tropical cyclones, drought, high temperature days and nights, and heat waves. Following a tropical cyclone, power may be disrupted, so that people may be unable to use electricity to keep their homes cool. During drought, cloud cover decreases, allowing more of the sun's warmth to reach the earth's surface. Precipitation is not available to cool the land or air. With high temperature days and nights, people face direct heat exposure, and hot spells early in the year have especially significant impacts, since people are not yet acclimated to the heat. Higher night-time temperatures do not allow complete recovery after hot days.

Due to these climatic patterns, heat-related deaths, hospitalizations, and emergency department visits may increase, particularly among vulnerable groups. In North Carolina, young, healthy males (19–44 years) are vulnerable to heat-related illness, especially related to work such as farm labor, construction, or landscaping. For example, a 2005 study found that among North Carolina occupation-related heat fatalities, nearly half occurred among farm workers. In addition, 15 to18 year olds are often seen in the emergency department for sports-related heat exposures. Older North Carolinians (>65) may be more likely to be hospitalized for heat-related illness. Heat waves may affect those with co-existing conditions, such as cardiovascular disease and stroke. Another vulnerable group is those taking medications that impair the body's ability to regulate temperature, such as the mentally ill or heart disease patients. In addition to heat injury, North Carolinians experience other types of injuries during climatic events. During heavy precipitation or tropical cyclones, the extreme weather conditions and the presence of large amounts of water increase risk of injury. Safe roadways and transportation may not be available; as a result, severe weather injuries, motor vehicle injuries, and drowning may occur. Falls would be another area that could increase. If conditions deteriorate sufficiently, domestic

violence, homicide or suicide may increase. Prior to a tropical cyclone, North Carolinians incur injuries from evacuation activities. Following the hurricane, cleanup activities differ, with some people experiencing insect bites and snake wounds from displaced creatures.

Infrastructure, Electricity, Critical Facilities, Adequate Shelter
When North Carolina experiences emergencies, state and local health departments may be required to divert critical resources, despite needs for essential public health services. Tropical storms have a tremendous impact on health services infrastructure. Storm surge may impact transportation and other infrastructure upon which the chronically ill rely. Hurricanes may limit access to life-saving medicines, and may overwhelm or close hospitals, clinics, and doctors' offices. In addition, people, many of whom are the most vulnerable North Carolinians, may lose their homes. Rising sea levels may cause loss of income, particularly among tourism, agriculture and fishing industries. These losses may alter the demand on the mental health system resulting from the mental stress of losing a home, income or livelihood.

Warm spells and heat waves that cause heat stress will have a compounding impact in that they will lead to increases in energy and water demands, as well as a decrease in air quality. Energy demands, in particular, will be impacted by heat waves as heat stress on humans lead to an increase in air conditioning needs, which is a primary mechanism to mitigate heat stress.

Mental Health
Exceptional drought may lead to loss of income or livelihood for persons in the tourism or agriculture sectors, thereby contributing to mental stress, mental health disorders, and an increased demand for mental health services. A tropical cyclone can increase mental stress by affecting access to adequate housing and other essential needs such as life-saving medicines and treatments. In the wake of a tropical cyclone, a local health department may respond to tremendous social disruption, mental stress, increased demand for mental health services, homelessness, increased substance abuse among abusers, and increased domestic violence.

Ultraviolet Radiation (UV)
In periods of drought, decreased cloud cover allows an increased exposure to UV radiation, which can increase skin cancer risk. In addition, more organic chemicals, some of which may contribute to cancer, may be released into the air when heated and turned into vapors.

Cardiovascular Disease and Stroke
North Carolinians living with cardiovascular disease (CVD) or stroke are particularly vulnerable to poor air quality, which is impacted by drought and high temperatures. These individuals are also at risk for heat-related injury.

Tropical storms have a tremendous impact on health services infrastructure. North Carolinians with pre-existing conditions such as CVD are highly vulnerable if they lose access to essential medications and medical care.

Current Efforts

One key event co-hosted by the Climate Ready N.C. Program was the Climate and Health N.C. Workshop held at the University of North Carolina at Chapel Hill, during August 2011. With more than seventy participants discussing the state of the science related to climate

and health in our state, the outcomes of the workshop informed the assessments and strategies found in this chapter.

In addition, the Climate Ready N.C. Program has convened a working group of thirty experts on health and climate to develop a strategic plan to address climate change in North Carolina. The Climate Ready N.C. Program has partnered with colleagues in diverse state departments, public health branches, non-profits, industry, academia, and various federal agencies to inform the planning effort and to build collaborations that can begin to adapt to the impacts of climate change on North Carolinians' health.

Climate change's effect on public health is so multi-faceted that it is impossible for one program to adequately respond to the impact without communication and support from other agencies, departments, companies, and universities.

Adaptive Response Options

North Carolina has several strengths that complement health adaptation planning, such as academic institutions engaging in primary research, strong weather and health tracking systems, support from the Centers for Disease Control and Prevention, public health infrastructure and robust emergency management. Health adaptation planning is already occurring in several arenas in North Carolina.

While climate contributes to a myriad of negative health outcomes, many non-climate factors are also implicated through health vulnerabilities. Underlying issues of disease management, income disparity, and lack of access to health care and fresh healthy foods significantly impact North Carolina's communities before, during, and after a weather event. Addressing these issues will result in a resilient, healthy North Carolina.

Illness and injury due to climate change may be prevented by taking some important steps:

- Utilize Health Impact Assessments (HIAs) to guide funding, investment, and planning decisions.
- Promote adaptation strategies that have multiple public health benefits, such as encouraging community-scale energy generation which increases preparedness of health care providers while improving air quality.
- Develop tools and products that translate weather and climate information into a form that is useful for public health workers and the general public.
- Encourage partnerships at a regional level to reduce duplication of efforts.
- Educate North Carolinians on heat-related illness and flood dangers through collaborations between meteorologists and public health officials.
- Increase heat response capacity, as well as distribution of information on all natural hazards and preparedness plans.
- Maintain or upgrade water and sewage infrastructure through retrofitting or replacement.
- Use geospatial data to identify vulnerable populations and susceptible water, sewer, and chemical storage facilities and take actions to reduce the

vulnerability.

- Train public health officials to respond to climate change.
- Re-establish a pest management program that conducts mosquito and tick surveillance.
- Improve drainage surrounding thoroughfares and building structures, potentially infiltrating stormwater to the ground or storing it for use, while promoting use of natural systems that reduce stormwater runoff.

A resilient, healthy North Carolina will have less water-borne disease following intense precipitation events, point-source spills or adverse impacts on agriculture following a tropical cyclone, and cities and counties that have undertaken vulnerability assessments for climate change. North Carolinians should begin to embark on health adaptation, because climate change impacts are already happening.

2. PUBLIC SAFETY: HAZARD MITIGATION PLANNING AND EMERGENCY RESPONSE

In North Carolina, Hazard Mitigation and Emergency Response are overseen by the Emergency Management Division (NCEM) within the Department of Public Safety. This program works with local, state, and federal partners and private sector organizations to assist people to effectively prepare for, respond to, recover from, and mitigate against all hazards and disasters.

Local Emergency Management Agencies and the Emergency Management Division work as a team to identify and analyze the hazards that may threaten communities. Emergency Operations Plans address the predictable consequences of disasters, i.e., isolated communities, lost power, downed trees – regardless of the hazard. Functional planning allows emergency planners to focus on operational tactics such as evacuation coordination, shelter operations, search and rescue, power restoration, debris removal, and resource management.

Through the Emergency Alert System, North Carolina radio and television stations voluntarily alert the public when threats become imminent, which aids in saving lives, reducing injuries and lessening the impact on property. The State Emergency Response Team (SERT), comprised of top-level management representatives of each state agency involved in response activities, provides technical expertise and coordinates the delivery of resources to support local emergency operations. When resource needs are beyond the capabilities of state agencies, mutual aid from other un-impacted local governments and states may be secured using the Statewide Mutual Aid agreement or Emergency Management Assistance Compact. Federal assistance may also be requested through the Federal Emergency Response Team.

Recovery activities are designed to restore public infrastructure and facilities, and to assist families with securing safe and secure housing. The Recovery Team is composed of representatives of state, local, and federal agencies as well as non-governmental agencies including The American Red Cross, Salvation Army, and religious organizations. When disaster recovery is beyond the capability of both the local and state government, the Governor may request the President to declare the event a "Major Disaster." This designation authorizes federal financial assistance

to supplement state and local recovery efforts with programs designed to assist disaster survivors through housing grants and individual assistance grants and loans. Government agencies may also receive assistance with disaster expenses and losses. The costs of these financial programs traditionally are shared between the federal and state government.

Hazard mitigation activities reduce the future impacts of natural and technological hazards on people and property. The priority is to make our homes, businesses, and communities as resilient as possible against the impacts of hurricanes, floods, tornadoes, earthquakes, wildfires and other hazards. Regular information and education outreach efforts are conducted to inform citizens, local governments and businesses on specific mitigation measures they can implement before a disaster ever occurs in order to reduce potential future losses.

Most hazard mitigation techniques are applied at the local government level, because this is where land use decisions are made, growth and development take place, and where hazards occur. Local mitigation plans identify the hazard risks facing a particular jurisdiction. Various tools and techniques can be used to reduce those risks. These may include acquisition or elevation of flood prone homes, adopting local ordinances, promoting purchase of insurance, and limiting the extension of infrastructure into known high hazard areas.

NCEM's involvement in climate change issues principally involves the functional areas of Operations (response), Recovery (mitigation), and Geospatial Technology Management (risk assessment and mapping).

Impacts, Risks, and Vulnerabilities

A change in climate and associated weather patterns over the course of this century may lead to an increase in mean sea level, severe damage to or destruction of the barrier islands, increase in the frequency of drought and heat waves, more powerful tropical storms, flooding, and increased intense weather episodes across the state. The primary concerns of NCEM are to understand the potential change in impact of these climatic stressors in order to better plan for response to, recovery from, and mitigation of known and unforeseen impacts. This involves a comprehensive risk assessment of the various hazards, which may change not in number, but in intensity due to climate change.

These efforts present a need to understand and stay current with the scientific research related to climate change and to find opportunities to work with other governmental agencies (both state and federal), universities, NGOs, local governments and landowners to address the immediate and potential long-term threats to people and resources resulting from climate change.

Increased Drought

The impacts of increased and more intense drought are considered more indirect in scope and applicable to a relatively narrow range of resources. The landscape conditions created by drought may be a contributing factor in increased damage from other stressors that will have more direct impacts. For example, intense and prolonged drought likely will cause certain types of vegetation to die and can produce exposed landscapes denuded of a protective vegetative cover. Lack of

covering vegetation can facilitate increased erosion once precipitation resumes, particularly on exposed slopes and waterways.

Drought reduces available water supply for consumption, industrial and agricultural use and sewage treatment. Extended and/or intense drought increases the probability of wildfire and extensive forest fire. These types of fire have the potential to destroy or heavily damage structures and infrastructure and create exposed landscapes that facilitates erosion as discussed above. Other indirect impacts may result from the necessary efforts to fight fires, such as construction of fire lines, backfires, and heavy water use from lakes. Given the nature of the impacts from drought, public safety will be affected by the impacts. Vulnerability ranges from moderate to high.

Increased and More Intense Precipitation
Climate change may foster an increase in the frequency and/ or intensity of storms and precipitation in all forms (liquid and frozen) across the state. These impacts also include high winds associated with certain weather systems. These types of storms will pose major threats to all sectors, resources, and the built environment from potential increases in wind and water damage.

North Carolina is well positioned to address flooding issues with extensive resources in floodplain mapping and risk assessment. It is important to understand how climate change will impact, and possibly alter, the frequency and intensity of precipitation and floods across the state. Given past weather and climate, response, recovery and mitigation measures are well understood and well implemented in most areas. Additional work will need to be done if North Carolina is to be adequately prepared for projected future climate changes.

Heat Waves
The impacts to safety from increased and more intense heat waves are more indirect in scope and applicable to a relatively narrow range of resources. Similar to the assessment noted for drought and given the indirect nature of the impacts from heat waves, public safety will be moderately exposed to the impacts.

Tropical Cyclones
On the Coastal Plain the destructive power of tropical cyclones (hurricanes) will likely be enhanced by sea-level rise increasing the negative impacts on the built environment from greater intensity and higher storm surges. More intense tropical cyclones will pose a major risk to all resources within the Coastal Plain and to areas inland. Nearly 50 percent of all tropical cyclone impacts on North Carolina have been the result of storm systems making landfall on the Gulf Coast. These storms bring heavy precipitation and high winds to the western half of the state and often result in hundreds of millions of dollars in damages and losses. Because no area in North Carolina is immune to the impacts of tropical cyclones, vulnerability for all sectors, including safety, is moderate to high.

Sea-level Rise
North Carolina's low-lying Coastal Plain and the barrier islands are famous for the many historic towns and villages. These sites now draw hundreds of thousands of visitors each year, generating significant economic benefit in this region. Any

significant rise in mean sea level will radically change the physical dynamics of the landscape and may pose a very real and direct threat to lowland property and infrastructure in the Coastal Plain. Many areas in the coastal plain (and extending far up-river along the estuarine system) may be inundated either periodically or permanently, depending on the magnitude of sea-level rise.

Current Efforts

The Division of Emergency Management continues to be a national leader in the development and implementation of hazard mitigation plans and activities at the local level. Using funding from past natural disasters, vast numbers of structures and dwellings have been removed from low-lying areas and the underlying land has been preserved as public open space in order to increase the functionality and storage capacity of the state's floodplains.

The Geospatial Technology Management Branch is a national leader in the study and development of risk assessment tools and models, and is currently in the final phases of several large-scale projects designed to increase our ability to address the multi-layered threats and hazards associated with climate change and sea-level rise. The branch is working on sophisticated modeling of the potential impacts of sea-level rise across the entire Coastal Plain. This team is also involved in the development of the Integrated Hazard Risk Management tool, known as iRisk, that is designed to look at the current and future impacts of all natural hazards and furthermore, to assess the potential cascading effects of simultaneous hazard impacts, or impacts affecting multiple levels of critical infrastructure and key resources.

Adaptive Response Options

The Division of Emergency Management addresses a wide range of risks through development of hazard mitigation plans. Beginning with the 2010 update, North Carolina's Hazard Mitigation Plan addressed the potential of impacts due to climate change. A new section of the Risk Assessment titled "Long-Term Hazards" identifies two inter-related categories of hazard associated with climate change. "Sea-level rise" and "Changes in Weather Patterns" are identified as long-term risks that have the ability to impact the rich quality of life that North Carolina residents and visitors currently enjoy. While a degree of uncertainty exists regarding the nature and severity of climate change impacts, actions may be taken to improve the resiliency of human and natural systems to these projected impacts.

The Division of Emergency Management is working on with UNC-CH School of City and Regional Planning to develop a planning resource handbook for local government stakeholders and planners who are interested in incorporating climate change issues into planning processes. The handbook should be complete in fall of 2013, to be followed by training if funding is available.

The North Carolina Division of Emergency Management will continue to participate in studies and conferences advancing climate change science, considering the probable impacts, and identifying planning parameters necessary for successful adaptation to climate change and its associated hazards. As better data becomes available, the North Carolina Hazard Mitigation Plan could serve as a framework for a statewide adaptation strategy.

Advances in weather forecasting will help the state be better prepared to respond to these issues in the future. Advances in climate science will position state and local leaders to take longer-term action through the use of data in developing and implementing land-use planning, zoning, and other tools to reduce the impact of these climate-related hazards.

There is an urgent need for planning a response to anticipated sea-level rise. Planning efforts might include strategies to steer new development away from high hazard areas and to develop contingency and other plans to remove people and resources out of harm's way ahead of the anticipated rise in water levels. There will also be the need to consult and coordinate any efforts with other federal and state governmental agencies, private individuals, local governments, and private organizations.

3. CULTURAL HERITAGE

The rich and diverse cultural heritage of North Carolina is promoted, preserved, and enhanced through the efforts of the N.C. Department of Cultural Resources (NCDCR). Many cultural resources exist within North Carolina and include music and arts, archival records and historic publications, museums, and historic and archaeological sites. In addition, North Carolina has many historical landscapes, historic structures, and historic districts within rural and urban settings. NCDCR functions to preserve these resources and expand public awareness of the state's cultural heritage through the management, operation, and/or support of these organizations and facilities:

- The State Library
- The State Archives and State Records Center
- The Outer Banks History Center
- 27 Historic Sites
- 7 History Museums
- The Historical Publication Section
- The Office of State Archaeology
- The State Historic Preservation Office
- The North Carolina Symphony
- The North Carolina Arts Council
- The North Carolina Museum of Art

NCDCR provides leadership in using the state's cultural resources to help build the social, cultural, and economic future of the state. This is sustained by facilitating the growth of creative industries and a sustainable creative economy in North Carolina. NCDCR provides assistance to the general public and academic scholars through many of these facilities with archival, genealogical, historical, and archaeological research. The department assists local landowners and communities in documenting, maintaining, and preserving historic properties and districts. The department encourages this growth by supporting heritage/cultural tourism, local arts and crafts industries, along with technical assistance to local communities helping to develop and revitalize historic residential and commercial districts and individual properties. http://www.ncdcr.gov.

In order to sustain these efforts NCDCR recognizes the value and necessity of a healthy physical environment. Any change in the environment that may affect and impose negative impacts on cultural resources is a cause of concern that has captured the attention of NCDCR over the past few years. The nature, scope, and potential impacts of climate change on cultural resources will be presented in the discussion below.

Impacts, Risks, and Vulnerabilities

A change in climate and associated weather patterns over the course of this century may lead to an increase in mean sea level, severe damage to or destruction of the barrier islands, more powerful tropical storms, flooding, and increased intense weather episodes across the state. We anticipate more intense precipitation in some areas and increased drought in others, and more intense heat waves. The primary concerns of NCDCR involve the need to understand and predict the potential impacts of these climatic stressors on the cultural resources of North Carolina. This involves a comprehensive inventory and assessment of the various sets of resources included under the mission of the department. These resources include such things as: state historic sites, museums, archival records and publications, monuments, archaeological sites, and National Register properties and districts. For a map of the museums and historic sites managed by NCDCR, please refer to http://www.ncdcr.gov/map.asp for more details.

It is important to know which resources may be at risk, what those risks entail, and how the department should respond to mitigate or adapt to the physical threats posed to those resources. In addition, the department needs to know which steps may be necessary in order to adapt our state's cultural resources to the changes which cannot be avoided. Included here is the need to understand and stay current with the scientific research related to climate change and to find opportunities to work with other governmental agencies (both state and federal), universities, NGOs, local governments and landowners to address the immediate and potential threats to cultural resources from climate change. These include issues related to 1) increased drought; 2) increased and more intense precipitation; 3) heat waves; 4) tropical cyclones; and 5) sea-level rise. Potential or expected impacts, inferred sensitivity and adaptive capacity, and vulnerabilities are considered for each of these.

Increased Drought

The impacts to cultural resources from increased and more intense drought are considered more indirect in scope and applicable to a relatively narrow range of resources. The conditions created upon the landscape by drought may be a contributing factor in increased damage from other stressors that will have more direct impacts. For example, intense and prolonged drought likely will cause certain types of vegetation to die and in some cases produce exposed landscapes denuded of a protective vegetative cover. In terms of some cultural resources like State Historic Sites and archaeological sites the lack of covering vegetation very likely will facilitate greater levels of erosion whenever precipitation resumes, particularly on exposed slopes. This type of erosion would serve to destroy or heavily damage the integrity and context of some of these sites. Once damaged in this manner the interpretive quality of some sites is irreparably destroyed. In addition, certain types of historic structures on exposed slopes such as early tobacco barns, ordering rooms,

cabins, and tenant houses would very likely be heavily damaged by increased or more intensive erosion.

Another issue to consider would regard the impacts to cultural resources within certain lakes across the state (e.g., Phelps Lake, Lake Mattamuskeet, Pungo Lake, New Lake, Lake Waccamaw, Falls Lake, Kerr Lake, and others). Extended drought would cause significant drops in lake levels and in some cases would expose certain types of cultural resources to the damaging effects of air and sunlight. For example, a number of prehistoric Native American dugout canoes are present within Phelps Lake. Many of these are located at relatively shallow depths and may possibly be exposed if the lake level drops significantly during a prolonged drought. Once exposed, these types of resources would be damaged rather quickly from exposure.

In addition, extended and/or intense drought increases the probability of wildfire and extensive forest fire. These types of fire have the potential to destroy or heavily damage historic structures and create exposed landscapes which facilitates erosion as discussed above. Other indirect impacts may result from the necessary efforts to fight fires, such as construction of fire lines, backfires, and heavy water use from lakes. The Office of State Archaeology works closely with agencies such as the U. S. Forest Service in North Carolina to assess the impacts to cultural resources from activities associated with containment and suppression of fires within the major national forests within the state.

Given the indirect nature of drought impacts, cultural resources will be moderately affected by the impacts. In spite of this level of sensitivity it is believed that cultural resources for the most part would sustain a relatively high adaptive capacity and be able to accommodate or adjust to most of the impacts from drought. As a result, cultural resources have a moderate to low vulnerability to drought at a statewide level.

Increased and More Intense Precipitation

Climate change may foster an increase in the frequency and intensity of storms and precipitation across the state. These include impacts from more intense rain , nor'easters, and associated tornados. These types of storms will pose major threats to cultural resources from wind and water damage to historic structures and districts, historic records and archives, museum collections, cemeteries, and archaeological sites. Two specific issues related to increased and more intense precipitation include erosion and flooding.

In terms of erosion, the primary concerns for NCDCR include damage or destruction of cultural resources from slope and shoreline/riverbank erosion. Increased and more damaging floods may occur across all physiographic regions of the state as a result of more intense precipitation. These floods will likely be the result of more intense storms, but may also be related to general changes in rainfall patterns across the state. Flooding will pose a major threat to various cultural resources such as archaeological sites, state historic sites, historic structures and districts, and archival records.

Increased flooding will damage numerous archaeological and historic sites on floodplains and terraces across all three physiographic regions and within every river

basin in the state. Many of these sites will be damaged by enhanced riverbank and floodplain erosion, sediment transportation, and sediment deposition. Deposition of transported archaeological and structural materials within sediment loads elsewhere within a given river basin will confuse the interpretation of the archaeological record and may lead to erroneous conclusions regarding certain aspects of prehistory and history within the state, such as patterns of settlement through time.

Given the direct nature of the impacts from increased and more intense precipitation, cultural resources are expected to be greatly exposed to and/or affected by the impacts (a high sensitivity). In spite of this high level of sensitivity it is believed that cultural resources for the most part would sustain a moderate adaptive capacity and be somewhat able to accommodate and adjust to many impacts associated with increased and more intense precipitation. As a result, cultural resources have a moderate to high vulnerability to the impacts of increased and more intense precipitation at a state-wide level.

Heat Waves

The impacts to cultural resources from increased and more intense heat waves, like drought, are considered by NCDCR staff to be more indirect in scope and applicable to a relatively narrow range of resources. More intense heat waves may have damaging effects on fragile archival records, documents, and some collections at certain historic sites and museums. High heat may cause some of these resources to dry, become brittle, and dissolve. In addition, high heat coupled with high humidity may cause an increase in mold and fungus damage to vulnerable records, documents, and other collections such as cloth, photographs, and paintings.

Similar to the assessment noted for drought and given the indirect nature of the impacts from heat waves, cultural resources will be somewhat exposed to and/or affected by the impacts (a moderate sensitivity). In spite of this level of sensitivity it is believed that cultural resources for the most part would sustain a relatively high adaptive capacity and be able to accommodate or adjust to most of the impacts from more intense heat waves. As a result, cultural resources have a moderate to low vulnerability to heat waves at a statewide level.

Tropical Cyclones

On the Coastal Plain the destructive power of tropical cyclones (hurricanes) will likely be enhanced by sea-level rise, increasing the negative impacts from greater intensity and higher storm surges on all cultural resources within the Coastal Plain. More intense tropical cyclones will pose a major risk to museums, archival records, historic districts and other National Register properties, state historic sites, cemeteries, and archaeological sites.

Tree Damage to a National Register Property in Wilson Resulting from Hurricane Irene, 2011. Photo adapted from Wilds (2011:5).

Wind and rain damage from more intense storms will also severely impact cultural resources across the other physiographic regions of the state (to include the inner Coastal Plain and Sandhills). In addition, wind and rain damage from hurricanes may extend further inland. Wind damage from Hurricanes Hugo and Fran dramatically impacted the Piedmont and Mountain Regions of the state. In 2004 Hurricanes Frances and Ivan brought heavy flooding to the western part of the state, resulting in massive damage to county and local governmental records. Thousands of documents needed to be freeze-dried in order to stabilize them after these disasters. Increased flooding due to more severe tropical cyclones may increase the incidents of this type of damage to archival and other historical records.

Increased activity related to these types of storms has the potential to damage inland historic sites, historic structures and archival records. These include:

Inland historic sites: Historic Halifax, Aycock Birthplace, CSS Neuse/Caswell Memorial, Bentonville Battlefield, Historic Stagville, Duke Homestead, the State Capitol building, House in the Horseshoe, Town Creek Indian Mound, President James K. Polk State Historic Site, Reed Gold Mine, Alamance Battleground, Bennett Place, Charlotte Hawkins Brown State Historic Site, Fort Dobbs, Horne Creek Living Historical Farm, Zebulon Vance Birthplace, and the Thomas Wolfe Memorial.

Inland state museums: Museum of the Cape Fear Historical Complex, NC Museum of Art, NC Museum of History, NC Transportation Museum, Southeastern Center for Contemporary Art, and the Mountain Gateway Museum.

Inland archival repositories: the State Archives, NC State Records Center, and the State Library.

Recently, the State Historic Preservation Office compiled an assessment of the damage to historic properties from Hurricane Irene in August of 2011 (Wilds, 2011). Many negative impacts from Irene to cultural resources resulted from tree fall damage and flooding. According to Wilds (2011:1-2), the most consistent damage across the Coastal Plain was sustained by historic cemeteries.

Tree Damage at a Historic Cemetery in Tarboro Resulting from Hurricane Irene, 2011. Photo adapted from Wilds (2011:3).

This report is on file with the N.C. Historic Preservation Office (HPO) and can be found at: http://www.hpo.ncdcr.gov/Irene%20Report%203.

Given the very direct and devastating nature of the impacts from tropical cyclones, cultural resources are expected to be greatly exposed to and/or affected by these impacts, especially within the Coastal Plain. In spite of this high level of sensitivity, it is believed that cultural resources for the most part can sustain a moderate adaptive capacity and be somewhat able to accommodate and adjusting to many impacts associated with more intense tropical cyclones. As a result, cultural resources have a moderate to high vulnerability to the impacts of tropical cyclones at the statewide level.

Sea-Level Rise

North Carolina's low-lying Coastal Plain and the barrier islands are famous for the many historic towns and villages. These sites draw thousands of visitors each year, generating significant economic benefit in that region. Any significant rise in mean sea level will change the physical dynamics of the landscape and may pose very real and direct threats to lowland historic towns and districts in the Coastal Plain (e.g., Manteo-Roanoke Island, Kitty Hawk, Bath, Edenton, New Bern, Washington, Wilmington, Elizabeth City, Beaufort, etc.). These and other districts within the

Coastal Plain contain thousands of our state's cherished historic houses, downtown buildings, public buildings, churches, and cemeteries. In addition, many private properties in the Coastal Plain are considered significant and are listed on the National Register of Historic Places. Many of the resources listed above may be inundated, severely damaged, or destroyed. There is a need to know which of these resources may be at risk, how they may be impacted and what actions are needed in order to adapt to the expected changes. There will also be the need to consult and coordinate any efforts with other federal and state governmental agencies, private individuals, municipal and county governmental agencies, and private organizations.

Sea-level rise may pose a threat to numerous state historic sites and museums within the Coastal Plain. These include:

State historic sites: Historic Edenton, Roanoke Island Festival Park, Somerset Place, Historic Bath, Tryon Palace, USS North Carolina Battleship Memorial, Fort Fisher, Brunswick Town and Fort Anderson.

State museums: Museum of the Albemarle, Roanoke Island Festival Park, Graveyard of the Atlantic Museum, N.C. Maritime Museum – Beaufort, North Carolina History Education Center – New Bern, and the N.C. Maritime Museum – Southport.

State archival repositories: Outer Banks History Center

Many of these resources may be inundated or subject to increased coastal and shoreline erosion and ultimately damaged or destroyed. It will be important to know which of these resources may be at risk, how they may be impacted and what actions are needed to adapt to the expected changes.

Prehistoric Shell Midden Eroding Into the Currituck Sound Near to Adylett, Currituck County. Photo is on File at the Office of State Archaeology.

There are nearly 5,800 prehistoric and historic archaeological sites in the Coastal Plain of North Carolina within 30 feet of mean sea level (Abbott, 2011). Many of these sites are already subject to severe damage from shoreline erosion and land loss due to flooding and wave action. Sea-level rise likely will increase the rate of site damage and loss from inundation, as well as from the enhanced energy from waves and coastal storms. If sea-level rise is significant, certain types of archaeological sites, such as Middle to Late Woodland prehistoric shell middens (circa 300 B.C. to A.D. 1600) and associated habitation sites may be completely lost (a near extinction of certain site types). In addition, significant resources in areas like Roanoke Island (site of the famous Lost Colony) may be completely inundated.

There is also a need to understand how sea-level rise will impact the large inland lakes of the Coastal Plain (e.g., Phelps Lake, Lake Mattamuskeet, Pungo Lake, New Lake, and Lake Waccamaw). The areas around (and actually within) these lakes contain many historic and archaeological sites.

Archival records and historical collections may be damaged and destroyed in certain Coastal Plain communities as a result of sea-level rise. Similar to historic and archaeological sites, most of these resources are irreplaceable. We will need to know which repositories may be impacted by sea-level rise in order to adapt to this potential threat. This may involve physical removal of records and historical collections to areas further inland.

Given the very direct and devastating nature of the impacts from sea-level rise, cultural resources are expected to be greatly exposed to and/or affected by these impacts (a high sensitivity), mainly within the Coastal Plain. In spite of this high level of sensitivity, it is believed that cultural resources have a moderate level of adaptive capacity and will be somewhat able to accommodate and adjust for many of the impacts associated with sea-level rise. At a statewide level, cultural resources will have a moderate-to-high vulnerability to the impacts of sea-level rise.

Current Efforts

NCDCR is developing a Climate Change Initiative Strategy Framework modeled after a N.C. Department of Environment and Natural Resources framework (NCDENR, 2010). The goals of this framework are the same as those noted by NCDENR and include the study of climate change in a comprehensive way and development of mitigation and adaptation strategies to increase resilience of the state's cultural resources to these complex changes. This framework seeks to facilitate and support a coordinated approach to address climate change policy and actions at state, regional, local, and federal levels. At its most basic level the framework will endeavor to 1) identify short-term, mid-term, and long-term potential impacts on cultural resources that may be related to climate change, 2) identify ways to address these impacts, and 3) coordinate strategies with other local, state, federal and non-governmental partners.

The Historic Preservation Office (HPO) has developed a disaster response plan which is posted on the HPO web site at: http://www.hpo.ncdcr.gov/disaster.htm. This site contains information sheets that discuss issues related to disaster management for cultural resources which includes: drying out water-damaged buildings, selecting

a contractor for repairs, insurance claims, landscape restoration, and state and federal rehabilitation tax credits, in addition to other services provided by the HPO. Prior to landfall of Hurricane Irene, the HPO notified all local historic preservation commissions regarding the information sheets posted on this web site. Emails were sent to various communities within the area of potential impact to advise them of the available disaster response information (Wilds, 2011:1). A damage report was compiled after the storm to assess the damage to historic properties and provide technical assistance to property owners (Wilds, 2011). It is expected that these efforts will be enhanced and expanded as the issues related to climate change begin to unfold over time.

Another major effort related to disaster planning and training in NCDCR is the North Carolina "Connecting to Collections" program (C2C) (Umfleet 2011). This project is part of an initiative funded by a grant from the Institute of Museum and Library Services in which NCDCR partners with the North Carolina Museums Council, the Federation of North Carolina Historical Societies and the North Carolina Preservation Consortium. The C2C project first sought to identify and assess museum and archival collections preservation efforts and disaster preparedness in the state's cultural heritage community. In addition, the project endeavors to facilitate close partnerships among individual entities and their professional associations within the preservation community and build relationships within the state's cultural heritage institutions (Umfleet 2011:2). Additional information on this program can be found on the Web at: http://c2c.ncdcr.gov/.

According to a 2010 survey of cultural heritage institutions (museums, libraries, archives, historic house museums), 72 percent of these do not have written disaster plans. A second survey found that most institutions with written plans do not routinely update those plans nor do they train staff on response and recovery strategies.

In response to information gathered through an intensive survey process, NCDCR has also sponsored sets of disaster workshops for cultural heritage institutions across the state through the C2C project. Workshop topics include information on writing disaster plans and information on response and recovery, including hands-on recovery workshops. Of note is the fire disaster workshop. In this workshop DCR partnered with a volunteer fire department on the Outer Banks to conduct a control burn of a mock museum and assess the damage to collections post-blaze. A link to the summary of this workshop can be found online at: http://collectionsconservations.wordpress.com/2012/02/17/c2c-controlled-burn-in-buxton/. Test data related to different storage materials can be found on the Web at: http://collectionsconversations.wordpress.com/2012/02/21/fire-recovery-discoveries/.

To date, these and other programs have identified over 950 cultural heritage institutions within the state and have worked with many to help develop disaster management plans. C2C's disaster recovery workshops routinely have a hands-on component where participants have to deal with wet and/or muddy materials. Based on the research related to these workshops, it appears that all disasters, regardless of the type or primary cause end with water damage of some sort.

A majority of the 950 cultural heritage institutions are museums. Of the museums,

most are small with 1–2 paid staff and a core support structure made up of volunteers. Most of these museums also operate on small budgets of less than $50,000/year. Therefore, to best assist these small institutions, C2C hopes to expand its disaster preparedness initiative inside NCDCR by establishing a statewide response team trained in FEMA/Emergency Management protocol but yet qualified to assist in recovery of artifacts, documents, images, and other objects of history, including historic structures and landscapes. The agency is currently seeking additional grant funding through the C2C office to begin development of the Cultural Resources Emergency Response Team. These types of programs and similar programs adapted to individual sectors will help all stake-holders, not just cultural heritage institutions, prepare for and recover from disasters related to climate change. In particular, the involvement of volunteers may be a key element for the future to help defray the increasing costs of adaptation.

The North Carolina Department of Cultural Resources, through the Office of State Archaeology (OSA) in partnership with the North Carolina Geological Survey at NCDENR, has undertaken an initial assessment of the potential effects of climate change and sea-level rise on archaeological resources within the Coastal Plain region of North Carolina. The OSA Sea-level Rise Project has taken this one major stressor, sea-level rise, as a pilot project to study its potential effects on archaeological resources within the Coastal Plain. This pilot project has been undertaken to start an inventory and assessment process for NCDCR and to provide information to support recommendations for an expanded program designed to determine the vulnerability and adaptive capacity of cultural resources in North Carolina relating to climate change and other stressors. Data were collected for 5,753 archaeological sites within 30 feet of existing mean sea level. This work is the first step in a proposed long-term study of climate change to determine its potential effects on cultural resources across the state.

Adaptive Response Options

The Department of Cultural Resource's Strategic Plan 2011-2013 outlines the future direction of this department. The entire plan can be found at: http://www.ncdcr.gov/images/dcr-strategicplan-2011-web.pdf. Two of the goals established in this plan include boosting public, private, and intergovernmental partnerships to support programs and facilities associated with NCDCR and preserving and protecting N.C.'s historical resources and sites, along with ensuring adequate capital assets. Underlying these goals is the core belief that cultural heritage is an actual resource similar to the environment that needs to be preserved and protected. It is important to convey this belief to the general public and encourage partnerships at the local level to help achieve the goals outlined in the plan. An example of this approach can be illustrated below.

North Carolina's Historic Preservation Plan is a six-year plan developed by the HPO. The plan reflects public input and participation from across the state and includes several issues about the role of historic preservation in North Carolina for the near future (2006-2012). These issues include land use, training and education, local preservation planning, heritage tourism, legislation, leadership, and economic factors. This plan outlines five goals for preservation outreach and communication, education, advocacy and policy, leadership and capacity, and identification and evaluation of

historic resources. For more details on the plan see http://www.hpo.ncdcr.gov/ .

A hallmark of the plan is the high level of public involvement in its creation. This level of involvement empowers citizens to shape the future of their communities and creates strong networks for communication and action. In the future, this approach to planning and decision-making will be crucial in shaping policies related to climate change. This will facilitate community evolution through self examination, will encourage the adoption of new technologies and techniques, and will inspire the next generation to understand its history and be good stewards.

Potential strategies and adaptive response options to climate change should incorporate a wide range of actions, such as:

- Understand how sea-level rise will impact the Coastal Plain in general.
- Understand how sea-level rise will impact specific physiographic systems of the Coastal Plain.
- Understand how climate change will impact and possibly alter the frequency and intensity of precipitation and floods across the state.
- Incorporate climate change-related information into a departmental GIS system to facilitate analysis of the impacts to cultural resources.
- Develop vulnerability assessments for cultural resources in terms of high, medium, and low probability of impact.
- Develop effective ways to physically monitor and track the impacts of climate change on cultural resources.

In the final analysis, the loss of cultural heritage-whether a state historic site, a prehistoric shell midden, or archival data-translates literally into a loss of those places and things that embody North Carolina's history and diverse cultural identity. Across the state this constitutes thousands of years of human activity and landscape use. These places are fixed on the landscape through history and cannot be moved without radically altering their respective historical contexts. Many of these sites are finite and once destroyed cannot be recreated elsewhere. Many of the archival documents and museum collections are one-of-a-kind items and cannot be replaced in their original forms. The impacts of climate change pose a potential threat to these cultural resources. It is important to know early in the climate change process (rather than later) whether these types of resources will be impacted by any of the stressors discussed above. If impacted, NCDCR will need to have some understanding of the level of impact and how the process may unfold in order to plan effectively to mitigate and/or adapt. It is equally important also to know those areas that may not be severely impacted in order to focus efforts effectively.

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Appendix C: North Carolina's Economy

This chapter on North Carolina's economy includes these sectors:

1. Agriculture and Forestry
2. Tourism
3. Insurance
4. Community Development

Introduction

A set of climate-related risks has been identified that has the potential to produce significant economic consequences for our state by the mid- to late 21st century.

The state's agricultural sector, a major economic engine, is at risk from droughts, severe weather and higher temperatures. If sufficient water supplies are not available to support agriculture, energy production, industrial uses, and consumer demands, it could have a significant economic impact. Water use restrictions during the 2007 drought affected 53 percent of public water systems. Sea-level rise due to climate change could have a major economic effect on North Carolina agriculture tourism, recreation and real estate. Reduced precipitation and increased heat could negatively impact several profitable recreational sectors, such as the ski industry and wildlife-associated recreation. North Carolina has more than 3.4 million acres at moderate to extreme risk of wildfire, and other natural disasters threaten the health and productivity of our forests. And the entire state is at risk from more intense tropical cyclone activity; recent hurricanes have produced millions of dollars in insured and uninsured losses.

With such significant potential economic losses, it is prudent to develop adaptation strategies to improve resiliency.

1. AGRICULTURE AND FORESTRY

Economic Impact

Agriculture and agribusiness, which includes the food, fiber and forestry industries, are North Carolina's number one industry. In total, they account for almost one-fifth of the state's income and employees. More than 17 percent, or $69.6 billion, of the $398 billion gross state product is generated by agriculture and agribusiness. These industries account for 648,000 of the state's 3.8 million employees. (Walden, 2011).

Impacts, Risks, and Vulnerabilities

Drought
Crop Productivity: Drought can cause severe reductions in crop yields. Drought impacts are often exacerbated by high temperatures. (Hatfield et al., 2008).

Aquaculture (rainbow trout) productivity: Impact to cold water aquaculture is severe. Clean, plentiful, cold water is a critical input for commercial trout production.

Forest Productivity: Changes in precipitation patterns will alter forests in

unpredictable ways. North Carolina experiences periodic drought episodes that put a great deal of stress on forest and landscape trees.

Sea-Level Rise
Crop productivity loss and damage to infrastructure (buildings and equipment) Increased frequency of flooding in coastal areas due to sea-level rise has the potential to cause crop losses and damage to buildings and equipment.

Forest productivity: Flooding affects trees at every stage of their development, from seed germination and flowering to sprouting and vegetative growth. At each life stage, flooding can cause injury, changes in anatomy and growth form, decline, and death. (Coder, 1994).

Tropical Cyclone
Crop/Livestock damage and productivity loss, as well as damage to infrastructure (buildings and equipment). Impacts to agriculture may be severe depending on the severity of the storm and the time of year in which it occurs. Without adequate planning and disaster assistance, agricultural interests can be devastated.

Forestry losses from high winds associated with tropical cyclones can be severe. Wind damage imposes costs on commercial forestry due to reduction in timber yields, unscheduled and costly thinnings, and added uncertainty for forestry planning. In addition, broken and uprooted trees not harvested can lead to additional costs by increasing the probability of disease outbreaks, insect infestations, and wildfires in the remaining growing stock as well as increasing the costs of containment. (Forestry Encyclopedia Network, 2011)

Heavy Precipitation
Crop productivity: Yield decreases may occur as a result of more frequent flooding of fields and delays to planting/harvesting.

Soil resources: Increased soil erosion may occur as a result of more frequent heavy rainfall events.

Forest productivity: Flooding affects trees at every stage of their development, from seed germination and flowering to sprouting and vegetative growth. At each life stage, flooding can cause injury, changes in anatomy and growth form, decline, and death. (Coder, 1994).

Heat Wave/High Temperature Days and Nights
Crop Yield Impacts: Yield response to temperature varies by crop. Plants will exhibit decreases in yield as temperatures increase above their optimum range. (Hatfield et al., 2008). However, "breeding for cold tolerance during germination and heat tolerance during grain filling probably will mitigate some impacts of increases in temperature variability and some extremes." (Reilly, 2001). Extended growing seasons may also provide opportunities for additional crop production (double cropping or alternative crops).

Forage productivity: Potential increases in temperature and a lengthening of the growing season would likely extend forage production into late fall and early spring.

"Agriculture has had and will continue to have the ability to adapt to new conditions. The ability to change with a changing climate will depend on a strong research base that can supply required information." (Reilly et al., 2001).

This would decrease the need for winter forage reserves. (Backlund et al., 2008).

Livestock Productivity: Potential for decreased feed conversion and animal growth as a result of warmer summer temperatures. Negative impacts may be offset by improvements in productivity during the winter. (Hatfield et al., 2008, p. 66). Potential for decrease in conception rates, particularly in instances when the breeding season primarily occurs in the spring and summer (this will particularly affect cattle). (Hatfield et al., 2008, p. 66).

Aquaculture: Virtually all types of aquaculture are severely stressed during sustained periods of high temperatures.

Forest productivity: Maximum and minimum temperature increases will impact natural systems more than the projected average temperature change (Karl et al., 2009)."Most studies support the conclusion that a modest warming of a few degrees Celsius will lead to greater tree growth in the United States." (Ryan et al, 2008).

Current Efforts

Because of its dependence on the natural environment, agriculture and agribusiness must be capable of adapting to a variety of broadly changing conditions, including potential changes in climate. Responding to climate variability "is manifest in nearly every dimension of farm management. Included are technologies such as crop drying, irrigation, drainage and tiling, and storage; shading and cooling for livestock; selection and breeding of livestock and crops that are hardy or hardier under a wider range of climatic conditions." (Reilly at al., 2001).

Even in the absence of global warming, there is strong reason for proactive planning given North Carolina's known vulnerabilities to hurricanes, winter storms, flooding, and drought. Maintaining and enhancing the ability of farmers and private landowners to provide an adequate, wholesome supply of food, natural fiber and wood products given potential changes in climate, technology and market conditions must be a continuing priority. Private firms, as well as numerous federal, state, and local agencies, provide assistance to producers in response to the variety of risks faced by the agricultural sector.

Adaptive Response Options

"Agriculture is considered one of the sectors most adaptable to changes in climate. However, increased heat, pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production." (Legislative Commission on Global Climate Change 2010). In order to remain in business, farmers must make production decisions in response to market incentives, available technology and the capacity of the natural resource to sustain production.

There are numerous actions that could be implemented in response to potential changes in climate:

- Promote research and technological innovation for new crop types/varieties and improved pesticides/herbicides to adapt to changing growing conditions.
- Provide education/outreach to the farming community regarding

recommendations for adaptation of new crops, varieties, or technologies.

- Conduct research regarding breeds of livestock most suitable for current climatic conditions, as well as educate/advise the livestock sector of adaptive strategies for dealing with variation in climate.
- Encourage livestock producers to select breeds that are genetically adapted to prevalent climatic conditions.
- Provide adequate disaster response resources in response to natural disasters.
- Minimize risk of disaster through adequate education, planning, emergency response capacity and appropriate disaster insurance.
- Ensure availability of flood/crop insurance in order to maintain land in agricultural production instead of a more intensive land use that has the potential to be more susceptable to flooding events and will have higher damages when flooding events occur.
- Provide for maintenance of drainage infrastructure to minimize flood severity and duration.
- Encourage adoption of agricultural best management practices to conserve water, reduce erosion, and increase soil productivity.
- Provide technical and financial assistance to producers to encourage adoption of water storage/water use efficiency technologies.
- Increase available on-farm water storage capacity to minimize drought impacts.
- Improve the availability of irrigation infrastructure in order to relieve drought/heat stress.
- Adopt more efficient irrigation technology to minimize drought stress and maximize the benefits of available water.

2. TOURISM

Economic Impact

According to the North Carolina Department of Commerce's Tourism Division, the state ranks as the 6th most visited in the United States making the tourism industry one of the state's leading economic drivers. The Division reports that both leisure and business visitors traveling to and within the state spent a record $17 billion in 2010, supporting more than 40,000 North Carolina businesses and directly supporting 183,900 jobs across the state. State and local tax revenues generated by visitor expenditures total more than $1.5 billion annually. While a most successful industry for the state, it is also an industry that is highly sensitive on both the supply and demand sides to climate and changes in climate.

Impacts, Risks and Vulnerabilities

North Carolina's tourism industry is complex and multifaceted. It includes a variety of operating sectors such as transportation, accommodations, food service, attractions, entertainment, events, travel trade, tourism services and adventure and outdoor recreation, each facing its own unique and distinct impacts regarding the effects of both climate in general and a climate undergoing change.

"Weather can ruin a holiday; but climate can ruin a destination." Dr. Daniel Scott, World Meteorological Organization Commission on Climate and Tourism

Francesco Frangialli, United Nations World Tourism Organization Secretary-General, stated that "Climate change will constitute an increasing risk for tourism operators in many destinations. With many tourism activities heavily dependent on the climate and with insurance policies increasingly affected by natural hazards, accurate weather information and forecasting of extreme climatic events are becoming ever more important for tourism businesses." (Scott and Lemieux, 2009)

Sea-Level Rise

For coastal tourism, sea-level rise poses a direct threat. The impacts will be felt through erosion, habitat loss, saltwater intrusion, changing insurance costs and property values, transportation infrastructure and the resulting coastal recreation and tourism choices, but will play out based on a case-by-case basis driven by distinctive local factors and individual events such as storm severity. (Curtis, et al, 2011, pp. 361-363)

On the heels of Hurricane Irene the Global Business Travel Association has quantified the impact of major weather events on business travel. The research uses GBTA's Business Travel Quarterly methodology to determine how a theoretical Category-3 hurricane on the East Coast would impact the business travel industry. The eleven East Coast states in the path of the scenario storm suffered an average business travel spending loss of $58 million per day. Business travel is a major driving force in the economy and disruptions in business travel will have wide-ranging repercussions. In this situation, business travel would initially lose about 514,000 trips and $606 million in spending due to storm related cancellations. This report also predicts that interrupted business trips would result in a total GDP loss of about $675 million and lost federal, state and local tax revenues of $176 million. (Global Business Travel Association, Nov. 28, 2011)

Drought

Another recurring theme of vulnerability across a wide variety of tourism businesses is drought.

The golf industry: Estimated to have a $5.3 billion impact on the state's economy in 2007, increased drought puts pressure on water use, use of fertilizers and course management. (SRI International, 2009)

The restaurant sector: Water usage is high, and so managing drought requires the practice of serving water to patrons only upon request.

The ski industry: Estimated to have a $146 million impact in the 2009-2010 season, climate will define those ski operators who ultimately stay in business due to shorter winter seasons and warming of higher elevations (RRC Associates, 2010)

Tourism destinations: The impact of climate change is complex, but direct. Generally there are two effects: 1) making a destination more or less attractive, and 2) making traveler's starting location more or less attractive. But not all destinations and industry sectors will experience the impacts of climate equally or within the same time line. For example, a 2011 focus group with tourism-related business operators conducted by East Carolina University revealed that current tourism business owners

felt their weather conditions today, although different than in the past, are still ideal for a tourism-dependent coastal environment. Regarding the future, these tourism business owners felt weather and climate do not appear to be changing dramatically, although increased storm surges are being observed and the wind seems to blow more now than before. Participants concurred that climatology trends might be better guides to use for making business decisions than weather forecasts. (Curtis, S., Long P. & Arrigo, J. (2011)

Vacation or second homes: Climate change will impact industries that support a tourism economy. One very substantive area of the built environment that is highly susceptible to climate change and its resulting effects across North Carolina is that of vacation or second homes. Second home properties are most often found in coastal and mountain environments, due to their natural beauty and recreation amenities. The 2010 U.S. Census Data for General Housing Characteristics reports 191,908 housing units in the "Seasonal, Recreational or Occasional Use" category in North Carolina, or 4.43% of the state's housing stock, which represents substantial vacation expenditures. The same data reported a total of 1,447,152 housing units in the "Seasonal, Recreational or Occasional Use" category across the 11-state Southeast Climate Region, or 4.04% of the total housing stock.

Second home tourism-related economies are oriented to support tourist demand, particularly as they relate to 1) construction and services, where homes have been built to meet the needs of the ever-growing visitor population and businesses have developed to provide the maintenance and upkeep services needed by second home property owners; 2) retail trade, from souvenir and clothing shops to grocery stores; 3) real estate, rental and leasing, including the sale of second homes and rental of beach and vacation houses; and, 4) leisure and hospitality services, to meet the recreation, accommodations, and food service needs of second home property owners. (Long and Hao, 2009)

A recent study of second home and full-time resident home owners in Currituck County found there were statistically significant differences in attitudes towards climate and tourism among three clusters of respondents based upon their residential status, education level, and perceptions of importance of sustainable actions. People who perceived that climate and weather affect both their current property ownership and future property values have a comparatively high level of education and feel sustainable actions are relatively important to the success of the tourism economy. Such information is helpful for decision-making entities in Currituck County to recognize their vulnerabilities to future impacts of climate change, more effectively manage their current property ownership practices, and develop adaptation strategies as necessary, particularly as it relates to second home ownership.

Risks and vulnerabilities to tourism are moderate to high as indicated in the impacts section. These impacts of climate change are likely to be realized to varying degrees in the tourism industry of North Carolina. Coastal tourism could be at significant risk. The magnitude of risk relative to other impacts is less well defined.

Current Efforts

Currently no specific statewide efforts are underway to adapt to the impacts of climate change within the tourism industry. A number of individual businesses and destinations are taking actions, however. Examples of such actions were presented during the "Tourism Business Owners and Operators Reactor Panel" at the Climate, Weather, and Tourism Workshop: Issues and Opportunities at East Carolina University.

Adaptive Response Options

The primary emphasis is on information to support decisions.

The application of Geographic Information System technologies could effectively combine the various economic and weather data sets for tourism businesses and destinations. Some climate sensitive tourism activities already have GIS-based informational resources online. One example is the local Outer Banks surf information website, www.obxsurfinfo.com. The website provides users with forecast models, webcams, reports, text alerts, and social networking and GIS information. Other uses of GIS information have been used to map such variables as climate, transportation infrastructure, tourism amenities, hotel receipts, foliage color, and corridors and trails. (Curtis, S. et al, 2010, pp. 6)

For the future success of tourism in North Carolina, it is also important that tourism businesses and destination communities have access to short- and long-term weather and climate data in a form that is easy to interpret. It is equally important that emerging examples and case studies be documented and shared. Researchers report that climate data is useful for consumers in determining the destination, timing of travel, and activity of choice.

Research is needed relevant to climate and tourism to address such pertinent questions as:

- What are the appropriate immediate and long-term planning strategies to empower tourism businesses to proactively manage the weather and climate-related aspects of their respective tourism sector when facing risks due to predictable changes in climate and weather variability?
- Are businesses that use climate and weather data more prepared for extreme weather conditions and better able to respond to risks due to hazard events than those who do not take advantage of climate and weather information?
- Do discrete sectors of the tourism industry, whether located in a coastal or mountain environment, have different needs for information on climate and weather? What are the differences for each tourism operator? How can this information be made readily and easily accessible for each specific tourism sector?
- Is the availability of climate and weather information as well as the application of a climate index helpful for coastal tourism businesses in terms of increasing their marketability and staying competitive?

Extreme weather is already causing more businesses and properties to be uninsurable in the private insurance markets, leaving the higher risks and costs to governments, taxpayers and individuals. *Stormy Future for U.S. Property/ Casualty Insurers: The Growing Costs and Risks of Extreme Weather Events. A Ceres Report.*

3. INSURANCE

"Insurance availability, affordability, and safety can be impacted by climate change, which is why the N.C. Department of Insurance is focusing on this issue. Climate change could have an impact across many lines of insurance, including property, health, and life insurance. The key issue for the Department is ensuring the availability of insurance and working with the insurance industry to develop solutions to maintain solvency so that the state's consumers are protected." *Commissioner Wayne Goodwin, speaking at the "Planning for North Carolina's Future: Ask the Climate Question" workshop on March 2, 2010.*

Impacts, Risks and Vulnerabilities

From an insurance perspective, the impacts the state faces include loss of property and increased storm damage. The hazards that we see on an annual basis are evolving and will have different effects for property owners all across the state.

There are a variety of hazards presented to our state annually which will change over time, these include:

Tropical Cyclones
It is estimated that the changing climate will produce more intense and longer duration storms. The effects of such storms could be felt for longer periods and could reach farther inland than storms in the past. This creates the possibility of increased damage and potential for loss of property.

Storm Surge
With the increased intensity of tropical cyclones comes another hazard, storm surge. As these storms grow stronger, the water that is pushed up against the coast as storm surge will produce more damage. They are also expected to push further into coastal waterways. This could produce damage in parts of the coastal region that had not been previously affected by storm surge or flooding.

Heavy Precipitation Events
The longer duration of tropical cyclones and other weather systems could increase the possibility of landslides in the western parts of the state. Increased heavy rainfall in vulnerable steep slope areas make it likely that landslides could increase, causing catastrophic property damage.

Local Extreme Weather Events
In 2011, North Carolina experienced the effects of localized extreme weather events. It is expected that changing climate conditions could lead to more frequent events of this type.

Sea-Level Rise
As the coastline changes, there will also be effects on properties that occupy the coastal area of our state. This impact will evolve over a much longer time frame and will vary based on the contours and geography of the coast. Due to the inundation of water, properties will be increasingly affected by all types of storms that affect the coast and will become increasingly vulnerable to loss.

Current Efforts

The Department of Insurance is currently working on several programs to enhance the state's resiliency to climate change.

Session Law 2009-472 addresses some of the issues of increased storm damage by providing mitigation credits to property owners who take steps to retrofit existing structures or build new structures to higher "fortified" building codes. These higher standards incorporate stronger building materials and design that will enable structures to withstand the forces of nature.

The Department of Insurance is responsible for enforcing building and engineering codes across the state and include updated flood and wind speed mapping, to account for impacts such as increased storm surge and drought.

The Department of Insurance provides risk management for all state facilities and considers local zoning ordinances when making decisions about state property as appropriate. When feasible, recommendations are made to move facilities to reduce possible future loss.

Plans have been developed to respond to local extreme weather events and to mobilize the Department of Insurance to respond and assist the consumers in our state in coordination with other local agencies as well as federal agencies.

Adaptive Response Options

Several strategies that the Department of Insurance is currently undertaking are not directly related to climate change, but could reduce the impact of any change.

- Mitigation credits are available to property owners that take steps to fortify their existing property or to build to a more fortified standard.
- The code enforcement section of the Department is enforcing the most recent building codes and exploring the potential of newer "green" building codes that would incorporate more energy efficient and weather resistant features.
- The code enforcement section addresses issues regarding potential wildfire. The Department of Insurance will continue to look at ways to enable consumers to reduce their risk within our state and mitigate the chances for severe damage potential.

4. COMMUNITY DEVELOPMENT

The Division of Community Planning, within the North Carolina Department of Commerce, has a team of skilled community planning professionals that are located in five regional offices across the state.

Community Planning Division staff have been providing planning, management and economic development services to North Carolina's small towns and rural communities for over fifty years. The division serves its rural community clients as a consultant to local governments (towns and rural counties) and works with communities that have limited resources and staff - helping them grow, develop, and

meet the requirements of regulatory agencies. The division planners also work in partnership with regional organizations to help ensure planning coverage for small communities through referrals to help make assistance affordable, or to help with capacity or expertise. The community planning staff routinely partners with Councils of Government and other agencies. The division works with the N.C. Department of Transportation (DOT) to ensure that communities have the proper land use plans necessary to meet DOT planning requirements.

The Commerce Community Planning staff also works with universities to provide regional training for local boards and commissions. Other partners include regional non-profits and economic development organizations. This offers the unique opportunity for the Department of Commerce to assist local communities with integrating climate change considerations into their community development strategies.

Impacts, Risks and Vulnerabilities

Drought
Climate change impacts to our communities could greatly impact residential, commercial and industrial development through reduced water supplies in drought conditions. This lack of an adequate supply of water in the short term could result in decisions to ration available water sources and/or assume costly avenues of locating and securing alternative water sources. Electrical brownouts or blackouts could occur if hydroelectric or nuclear facilities face restricted water flows. The lack of adequate water supplies could have the long-term impact of restricting the community's inability to grow.

Heat waves or extreme winter weather: Increased demand on energy consumption, due to summer heat waves or extreme winter weather could also have negative impacts on communities, impacting municipal, residential, and commercial budgets.

Heavy precipitation events: Heavy precipitation and excessive flooding could erode community infrastructures and severely damage the built environment. Having appropriate storm water management, building codes and development standards will be critical.

Sea-level rise and Tropical cyclones: The state's coastal communities could face devastating losses of residential and commercial properties, as well as costly damage to municipal infrastructure, due to sea-level rise or the increased threat of tropical storm impacts. Extreme inundation and wind damage could result in population displacement and property losses.

Current Efforts

While not solely focused on climate change, it is believed that incorporation of best practices for sustainability in community development planning and implementation will, in part, help communities address climate change concerns.

The Division of Community Planning, within the North Carolina Department of Commerce, has planning staff that are providing in-kind resource support to the

HUD Sustainable Communities Planning grant recipients in the Piedmont Triad and Western North Carolina areas. They are also providing staff support to the North Carolina Sustainable Communities Task Force.

Adaptive Response Options

The Community Planning Division could help raise awareness of potential impacts of climate change and encourage the integration of mitigation and adaptation strategies into community development strategies.

By sharing resources among offices, the division utilizes the varied technical skills of the staff and is able to efficiently offer planning services to client communities in the following areas:

- Improving Community Design and Land Use by providing technical assistance that helps to ensure that communities are well planned and attractive.
- Facilitation and Training by assisting communities in goal setting, consensus building and policy development and offering training for local officials.
- Developing New Economic Markets through analyzing new economic opportunities and developing tailored approaches to growth and vitality.
- Encouraging Sustainability by assisting communities in developing methods to protect their heritage, natural resources, financial resources and infrastructure.

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Appendix D: North Carolina's Built Environment

This chapter on North Carolina's Built Environment:

1. Transportation
2. Water Resources
3. Energy Production, Distribution and Use
4. Dams and Water Management
5. Coastal Resources and Structures

Introduction

The built environment includes a variety of infrastructure assets, such as facilities associated with transportation, energy, water supply, waste treatment, reservoirs, and assorted other buildings. (In this first assessment, we did not directly consider phone, cable/broadband lines, and other telecommunications infrastructure. Impacts to these may be similar to electrical distribution lines. In North Carolina, these infrastructure assets are at risk from several significant climate change impacts. Damage or destruction may occur from extreme precipitation events; rising sea level could produce coastal flooding, inundation and possible destruction of facilities; water availability fluctuates with varying rainfall patterns; and higher temperatures could increase operating costs. Specific climate related impacts on infrastructure are detailed below.

Heavy precipitation events
Heavy precipitation events can cause substantial impacts to manmade and natural land features. This can be caused mainly from flooding, and would especially impact infrastructure located within floodplains. Transportation infrastructure (land, air and marine-based) can be inundated and/or damaged, disrupting the movement of people and goods. Buildings and homes can also be damaged or destroyed. Emergency access can be impeded, creating threats to human safety if transportation corridors become impassable. More intense rainfall events can produce higher flood heights, causing dams and flood control structures possibly to the point of overtopping and/or failure, as well as impacting reservoirs and intakes structures that provide municipal drinking water. Landslides and sinkholes can be triggered by intense precipitation, creating public safety concerns, loss of roadways and buildings, and significant economic impacts. Heavy rain events can cause untreated waste from waste treatment plants or animal operations to be released into drinking water sources.

Tropical cyclones
Major tropical cyclones, which include hurricanes, tropical storms, and tropical depressions, also can cause a number of devastating impacts to manmade and natural land features. The entire state of North Carolina is subject to the effects of tropical cyclones, which are characterized by heavy rain accompanied by strong winds. The flooding impacts described above for heavy precipitation events may be exacerbated by high winds, which increase the possibility for damage to buildings, trees, other infrastructure, and contamination of drinking water supplies. In coastal areas, high winds can increase tidal levels, creating even more water damage to

buildings, docks, bulkheads and other coastal development, as well as increasing shoreline erosion. Tropical cyclones have damaged or destroyed transportation facilities, utility distribution and communication lines, sewer infrastructure, drinking water infrastructure, and other structures in the past. These losses threaten human health and public safety, as a result of loss of electricity, sewer services, and drinking water services, and interruption or loss of communications. Power loss or damage to infrastructure, such as water tanks, can interrupt water supplies and cause pressure losses resulting in contamination. Such damage produces regional negative economic impacts to communities in the region.

Sea-level rise and accompanying storm surge
In coastal areas, sea-level rise and increasing storm surges can result in damage to and loss of homes and businesses; transportation, energy, water/sewer and communications infrastructure; and other coastal structures. Sea-level rise allows storm surge to move farther inland, and can extend damage from tropical cyclone events.

Drought
Droughts impact many sectors of North Carolina's economy and therefore many of the state's residents. Reduced public and industrial water supplies can threaten public health, business continuity and employment. Reduced stream flows can reduce electric generation from hydropower projects. Declining water levels and increasing water temperatures can reduce or curtail generation from thermoelectric plants because of reduced cooling capabilities and existing permit requirements. Drought conditions during critical periods in the growing season will increase stress on water resources as farmers provide supplemental water to maintain production of food and fiber crops and livestock. Structures located along the boundaries of forests, pastures and other undeveloped lands face increased susceptibility to damage and loss from wildfires during droughts. In addition, droughts lead to decreased air quality. Reduced precipitation results in more particulate matter in the air. Drier soil and roadways also generates more airborne particulate matter.

Heat waves
Heat waves create higher demands for cooling of buildings, which in turn induces greater demand for electricity and water. The increased water temperatures can impact the cooling capabilities for thermo-electric power generation facilities. Water demands for drinking water, cooling water, and irrigation are greater. Residents who do not have access to air-conditioned facilities face increased threat to their health from higher temperatures, especially those in susceptible groups such as the elderly and infirm. Increased use of electricity will increase emissions of air pollutants. Heat waves and high temperature days have the potential to produce significant increases in ground-level ozone, particularly for the highest-ozone events. More regions may experience high ozone events and an increase in the number of days with high ozone, which could lead to non-attainment status. Heat waves can also affect transportation facilities and operations, such as rail lines and associated rail passenger service.

TRANSPORTATION

Today more people are going more places than at any time in history, and the North Carolina transportation system is a vital component of the state's ability to thrive.

The economic vitality and quality of life of the residents of North Carolina is highly dependent on a safe, reliable, and efficient transportation network.

The North Carolina Department of Transportation (NCDOT) maintains a 79,000-mile network, including roadways and bridges. Six inter-city passenger trains operated by Amtrak currently serve cities in North Carolina; NCDOT operates trains between Raleigh and Charlotte. Regional passenger rail is available in Charlotte; public agencies are making plans to develop light rail or commuter rail service in the Raleigh-Durham, Charlotte and Greensboro-Winston-Salem areas. Freight rail service is provided in 86 of the state's 100 counties, with most of the 3,345-mile rail system owned, operated, and maintained by the private sector. The North Carolina State Ports Authority owns and operates the Ports of Wilmington and Morehead City, plus inland terminals in Charlotte and in the Piedmont Triad at Greensboro. North Carolina has 72 publicly owned and nearly 300 privately owned airports. Of the 72 publicly owned airports, 11 have scheduled service and the remaining 61 are for general aviation.

Impacts, Risks and Vulnerabilities

Transportation engineers have long realized the affect climate has on the design, construction, safety, operations and maintenance of transportation infrastructure and systems. The prospect of a changing climate may raise critical questions regarding how alterations in temperature, precipitation, storm events and other aspects of climate change could affect design parameters, materials selection, construction sequencing/scheduling and maintenance of North Carolina's transportation infrastructure.

Transportation infrastructure in the state could be affected most by those climate changes that cause environmental conditions to extend outside the range for which the system was designed. In 2008 the Transportation Research Board published the "Special Report 290: Potential Impacts of Climate Change on U.S. Transportation" in which it identified some of the impacts that climate change poses for transportation infrastructure. More extremely hot days could increase the frequency of wildfires, compromise pavement integrity, and deform rail lines; increased flooding of coastal areas could inundate roads, bridges, and rail lines. Heavier rainfall could require redesign and replacement of drainage structures; and more frequent and more severe hurricanes could disrupt service in affected areas and require more resources devoted to evacuations. In addition, increased air pollution in metropolitan areas during droughts and/or heat waves could require incorporating voluntary or enforced limits on the use of cars, trucks and construction/landscaping equipment.

North Carolina's assessment of potential climate impacts indicates that this state is most vulnerable to sea-level rise, drought, heavy precipitation events, tropical cyclones, and heat waves. Qualitative assessments have derived that North Carolina's transportation system and infrastructure may experience a number of potential impacts resulting from these climate conditions. The impacts will vary by mode of transportation and region of the state. Adapting to these potential impacts will require continued monitoring of surface transportation conditions and data and consideration of climate changes as applicable, in the planning, design, construction, operation, and maintenance of transportation systems. The potential consequences of climate

change to transportation infrastructure and system operations are described below.

Sea-level rise

Sea-level rise creates risks and vulnerabilities to the transportation system in coastal areas and can result in the loss of access to many built and natural resources. The impacts of sea-level rise could potentially affect the infrastructure and operations of both land and marine transportation systems in the coastal areas of North Carolina. Transportation infrastructure may be impacted by the inundation of roads, more frequent or severe flooding of low-lying infrastructure, the erosion of road base and bridge supports, and the loss of barrier shoreline due to sea-level rise. More severe storm surges may also cause more frequent interruptions in travel on coastal and low-lying roadways, and may also require evacuation of vulnerable areas.

Storm surge from Hurricane Irene washes out NC 12 on NC's Outer Banks. Just North of Rodanthe. 08/2011

The state's marine transportation system could also be affected. Rising sea levels may require some changes in port and ferry facilities to accommodate higher tides and storm surges. More severe storm surges may also result in interruptions to ferry services, shipping services, and port operations.

A few general aviation airports in close proximity to the water may be vulnerable to the impacts of sea-level rise.

The loss of pavement and the roadbed can impact the quality of life in coastal areas due to reduced access to housing, goods, and services. Sea-level rise could also increase maintenance and repair costs and result in a reduction of overall system reliability in vulnerable areas.

Drought

While drought may not have many notable effects on transportation infrastructure, drier conditions could have impacts on the safety of the transportation system. Roadways, bridges, and airports located in drought-susceptible areas may be affected by the potential increase in wildfires. Smoky conditions could create decreased visibility for road and air travel, potentially causing delays and reduced safety. Increased air pollution in metropolitan areas during droughts could necessitate voluntary or enforced limits on the use of cars, trucks and construction/landscaping equipment.

Heavy Precipitation

Changes in the amount, intensity, frequency, and type of precipitation could have a serious impact on transportation. The Interstate highway system was designed so that bridge and hydraulic structures would not be flooded by 100-year storms. Thus, similar to site plans for residential and industrial buildings, rainfall events including increased rainfall amounts and intensity are key considerations in the design of drainage systems for highways and bridges.

Road washout from heavy rainfall event.

Heavy precipitation events have resulted in problems for transportation infrastructure and operations, making infrastructure more vulnerable and resulting in system interruptions. More intense precipitation could increase the severity of extensive flooding events. The overloading of drainage systems can cause backups, resulting in street and highway flooding. Flooding of a waterway system can knock out rail operations on rail rights-of-way adjacent to the river, as well as on highway approaches to bridge crossings over flooded rivers. Changes in rain, snowfall, and seasonal flooding may affect safety and maintenance operations. Heavy precipitation events could impact land transportation operations, resulting in weather related delays and traffic disruptions. Intense downpours could cause increases in road washout, damages to rail bed support structures, and landslides and mudslides that damage roadways and tracks. In addition, transportation construction activities can be disrupted, which has the potential to delay projects.

Rock Slide on I-40 in 12/2009 and 01/2012, respectively, in Haywood County near the Tennessee state line. This is the site of repeated rockslides.

Similar to land transportation effects, heavy precipitation events impact air transportation. Heavy precipitation can disable or destroy navigational air instruments, and cause infrastructure damage due to flooding. Convective weather, including hail and high wind associated with heavy precipitation events, can result in increases in operational delays. Intense rainfall also has implications for emergency evacuation planning, facility maintenance, and safety management.

Marine transportation can also be affected by heavy precipitation, impacting infrastructure and operations of ferry and port facilities. Wave damage may impact infrastructure including ports, terminals, boats, and land-side facilities. These events may also cause delays in ferry and port services.

Tropical Cyclones

North Carolina's transportation system has already experienced many impacts associated with damage from hurricanes. More intense storms in the future could produce even more damage.

The impact of tropical cyclones on land transportation could include more debris on roads and rail lines, interrupting travel and movement of people and goods. Storms of this magnitude could generate increased damage to signs, lighting fixtures, and supports. Along the coast, highways that are exposed to storm surge could be expected to have shorter functional life spans.

For air transportation, hurricane force winds can produce significant damage to land-side and airport facilities including signals, signage and ground transportation, runways and terminals, and parking structures and facilities. In addition, such storms can cause more frequent interruptions in air service including system functionality and reliability, operations of runways and terminals, and internal and external vehicular access routes.

The impact of tropical cyclones on marine transportation could include damage to port and ferry infrastructure resulting from wave action and storm surges. Implications for facility maintenance and safety management include operations of ferry services and ports and facility safety. Tropical cyclones can also cause marine channels to filled in; this may impede general mobility along the waterways and the state's ferry service along the marine highway system.

Heat Waves

Extended periods of high temperatures can cause significant damage to transportation infrastructure. Pavement and structure design models have evolved to include research regarding the environmental of climate effect on distress and estimates of service life. These models have always considered the effects of research to improve the data quality of such climate factors as average temperature, minimum and maximum temperature within a short time frame and minimum and maximum temperature over longer time periods. This data serves as inputs to design formulas and material selection for the structure of highways, bridges, structures, and buildings. Highway construction

"Pavement buckling" is also known as a blow up or blow out, caused by heat expansion of the concrete slabs. If the joints are not wide enough to accommodate the expansion, the concrete "tents up". It is relatively rare.

specifications often contain seasonal restrictions to minimize the amount of time that construction activities occur in less than satisfactory weather conditions.

As the frequency of heats waves increase, higher temperature extremes could lead to buckling of pavements, also referred to as a "pavement blow out," and misalignment of rail lines.

At airports, heat waves can produce heat-related weathering and damage to pavement. High temperatures can impact lift-off load limits at high altitude or hot weather airports with insufficient runway lengths, resulting in flight delays or cancellations and/or limits on pay-load (weight restrictions). Air terminals could consume more energy to stay cool during high temperature periods. In addition, excessive heat can cause exacerbated weathering of vehicle stock.

Current Efforts

NCDOT is working to identify ways to practically integrate climate adaptation considerations as part of its planning processes.

The American Association of State Highway and Transportation Officials (AASHTO) selected North Carolina's Department of Transportation to host a workshop about transportation and climate change. An outcome from the April 2011 workshop was a menu of ideas generated by the participants for next steps on responding to climate challenges within a wide range of DOT functions. Suggestions were provided about consideration of climate as it relates to long range planning, pre-construction, operations, and maintenance. (http://climatechange.transportation.org/tools/state_by_state/).

NCDOT's Rail Environmental and Planning Section staff facilitate the development of passenger and freight rail in NC. As it develops rail projects, the Rail Program considers increased flooding, worse heat waves, and sea-level rise. For new rail service in a coastal area, the current design process considers rail track elevations with regard to projections in sea-level rise. In design, the effects of increased flash flooding are considered; this affects hydraulic designs for structures and for drainage. In construction, continuous welded rail requires temperatures less than 92 degrees F. For installation, planning must allow for decreased windows of time for construction in the hotter summers. Increasing temperatures also make it necessary to install higher capacity air conditioning on the passenger cars.

An additional strategy has been employed to conduct vulnerability and risk assessments related to potential climate impacts. North Carolina was one of the first to conduct a vulnerability and risk assessment for the replacement of the Bonner Bridge.

The USACOE issued a Water Resource Policies and Authorities Incorporating Sea-level Change considerations in Civil Works Programs. "The USACE considers global changes that result in local impacts and responses as the major challenges of the 21st century. … It is the policy of USACE to integrate climate change adaptation planning and actions into our Agency's missions, operations, programs, and projects…..Relatedly, USACE understands and is acting to integrate climate adaptation (managing the unavoidable impacts) with mitigation (avoiding the

unmanageable impacts)." See USACE Climate Change Adaptation Policy Statement http://www.corpsclimate.us/docs/USACEAdaptationPolicy3June2011.pdf

The Federal Highway Administration (FHWA) issued a September 24, 2012 memorandum highlighting the impact that extreme weather events can have on transportation infrastructure and providing information on the eligibility of activities to adapt to climate change and extreme weather events under the Federal-Aid and Federal Lands Highway programs. This memorandum can be found at the following link: http://www.fhwa.dot.gov/federalaid/120924.cfm

Adaptive Response Options

There are a range of possible response options, by climate impact, that could be used to adapt to the possible impacts to the transportation infrastructure in North Carolina.

Increased monitoring, data collection, and modeling are needed to better inform decision making regarding the type of overarching strategies that could be employed. Initial consideration will be for low-cost, no regret options.

The following are overarching strategies that could be considered:

1. Develop a framework for considering climate change impacts as part of the long-range Comprehensive Transportation Planning process.
2. Low cost retrofits to infrastructure as part of routine maintenance or planned improvements
3. Low-cost changes in design standards, materials, and construction methods.
4. Operational planning and changes, such as emergency evaluation, payload restrictions, and flight cancellations

Possible response options, by climate impact, that could be used to adapt to the possible impacts to the transportation infrastructure in North Carolina:
(excerpted from Transportation Research Board report 290: Potential Impacts of Climate Change on U.S. Transportation, 2008)

To adapt to hotter days and heat waves:

- Shift construction schedules to cooler parts of the day for the health and safety of construction workers
- Increase payload restrictions on aircraft at high-altitude or hot-weather airports
- Use heat tolerant street and highway landscaping

To adapt to increased precipitation:

- Expand monitoring systems for scour of bridge piers and abutments
- Increase monitoring of land slopes and drainage systems

- Real-time monitoring of flood levels and water flows
- Upgrade road drainage and conveyance systems as road improvements are made
- Protect bridge piers and abutments with riprap
- Addition of slope retention structures for landslides
- Use bridges instead of culverts to prevent flooding

To adapt to tropical cyclones:

- Remove traffic bottlenecks on critical evacuation routes
- Improve monitoring of road conditions and issuance of real-time messages to motorists
- Increase drainage capacity for new transportation infrastructure or major rehabilitation projects
- Adopt modular construction techniques where infrastructure is in danger of failure

WATER RESOURCES

Management of the state's more than 6,000 public water supply systems is critical for the welfare of the public, the continued growth of the economy, and the ecological health of the state's fragile water resources. The development of water resources plans for all 17 major river basins will provide the technical guidance to manage the state's water resources. Water management during droughts is coordinated by the Division of Water Resources and the N.C. Drought Management Advisory Council.

Impacts, Risks, and Vulnerabilities

Drought

Increased temperatures are usually associated with periods of decreased precipitation. These combined impacts can generally raise the stress on available water supply, restricting the ability to satisfy essential water needs. The resulting drought conditions have a tendency to increase water demands; increase the potential for widespread economic damage; and reduce the availability of water in reservoirs, streams, and some wells, restricting the ability to fully meet water use demands.

North Carolina has historically experienced periodic droughts that are within the range of natural climate variability. With the potential for changes to the range of climate conditions the question is how to plan for more frequent and/or more intense droughts takes on

more importance. If the frequency or duration of extreme and exceptional droughts increase, the impacts are likely to be more disruptive . Such droughts have the potential to result in widespread economic damage, caused by exceptional and widespread crop and pasture losses, as well as water emergencies triggered by water shortages in reservoirs, streams, and wells.

The additional vulnerabilities to public water supplies associated with drought conditions include:

- When water levels fall too low, intakes in rivers and reservoirs are no longer useable.
- Poorer water quality in rivers and streams results when flow is reduced, particularly those receiving wastewater discharges.
- Firefighting capacity for wild and structure fires can be reduced due to lack of water.
- Cost to supply water to customers increases due to poorer source water quality and the need to acquire alternative sources of water.
- Reduced availability of water for irrigation leading to poor crop production and increased feed costs, and inadequate supplies of water to support livestock.
- Reduced electrical generation due to lack of adequate cooling water and higher temperature cooling water for thermoelectric power plants.
- Water utilities must implement water use restrictions which results in loss of revenue due to water conservation efforts by consumers.
- Upstream migration of salt wedge in coastal rivers due to reduced stream flows necessitates changing water treatment methods or switching to alternative water sources, such as groundwater, or blending water from several sources to manage changing salinity levels.

Non-climate factors are at least as important as climate-driven factors during drought. Non-climate factors, such as population growth and land use changes, determine the level of water demand that water systems and other water withdrawals seek to satisfy.

Extreme rainfall events

More extreme rainfall events can produce higher flood heights, causing dams and flood control structures designed for historical conditions to overtop and/or fail. Flooding can directly contaminate source waters, causing drinking water service interruptions. The resulting rapid release of stored water can cause significant damage to structures in the floodplain like houses, roads, and utility services and including additional dams. In addition, the destruction of the dam can result in the loss of the fresh water stored for municipal drinking water or cooling water for thermoelectric plants.

Massive rainfall can force thousands of tons of sediment, millions of gallons of untreated sewage, and animal waste into streams and rivers from overwhelmed control features. Such flooding causes contamination of the water supply and creates a public health hazard for those who must come in contact with the contaminated

water Whole streams can be completely buried with sediment which degrades the health of the stream and its associated water quality. Water quality can be impaired to the extent of stopping operation of a water plant for drinking water.

Rising sea-level
Rising sea level can negatively impact water supplies for municipalities and industries. The degree of impact may vary, depending on whether it is caused by temporary flooding during storm surge or extreme high tides, or because a low-lying area becomes permanently inundated.

There are additional vulnerabilities to public water supply associated with rising sea level:

- Salt water intrusion could affect water supply, wells, pump stations, as well as fresh water in streams and aquifers.
- Inundation could result in loss of community water systems as a result of temporary contamination of source water for drinking and associated power outages.
- Wells that are abandoned because of inundation could cause contamination of aquifers.
- More costly treatment process for saline water could be necessary for drinking water systems.
- Infrastructure improvements and interconnections to other water systems may be needed.

Infrastructure failure may occur due to coastal inundation of water and wastewater components, like septic tanks, sewer lines, and pump stations. Septic tank failure in poorly drained coastal soils creates a need for alternative waste treatment. When pump stations, sewer lines, and wastewater treatment plants are inundated, the environment is contaminated, and the infrastructure must be replaced.

Current Efforts

The N.C. Drought Management Advisory Council (NCDMAC) monitors hydrologic conditions and advises the Secretary of the Department of Environment and Natural Resources of appropriate drought classifications for specified areas for the state. NCDMAC coordinates with the U.S. Drought Monitor (USDM), to ensure that the weekly USDM report accurately reflects conditions in North Carolina. The staff of DENR's Division of Water Resources is responsible for monitoring hydrologic conditions and the effectiveness of community water conservation measures in anticipation of the need for a declaration of a Water Shortage Emergency by the Secretary of DENR.

The 2008 Drought Bill (SL 2008-143) contains initiatives for drought response that include registration and reporting requirements, DENR approval of Water Shortage Response Plans (WSRP) with mandatory implementation of increasing strict mandatory conservation tiers as the drought becomes more severe, enhanced enforcement measures, and water efficiency standards. Additional direction is provided in the administrative rules under 15A NCAC 02E .0600 that define certain

actions to be taken by various water users and purveyors during droughts and other water shortages.

Local officials are responsible for developing and implementing an effective water shortage response plan to minimize the detrimental impacts of water shortages, including shortages caused by drought, on their community. Based on the Drought Monitor, local government officials decide how to respond based on their water shortage response plans and the status of their water source. The staff of DENR's Division of Water Resources (DWR) provides technical assistance to help water system operators adapt to changing water supply conditions, including treatment process changes and accessing alternative sources of water.

Other drought-related actions include:

- Managers of self-supplied industrial facility are responsible for developing a plan adjusting to temporary shortages in water supply to minimize impacts to their operations.
- Local officials and industry managers are responsible for developing an effective water shortage response plan defining a protocol for adjusting to increasing salinity levels in the vicinity of surface water intakes.
- DENR's Division of Water Quality (DWQ) is responsible for monitoring water quality conditions in the state's surface waters.
- Local emergency management officials are responsible for coordinating emergency response activities which can include responses to problems created by extreme drought conditions.
- The Employment Security Commission will face the cost of paying unemployment claims for workers laid off because operations are cut back or closed due to water shortages.
- DENR's DWR Public Water Supply Section design review process encourages and requires water system designs that are resilient. Funding priorities under the Drinking Water State Revolving Fund are tailored to encourage resilient water system improvements.

In addition there are significant long-term planning initiatives under way that should improve our state's ability to manage water. These include:

Session Law 2010-143, Improve River Basin Modeling, mandates that ecological flows, specific to each river basin, be developed and incorporated into future DWR hydrologic river basin models. SL 2010-143 further requires that DENR create a Science Advisory Board to assist in characterizing the natural ecology and identifying flow requirements. This Board has been established and is making significant progress in the development of scientifically defensible ecological flow regimes for the waters of North Carolina. The Environmental Management Commission must approve the models, and a Technical Advisory Group in each basin is created to assist DWR in the model development.

The recently enacted Session Law 2011-374, Promote Water Supply Development, has the potential to significantly alter the way local governments pursue new water

supply sources to support economic expansion and expected population growth. Under the terms of SL 2011-374, local governments will now have the opportunity to form a partnership with the Department of Environment and Natural Resources (DENR). Under this partnership arrangement, DENR can provide the following assistance to local governments:

- Cooperate in the identification of water supply needs and appropriate water supply sources and water storage projects.
- Assist in the assessment of alternatives for meeting the water supply needs of a local government.
- Develop estimates of the costs of the proposed new water supply.
- Apply for state and federal permits for the development of regional water supplies.
- Act as the principal state agency to cooperate with other state agencies, the U.S. Army Corps of Engineers, and all other federal agencies involved in the planning and development of water supply and water storage projects.

Water Resources River Basin Plans are being developed for all 17 river basins by the Division of Water Resources, starting with the Neuse River Basin. This plan is based on the hydrologic model of the Neuse River Basin and projects future water availability based on projected population growth patterns in the river basin. Included in these projections is a model scenario in which inflows into the river basin are decreased by 10 percent. This scenario was designed to represent a potential decrease in rainfall due to changing climate patterns. The plan also incorporated specific sections discussing potential sea-level rise and salt water intrusion in the groundwater aquifers of the coastal portion of the Neuse River Basin.

DWR is working with Research Triangle Institute (RTI) on the WaterFall model (Watershed Flow and Allocation Modeling System) to include climate induced variations for hydrologic modeling scenarios. A pilot study has begun with the Tar River basin to evaluate if the current drought management plans are adequate and to test an improved modeling scenario to account for changing climate patterns. Intended uses of the model include:

- Climate Change Adaptation Planning
- Water Allocation and Management
- Ecological Flow Development
- Water Supply Risk and Impact Assessment

Applicants for an Interbasin Transfer (IBT) certificate are required to include at least one climate change analysis as part of their required environmental impact analysis.

The Albemarle Pamlico National Estuaries Program (APNEP) and Environmental Protection Agency (EPA) have developed a Climate Resilience Awareness and Assessment Tool (CREAT) for drinking water and utility system evaluation of climate change impacts on water resources (http://water.epa.gov/infrastructure/

watersecurity/climate/creat.cfm).

Adaptive Response Options

Water is a finite asset that should be utilized as efficiently as possible. The state needs to explore more efficient ways to use the water we have. Effective contingency planning can minimize the impacts of extreme and exceptional drought conditions. The following strategies should help North Carolina move in that direction.

Drought Strategies:

1. Explore how an integrated water management plan might be developed for better management of North Carolina's water resources.
2. Encourage wise water use through education and communication.
3. Work with local governments to adapt Water Shortage Response Plans to address variable climatic conditions.
4. Pursue resources to adapt existing hydrological river basin models to include increasing climate variability scenarios as adequate science becomes available.
5. Encourage and require water system designs that are resilient in DENR's DWR PWSS design review process.
6. Fund projects under the DWSRF that improve resilience of water systems.
7. Provide technical support for businesses and homeowners to encourage local water storage and systems for water reuse.

ENERGY PRODUCTION, DISTRIBUTION AND USE

Maintaining a consistent energy supply is crucial to North Carolina's economy. How energy is produced is closely tied to concerns about greenhouse gas levels in the atmosphere, but the focus of this strategy framework is on adaptation, not mitigation. Assessments for most other sectors included energy supply disruptions as an area of great concern. However, the state agencies that were involved with this assessment process do not have direct responsibility for energy systems. This assessment is a basic overview, based on general information. Further study by those responsible for energy production, distribution and use would be advisable in the future.

Impacts, Risks, and Vulnerabilities

Energy production, distribution, and use are likely to be heavily impacted by projected changes in temperature and precipitation patterns. Both higher temperatures and reduced rainfall would affect the demand for energy, especially electricity, and present problems for energy production in our state. Increased temperatures will increase demand for cooling homes and businesses and potentially reduce the electric generation capacity because of warmer cooling water. Severe drought could reduce the amount of cooling water available in a reservoir for power plants. Increased demand will also increase air pollution. In addition, rising sea level and extreme weather events threaten to disrupt fuel deliveries, energy production, transmission, and distribution systems.

There is a strong connection between energy production and water. Eighty percent of the fresh water used in our state is used for the production of energy. This includes water released through dams to generate hydropower, as well as water used as a coolant in coal-fired and nuclear power plants. Power production competes for available water with all other community uses, such as agriculture, residential, commercial, and industrial uses. However most of the water withdrawn for power plant cooling is returned to the source and is available for other users.

There is also a strong connection between energy production and air pollution. Electricity generation is responsible for emitting approximately 238,000 tons of criteria air pollutants annually, over 50% of North Carolina's total emissions, and over 1,000 pounds per year of mercury.

Heat Waves and Drought

In a heat wave, there may be increased energy demand for air conditioning homes and businesses while there is reduced water availability for power plants. If there is a severe drought and adequate water is not available to cool thermoelectric power plants, or if the water becomes too warm, these plants have to cut back on generation or shut down completely. Decreased generation means more electricity has to be produced using more costly fuels or purchased from other utilities raising the cost of operations for the utility company. Increased energy demand during heat waves can lead to decreased air quality and a longer ozone season, which could have impacts to the current air permits held by electricity generating units. Additional pollution control measures and/or equipment may be required to ensure public health.

Increasing Tropical Cyclone Intensity

Following Hurricane Fran, the Brunswick nuclear power plant shut down temporarily. The outage was due to 1) storm damage to the fencing around the plant's security zone, (2) loss of off-site power, also due to storm damage, and (3) storm debris that made the 10-mile emergency evacuation routes inaccessible. An increase in tropical storm intensity could also result in greater and longer-lasting damage to energy generation, transmission and distribution systems, making it necessary to shut them down during intense storms. Throughout the coastal area and beyond, there may be damage to power generation facilities and transmission lines. Gas and oil pumping stations that lack backup generation, are not operational during and after significant storm events.

Sea-level rise and storm surge flooding

The Brunswick nuclear power plant is in close proximity to the shoreline. Following the Fukushima, Japan earthquake and tsunami the U.S. Nuclear Regulatory Commission ordered the evaluation of all nuclear power plants along the nation's coastline for tsunami vulnerabilities. Upgrades were made to some doors to prevent impacts from a potential tsunami at the Brunswick location. As sea-level rises, coastal erosion and shoreline retreat might make it necessary to shut this power plant down during intense storms.

Heavy precipitation events can include ice storms in winter, and flooding in any season

Climate change means N.C. may experience more extreme weather events in the future; this may include cold extremes as well as heat extremes. In rural areas, severe winter storms can increase demand for heating oil and propane, which provide the main fuel supply for many homes and businesses. Transmission lines and sub-stations may be damaged resulting in disruption of energy transmission.

Current Efforts

An Energy Assurance Plan has been written and exercised by state emergency managers in collaboration with the State Energy Office. The plan includes procedures to coordinate the permitting necessary to bring repair equipment into the state, as well as waivers for the seasonal change in motor vehicle fuel composition. Pipeline companies have been included in these exercises, as well as representatives from the fuel marketers trade groups.

Adaptive Response Options

For the next revision of this state climate adaptation strategy, it is recommended that these steps be considered:

- Coordinate with staff of the N.C. Utilities Commission and the State Energy Office to evaluate the completeness of the State Energy Assurance Plan.
- Document the inclusion of a modified State Energy Assurance Plan into the State Emergency Operations Plan so that all activities under the Emergency Support Function – Energy can be covered. Issues to be addressed: duties and responsibilities for all three levels of government — federal, state, and local — as well as private sector energy companies that have infrastructure in the generation, transportation (transmission), or distribution chain.
- Determine the drought conditions that would cause the State to put limits on electricity production.
- Assess the worst-case scenario for sea-level rise and Category 3-5 storm on Brunswick nuclear power plant.

DAMS AND WATER MANAGEMENT

Water management during droughts is coordinated by the Division of Water Resources and the North Carolina Drought Management Advisory Council. Federally owned and licensed dams have protocols in-place to manage reservoir storage and releases during high water events. During large rainfall events, either from large tropical cyclones or heavy precipitation events, the State Emergency Response Team (SERT) might require dam owners to increase discharges to prevent overtopping. Such procedures have not been tested. In most cases, the Dam Safety Program would look at evacuation of the downstream vulnerable population as the appropriate emergency action. A widespread, extreme precipitation impact from a slow-moving extensive tropical cyclone could be reduced by a coordinated SERT message to dam owners to increase dam releases to drawdown impoundments. The volume of releases prior to such events may reduce the flooding downstream.

Impacts, Risks, and Vulnerabilities

Large tropical cyclones and heavy precipitation
Large tropical cyclones and heavy precipitation events can cause a number of devastating impacts to manmade and natural land features. Even in river basins with impoundments that can store and manage the releases of water from heavy precipitation events structures, roadways and utility infrastructure, can be severely impacted by excess volumes of water, especially those in the floodplain. If extreme precipitation events become more common, floodplain residents can expect to experience high water events more frequently than they have in the past.

Loss of flood control and water reservoirs
If climate variability changes to produce less frequent but higher magnitude rainfall events, the resulting higher flood heights will increase the risk of overtopping of dams and potentially of dam failure. The uncontrolled release of stored water will produce a cascading series of damaging impacts downstream, including the possibility of compromising the integrity of downstream dams. Increased debris carried by the floodwaters can interfere with hydro-power generation and create other hazards. In addition, the destruction of the dam results in the loss of the fresh water stored in the reservoir for municipal drinking water, increasing the threats to public health from the lack of potable water delivery.

Landslides
Landslides can be triggered by as little as five inches of rain within 24 hours. Depending on how widespread or isolated the rain event is, the impact can range from only a few slides in one or two adjacent watersheds to hundreds of individual slides. Depending on preceding conditions, isolated landslides can merge and become more extensive, which happened in Watauga County in 1940.

Sinkhole formation
After a flooding event, sinkholes can appear as the region transitions from flooded to more moderate conditions. Either a rising water table or the return of the water table after a drought can also trigger sinkhole formation. When sinkholes occur near buildings, it causes structural damage to walls and foundations. Sinkholes can also damage public infrastructure, including roadways and water lines. Lack of land-use planning can exacerbate the situation. Sinkholes can be enlarged by development in karst (sinkhole-prone) terrain in eastern North Carolina.

Current Efforts

When tropical cyclones and/or heavy precipitation events are predicted, there are several actions that are currently taken:

The managers of federally owned and federally licensed reservoirs evaluate conditions and make provisions to deal with the anticipated volume of water. Initiation of the Emergency Action Plan (EAP) for potentially threatened dams to prevent loss of life, notifying State Dam Safety officials and dam owners (both private and public).

Notification is made to persons living in vulnerable areas which are prone to flooding, sinkholes or landslides. Notification is also made to managers of critical facilities

located in sinkhole and landslide-prone areas. Preparations are made for evacuation and rapid response actions to extricate residents who not remove themselves from harm's way.

Adaptive Response Options

Establish programs to educate residents about the dangers of building within floodplains. For infrastructure components that have to be placed within the floodplain, evaluate the implications of defensible estimates of increased risks associated with changes in climate patterns. Adapt development policies and construction techniques to minimize the detrimental impacts related to increased levels of risk.

Additional sedimentation and erosion control features could be erected to prevent a complete loss of sediment and erosion control.

Land-use planning which avoids sinkhole hazards as well as regulated construction on karst (sinkhole-prone) landscapes would prevent and mitigate that hazard.

Land-use planning which avoids landslide hazards as well as regulated construction on steep slopes would prevent and mitigate that hazard. Lack of land-use planning results in a much worse situation. Slides occur at much lower triggering thresholds due to the modification of steep slopes with road construction or residential/ commercial construction.

Coordinate water management at dams with fishery resource managers, using the findings of the DENR Ecological Flows Science Advisory Board.

COASTAL RESOURCES AND STRUCTURES

North Carolina's twenty coastal counties contain a diverse mix of natural and built environments, much of which is only a few feet above sea level. Development has occurred everywhere from the oceanfront beaches that absorb the pounding force of the Atlantic Ocean, to the protected Sandhills on the southern Coastal Plain, to the flatter and wetter pocosins and farmland on the northern Coastal Plain. Development patterns are nearly as diverse as the natural environment, from modest inland cottages, to oceanfront mansions, to multi-million dollar condominium towers. The diversity of coastal landscapes and development creates a high level of complexity for assessing potential risks from climate change, as well as possible strategies for adaptation. Adding to the complexity is the challenge of protecting development without sacrificing public trust rights and resources. Beach tourism is one of the state's biggest economic engines, and commercial fishing remains an important cultural and economic activity. Public waters and beaches will be adversely impacted if the responses to climate change and sea-level rise are not properly managed.

Impacts, Risks, and Vulnerabilities

Rising sea level

Many variables, including the coastal slope, geological makeup, erosion rates, and the shape of the coastline, combine to make N.C.'s coastline vulnerable to higher sea

level. In combination with tropical storms that may increase in intensity, sea-level rise magnifies existing coastal hazards such as flooding and storm surge.

Rising sea level poses a significant threat to public infrastructure, public trust resources and private property and development along the coast. Many homes and businesses are in low-lying areas, where they already face risk of storm-related damage. "It is estimated that an 18 inch rise in sea level by 2080 would result in total loss in value of more than $2.8 billion for residential and non-residential property in four North Carolina Counties – New Hanover, Dare, Carteret and Bertie."(O. Bin et al, Measuring Impacts of Climate Change on N.C. Coastal Resources)

Already, shoreline erosion has required structural defense and loss of homes along the beach. Decisions will need to be made about the long-term sustainability of some communities.

In addition to the homes, associated infrastructure failure may occur due to coastal inundation of water and wastewater components, like septic tanks, sewer lines and pump stations. The limited ability to use traditional septic systems and septic tank failures in poorly drained coastal soils already requires the use of alternative waste treatment systems to support current levels of development. When pump stations, sewer lines, and wastewater treatment plants are inundated the infrastructure must be replaced and the surrounding contaminated environment must be remediated. In addition to the homes, associated infrastructure failure may occur due to coastal inundation of water and wastewater components, like septic tanks, sewer lines and pump stations. Septic tank failure in poorly drained coastal soils, creates a need for alternative waste treatment. When pump stations, sewer lines, and wastewater treatment plants are inundated, the environment is contaminated, and the infrastructure must be replaced.

Public access facilities and amenities (e.g., parking, restrooms, docks, and piers) which are frequently inundated may be damaged and unavailable for public use. Some of these facilities may become permanently inundated.

Tropical cyclones

A direct hit by a strong hurricane would be expected to damage and/or destroy many coastal structures. Wind, flooding, and storm surge are all likely to cause major impacts.

Damage to tourist infrastructure, including attractions, services, and accommodations, could have a significant impact on the coastal economy. Depending on the magnitude and severity of the storm, there could be large uninsured losses that may qualify for state or federal disaster declaration and aid.

Public and private property would also be affected by a major storm. As storm intensity is expected to increase as the climate warms, more property owners who have not previously been affected by such disasters would be at risk. The cost of insurance will rise to cover the increased risks and claims will rise because of increased property losses.

Current Efforts

Because a changing climate raises broad and complex issues, the Albemarle Pamlico National Estuary Partnership (APNEP) partnered with the Nicholas Institute for Environmental Policy Solutions to develop a report: "Climate Ready Estuaries: A Blueprint for Change." This comprehensive document includes a great deal of useful information, including public opinion surveys and recommendations for addressing challenges associated with a changing climate. Selected recommendations from this report have been integrated into APNEP's overarching management plan, its communications and outreach efforts, and its staff initiatives.

APNEP is also working with municipal governments to evaluate climate risks to their water and wastewater infrastructure. This work incorporates EPA's Climate Resilience Awareness and Assessment Tool (CREAT) to study future hurricane, flooding, and inundation risks. Local partners will also receive recommendations for cost-effective measures to improve their climate resiliency.

The Coastal Resources Commission has developed a draft policy to deal with the impacts of rising sea levels. Public hearings will be held in 2013 to consider this draft policy. The text below is taken directly from that draft policy and is subject to change prior to final adoption:

N.C. Coastal Resources Commission, DRAFT Sea-Level Rise Policy, Public Hearing Version (August 30, 2012)

15A NCAC 07M.1301 DECLARATION OF GENERAL POLICY

The Coastal Resources Commission (hereafter referred to as the "Commission") is charged under the Coastal Area Management Act (CAMA) with the protection, preservation, orderly development, and management of the coastal area of North Carolina. To that end, the Commission is specifically charged with the protection of certain rights and values, which include ensuring the protection of public trust resources and access to those resources, preserving the quality and optimum use of water resources, managing land use and development to minimize environmental damage, and preserving private property rights.

The Commission finds that global sea-level rise is occurring and presents a gradual but significant coastal hazard along the coast of North Carolina. While uncertainties exist with any kind of forecast or projection, continued or accelerated sea-level rise is expected to intensify the challenges that the Commission faces in protecting public trust resources including the estuarine system, coastal sounds and inlets, and barrier dune systems and beaches.

While sea-level rise can be difficult to perceive in the short-term, it presents a gradual threat that may intensify other coastal hazards such as flooding, storm surge, shoreline erosion, and shoreline recession. Sea-level rise can also pose a threat to freshwater resources and quality, private property and development, tourism and economic vitality, historic and cultural resources, agriculture, forestry, and public property and infrastructure.

The goal of this policy is to establish a framework for improved understanding of

the potential impacts of sea-level rise, and for supporting planned adaptation and resilience to rising sea levels. Planned adaptation can help to minimize economic, property and natural resource losses, minimize social disruption and losses to public trust areas and access, and lessen the need for disaster recovery spending.

History Note: Authority G.S. 113A-102; 113A-106; 113A-107; 113A-124

15A NCAC 07M.1302 DEFINITIONS

As used in this Section:

1. "Accommodate" means designing development and property uses such that their function is not eliminated as sea level rises.
2. "Conservation measures" are non-regulatory tools that can include easements, land acquisition, habitat restoration and similar measures.
3. "Planned adaptation" means taking a proactive and deliberate approach to promoting resiliency of communities, economies and ecosystems, by identifying hazards and vulnerabilities and designing and implementing measures to adjust to, or relocate from, rising seas.
4. "Relative sea-level rise" means an increase in the average surface height of the oceans over a long period of time that may be caused by an absolute increase in the water level, by sinking of the land at the water's edge, or by a combination of the two.
5. "Resilience" is the ability of communities, economies and ecosystems to withstand, recover from, or adjust to disruptive influences without collapse.
6. "Sea-level rise" means a long-term increase in the average surface height of the oceans.
7. "Shoreline erosion" refers to the chronic or episodic landward migration of a shoreline caused by the loss or displacement of sediment.
8. "Shoreline recession" means the long-term landward migration of the average position of a shoreline.
9. "Subsidence" is the sinking or decrease in land elevation over time.

History Note: Authority G.S. 113A-102; 113A-107; 113A-124

15A NCAC 07M.1303 POLICY STATEMENTS

(a) The Commission will promote public education of the impacts associated with rising sea levels and measures to adapt to changing shorelines.

(b) The Division of Coastal Management shall be responsible for providing the Commission, local governments, and coastal residents information on sea-level rise trends, research, projections, implications, and adaptation options through ongoing collaboration with federal and other state agencies and the scientific community. Based on this information, the Commission should provide an assessment of sea-level rise to the twenty coastal counties at least every five years for their consideration in local land-use and hazard mitigation planning.

(c) Relative sea-level rise is not uniform across the State's coastal zone, and the

differences are amplified by topographical variations and regional subsidence. As a result, specific adaptation measures might not be appropriate for all communities in the coastal zone, or at the same time. The Commission encourages coastal communities to consider regional trends and projected rates of sea-level rise in hazard mitigation, local land use, and development planning. The Commission also supports the development of scientific data and the advancement of adaptation measures that are tailored to different regions of the coast.

(d) As sea level rises, intertidal areas are being flooded at greater frequency and to greater depths, spurring the natural, landward migration of coastal habitats. In order to maintain their ecological functions, fisheries habitats and coastal wetlands may migrate landward to keep pace with rising waters. In consultation with appropriate resource protection agencies and stakeholders, the Commission should consider conservation and regulatory measures to enhance the resilience of natural systems and habitats.

(e) The Commission has the responsibility to assist local governments with land-use planning guidance and support. Due to the technical nature of sea-level rise science and varying needs for adaptation strategies, the Commission shall, to the best of its ability, provide local governments with scientific data to support local education and planning efforts. The Division may also provide financial assistance for local adaptation planning and implementation as available.

(f) It is in the State's interest to invest in long-term sea-level rise research and monitoring, as such investments will contribute to enhanced natural, economic, and societal resilience, and reduced future losses and disruption. The Commission will actively support state, federal, and private efforts to fund data collection, research, monitoring, and utilization of results.

(g) In order to minimize the impacts of hazards, disruption and losses associated with rising water levels, the Commission encourages new private development and public infrastructure be designed and constructed to accommodate projected sea-level rise impacts within the structure's design life.

History Note: Authority G.S. 113A-102; 113A-106; 113A-107; 113A-110; 113A-112; 113A-124

Adaptive Response Options

- Finalize Coastal Resources Commission policy on sea-level rise.
- Promote public education of the impacts associated with rising sea levels and measures to adapt to changing conditions.
- Provide local governments with scientific data, tools, and resources to support local education and planning efforts.
- Update the Commission's Sea Level Rise Assessment Report at least every five years.
- Actively support state, federal, and private efforts in data collection, research, monitoring, and utilization of results.
- Design and construct public infrastructure to accommodate sea-level rise impacts within the structure's design life.

References

Transportation Research Board. Report 290: "Potential Impacts of Climate Change on U.S. Transportation." (2008)

American Association of State Highway and Transportation Officials (AASHTO). "Primer on Transportation and Climate Change". (2008)

Bin, O., Dumas, C., Poulter, B. and Whitehead, J. "Measuring Impacts of Climate Change on N.C. Coastal Resources." National Commission on Energy Policy (2007) accessed at http://econ.appstate.edu/climate/NC-NCEP%20final%20report.031507.pdf

Appendix E: North Carolina's Natural Environment

This chapter on North Carolina's Natural Environment includes these sectors:

1. Aquatic Ecosystems
2. Wetland Ecosystems
3. Upland Ecosystems

Introduction

This assessment of climate change impacts to ecosystems in North Carolina was a collaborative effort among the N.C. Natural Heritage Program, the N.C. Wildlife Resources Commission, and the U.S. Fish and Wildlife Service. In addition to this assessment, the NC Wildlife Resources Commission is working to incorporate potential climate change impacts and adaptive management into the revision of its Wildlife Action Plan (2005). The Coastal Habitat Protection Plan incorporated climate change impacts in its 2010 update.

The natural environment is already experiencing impacts from non-climate related stressors. Activities such as conversion of natural habitats to agriculture and development, habitat degradation, altered flow regimes, groundwater extraction, and invasive species, have had significant impacts on native ecosystems. When these existing impacts are combined with the additional stressors from climatic change and variability, the disruption may overwhelm some ecosystems. Species dispersal corridors may be blocked, resulting in genetic isolation that can eventually lead to region-wide extirpations or even extinction of certain species or rare natural communities.

The N.C. Natural Heritage Program (NHP) began a more comprehensive evaluation of possible effects of climate change on North Carolina's ecosystems, natural communities, and species (North Carolina Natural Heritage Program, 2010). NHP's analysis estimates regional changes related to climate change and integrates this information with what is already known about ongoing threats. The goal of this analysis is to provide the projected climate change effects and possible ecosystem responses to these effects. Once this integrated picture is obtained, NHP recommends a set of conservation measures to help offset the combined impacts that are projected to occur and help NC's native species and ecosystems be as resilient as possible for the anticipated effects of climate change. For purposes of this effort, the ecosystems are defined by habitat types that consist of an assemblage of two or more of the natural community types, as described in the "Natural Communities of North Carolina, 3rd Approximation" (Schafale & Weakley, 1990). This analysis is being used by Wildlife Resources Commission and other partner agencies in developing conservation plans. Because of the comprehensive and in-depth nature of the NHP climate change assessment, information from it is included at a very general level in this report.

In 2005, the N.C. Wildlife Resources Commission (Commission) developed the N.C. Wildlife Action Plan (Plan) which is a blueprint for fish and wildlife conservation statewide by providing guidance and assistance to other conservation-minded

agencies, organizations, industries, academics, and individuals. This Plan lays out a framework for identifying critical fish and wildlife resources and priority conservation needs associated with those resources. With a revision cycle approaching in 2015, the Commission intends for the updated plan to specifically address the threat of climate change on wildlife resources along with all the other identified threats and proposing practical conservation strategies to consider. In 2010, Defenders of Wildlife produced a report for the N.C. Wildlife Resources Commission titled, "Understanding the Impacts of Climate Change on Fish and Wildlife in North Carolina," which provides a comprehensive overview for North Carolina for the potential vulnerability of wildlife and their habitats to changing weather patterns, and the potential impacts on wildlife and their habitats (DeWan et al,. 2010). Much of the following information is drawn from that report.

For the assessment presented in this chapter, the possible impacts of a changing climate, and the risks and vulnerabilities of natural features are analyzed and described in three broad categories: aquatic ecosystems, wetland ecosystems, and upland ecosystems. These are described separately below.

1. AQUATIC ECOSYSTEMS

Aquatic ecosystems in North Carolina comprise a wide range of fresh, brackish and salt water bodies. Specific types of aquatic ecosystems discussed below include large rivers, streams, swamps, and natural lakes in the Coastal Plain; large rivers, small rivers, headwater streams, upland pools, and depressions in the Piedmont; and cold water streams and cool water streams in the Mountains.

Impacts, Risks and Vulnerabilities

Increase in Heat Waves and High Temperature Days/Nights

Increased air temperatures will lead to increased water temperatures and lower dissolved oxygen levels for most streams and rivers. Since aquatic species are primarily cold-blooded organisms with no physiological ability to regulate their body temperature, they are particularly sensitive to changes in water temperature. Species, such as trout, that are already at the edge of their natural range are likely to be affected by temperature increases. Smaller streams, particularly in the Piedmont and Coastal Plain, are also likely to be impacted. As a result of warmer waters, algal blooms are more likely in the larger, slower rivers and these can exacerbate dissolved oxygen problems, particularly when flows are low. Increased water temperature, re-suspension of bottom sediment during storms, and increased nutrient content of freshwater and coastal waters can increase physiological stress in aquatic animals and result in increased effects of pathogens. These factors will likely result in increased number and size of fish kills, especially when combined with human-caused factors such as pollution.

Increases in water temperature could also cause aquatic species to experience shifts in their range or distribution, and sensitive species may experience decline or extirpation. Species at the edge of their range will be most affected, as will species that are limited to headwater systems, because pathways to disperse to new habitats do not exist. Overall, cool water ecosystems are expected to become established upstream, replacing coldwater ecosystems.

The prevalence of warmer water temperatures may increase the likelihood of additional exotic species that were previously considered to be non-threatening when the winters were too cold for survival. Warmer temperatures could allow range expansion and increased competition from species dispersing from adjacent regions. In coastal waters, increased water temperature combined with declining pH reduces calcification of mollusks and crustaceans. As a result, the density and distribution of shell bottom habitat is likely to decline, leading to greatly reduced habitat complexity and loss of biodiversity (Deaton, 2010).

Increase in Drought Frequency and Severity

Potential changes in precipitation may have numerous and varied effects. Severe droughts will decrease streamflow, decrease groundwater recharge, and increase evaporation, resulting in negative impacts to streams and rivers, particularly small ones. Decreases in overall summer precipitation will likely cause reduced water flows, which will further contribute to warmer water temperatures and further stress water quality. Drought reduces hydrologic recharge of groundwater and aquifer systems. Low hydrologic recharge reduces freshwater inputs to perennial surface waters (ponds, lakes, streams, and rivers). Reduced precipitation is particularly important in the context of seasonal droughts because during low-flow periods, nutrients may become concentrated and flush out of systems more slowly. Headwater and other small streams in the state could dry up, posing significant impacts to populations of aquatic species.

Increase in Heavy Precipitation

Increased storm intensity or frequency may lead to flash flooding and increased erosion. With increased stormwater runoff, there may be an increase in sediments, nutrients and contaminants in streams, rivers and reservoirs, resulting in negative effects on aquatic species and their habitats. Changes in rainfall intensity and variability will also affect stream flow patterns, channel hydrodynamics, lake levels, and the volume of groundwater recharge from aquifers. These changes, in addition to major disruption to channel design and hydrodynamics related to increased erosion, potentially could upset the physical, chemical, and biological structure of streams. Additionally, storms may cause streamside trees to fall, increasing woody debris in streams, which can change channel hydrodynamics and habitats. An increase in heavy precipitation events would also increase the frequency that anoxic water is flushed from coastal wetlands into coastal rivers, which would result in an increase in fish kills.

Rising Sea Level

Sea-level rise is very likely to impact coastal rivers, streams, swamps and estuaries by causing inundation, saltwater intrusion, and coastal erosion. As salt water moves further upstream into these rivers, the chemical composition of existing freshwater systems will change, affecting freshwater species and spawning habitats. Water chemistry changes would influence vegetative community composition along shorelines, thereby changing habitats and possibly altering the number and types of species able to survive in those habitats.

Sea-level rise is likely to impact the lower reaches of large rivers and freshwater streams in the Coastal Plain, depending upon the frequency and range of coastal inundation. The combined increase of inland flooding due to higher precipitation

events with elevated sea levels will exacerbate coastal inundation. Additionally, salt water intrusion into currently freshwater rivers and streams as sea level rises would change the chemical composition of currently freshwater systems. Sea-level rise may increase the effect of more extreme weather, both drought and flooding, in the inland watersheds, causing more dramatic salinity fluctuations in the estuaries because of varying freshwater input.

In marine and estuarine coastal habitats, increasing water temperatures combined with sea-level rise are thought to influence aquatic community structure. (Deaton et al, 2010). Changes and shifts in barrier islands and wetlands could reduce the productivity of estuarine nursery areas, negatively impacting N.C. fisheries. Fish species distribution could change, especially species that are already at their southern or northern distribution limits.

Estuarine communities will be some of the most severely affected by rising sea level. Rising sea levels, ground subsidence, and coastal erosion may create new channels through the Outer Banks, which can have marked effects on the salinity and tidal regime of the Albemarle-Pamlico Estuary. Severe storms, combined with high surge and sea-level rise, could result in more breaches along the Outer Banks as experienced during Hurricane Isabel in 2003 and Hurricane Irene in 2011. Breaches and inlet creation can result in changes to the salinity and tidal regimes in the sounds and estuarine waters. Inundation and increased shoreline erosion could impact areas of marsh, thus increasing the extent of open water. Brackish and salt marshes would move farther upstream in the estuaries. Development in uplands adjacent to marshes and other coastal waters could restrict or prevent natural movement of these systems.

2. WETLAND ECOSYSTEMS

Wetland ecosystems in North Carolina generally have hydric soils and hydrophytic vegetation that occur on those soil types and moisture gradients. Broad wetland ecosystem types included in this assessment are blackwater floodplains, brownwater floodplains, non-alluvial mineral wetlands, estuaries, freshwater tidal wetlands, maritime wetland forests, peatland pocosins, streamhead pocosins, wet pine savannas, mountain bogs and fens, Piedmont and Mountain floodplains, successional wetlands, and upland seepages and spray cliffs.

Impacts, Risks, and Vulnerabilities

Increase in Drought Frequency and Changes in Rainfall Frequency / Intensity
Changes in input of fresh water may be significant to tidal wetlands. Most of the freshwater tidal wetlands in the northern part of the state receive limited freshwater from rivers, but the hydrologic recharge from creeks and from sheetflow may be important. Changes in salinity associated with recent droughts have been observed, and may have had effects on existing vegetation. An increase in drought frequency or severity would make such effects more important. Generally, droughts are likely to increase the expansion of exotic invasive species into wetlands and increase the chances of wildfires. Conversely, an increase in extreme rainfall events could bring increased freshwater flow at times, resulting in more fluctuation of salinity than now occurs.

The effect of an expected increase in both droughts and intense rainfall events may be particularly important for mountain bogs and fens. Many bogs are located in bottomlands

that do not regularly flood, but which could flood in extreme events. Besides stream flooding, overland runoff from adjacent uplands during severe storms would be a problem in many bogs. The nutrient input, sedimentation, and potential scouring of severe floods would be detrimental to bog communities. While plants in bogs are probably never truly limited by moisture, droughts would have significant effects on competitive relationships among species and on the community as a whole. Droughts in the present climate appear to have exacerbated the ongoing invasion of upland and generalist wetland plants in some bogs.

The direct impacts of climate change on piedmont and mountain floodplains may be fairly limited compared to other threats. Indirectly, however, changes in rainfall patterns, including increases in severe flooding, may spur construction of more reservoirs, both to secure water supplies and to serve for flood control and power generation. These new reservoirs could result in loss of floodplain habitats and in severe habitat fragmentation within entire river basins. Increased flooding and scouring are likely to have an adverse effect on some of the state's rarest plant species, which occupy the unstable mud and gravel bars in piedmont and mountain rivers. Increased watershed and floodplain erosion, scour, and transport and deposition of sediment by floodwaters could also result in adverse impacts to habitat for aquatic organisms and terrestrial organisms dependent on specific hydrological features. For example, repeated severe flooding could increase the depth of a stream channel, which might lower the water table and disconnect trees and other streamside vegetation from access to subsurface moisture, destroying adjacent wetland communities. Given that floodplains provide some of the most important remaining dispersal corridors for upland and bottomland species, any further losses in acreage will have impacts far beyond the limits of the floodplains themselves.

Climate change effects and responses will likely be varied among different types of upland seepages and spray cliffs. However, drought and increased temperature associated with climate change are the most severe threats to these systems. These habitats support many rare plant species which are not likely to be able to disperse given their close association with these specialized environments. These communities are also susceptible to invasive species, which may be exacerbated with climate change. These communities are highly threatened overall by altered flood regime, groundwater depletion, development, and invasive species.

Rising Sea Level

Climate change is a significant threat to coastal plain nonalluvial mineral wetlands (non-riverine wetlands such as wet marl forests, or swamp forests) primarily due to the likelihood of inundation from sea-level rise. Other non-climate threats such as logging and the alteration of hydrology in the form of ditches and groundwater pumping, pose equal threats to these systems. Rising sea level will be more of a concern in the larger riverine wetlands at lower elevations, such as those around the Alligator River, than to wetlands further inland.

Freshwater tidal wetlands are likely to be among the most severely affected by climate change. Changes caused by rising sea level are the greatest threat, but also important will be increased intensity of storms, both in rainfall and wind. Permanent inundation and shoreline erosion are already occurring due to gradual sinking of the land in some areas and can be expected to continue. Salt intrusion into freshwater

peat lands accelerates their collapse, particularly in the Albemarle Pamlico peninsula. Tidal influence can be expected to penetrate farther inland into non-riverine wetlands in some of these areas, allowing the potential for inland migration. In other portions, abrupt slopes to uplands, development, or lack of any higher land adjacent would make migration of wetlands impossible.

Downstream reaches of blackwater and brownwater coastal plain floodplains may eventually transform into tidal marshes. No expansion is possible upstream, and expansion into the piedmont is not possible for these ecosystems. Consequently, the net effect will be an overall loss of acreage of these types of ecosystems.

The Outer Banks are likely to be impacted significantly due to sea-level rise and storm activity, which can cause inlets to open and close. Barrier islands that are not artificially stabilized may be able to move inland to keep pace with rising sea level in the near term, but the limited sand supply and deeper water behind them make long-term relocation of these islands unlikely. Artificial stabilization, which interferes with natural movement, can result in narrowing of barrier island height and width, and a decrease their ability to withstand storms. Before the Outer Banks developed in historic times, not only were the sounds salty, but the shape of the bay led to a larger lunar tidal amplitude than currently occurs in this part of the coast. Such changes could occur gradually, as barrier islands narrow and disappear. However, these processes could also happen more rapidly, if a large storm opens substantial portions of barrier islands at one time.

Wind increases wave erosion along the shoreline, and is likely to be significant for the forested freshwater tidal wetlands. Wind fetch effects on shoreline erosion are also significant in Kitty Hawk Bay to areas that have emergent vegetation and are not forested. Wind is likely to be less important than changes in salt levels and tides, but could alter forest structure or contribute to the shift from swamp forests to marshes.

3. UPLAND ECOSYSTEMS

Upland ecosystems in North Carolina are those that are not dependent upon the existence of surface water or extremely wet soils. Specific types of upland ecosystems addressed in this assessment include coastal plain marl outcrops, dry longleaf pine forests, granitic flatrocks, grass and heath balds, high and low elevation rock outcrops, mafic glades and barrens, maritime grasslands, maritime upland forests, montane oak forests, mountain cove forests, northern hardwood forests, piedmont and coastal plain mesic forests and oak forests, dry coniferous woodlands, and spruce-fir forests.

Impacts, Risks, and Vulnerabilities

Changes in Air Temperature and Precipitation

Milder temperatures, changes in precipitation, and natural ecological succession can be expected to change the species composition of many upland ecosystems. Species native to comparable communities farther south may be able to move into North Carolina and some of North Carolina's native species may be able to relocate northward. However, fragmentation caused by development will limit the ability of many species to disperse. Due to their disjunct spatial distribution, a number of endemic species found in some of these community types face outright extinction.

Other species, if lost, are unlikely to re-establish within the region.

Communities and species associated with high elevation northern hardwood forests and spruce-fir forests are all highly likely to be affected by changes in temperature and moisture associated with climate change. These communities contain high proportions of endemics, the loss of which cannot be replaced. Invasion by species from lower elevations could eventually lead to competitive exclusion of these distinctive communities from the lower parts of their elevational range. There is concern and uncertainty about whether these shifts will "push communities off the top of the mountains." Changes might be either gradual (resulting from shifts in reproductive success, or impacts from disease and insect infestation) or may be abrupt (tied to severe weather or fire). Fire would likely be catastrophic, for spruce-fir forests are not adapted to fire. Spruce-fir forests that are burned completely could lose most of their resident species and never fully recover.

Communities and species associated with high elevation rock outcrops and grass and heath balds are among the most vulnerable to changes in temperature and mild winters associated with climate change. Changes in precipitation may not be drastic, but could be significant in areas where snow accumulation is an important input to the hydrologic cycle. It is uncertain whether fog and cloud cover will change in these high elevation communities as a result of changing climate; if this happens, it could significantly alter the amount of moisture deposited by fog.

Any expansion of longleaf pine forests in the warmer climate would likely depend on fire. Such shifts should not necessarily be regarded as negative. Pine forests have declined since fire suppression began, and a further expansion of them would be appropriate in a warmer, drier climate (National Wildlife Federation 2009).

Increased drought conditions combined with increased thunderstorm intensity are likely to produce more wildfires. Some upland systems, such as longleaf pine forests, depend on fire and are often degraded by lack of fire. Some wildfires may burn in a way that is ecologically beneficial; however, wildfires in drought conditions are more likely to be too intense or too extensive, and may harm some species. In small, isolated sites, an increase in large wildfires may have catastrophic impacts on insects and other animals that rely on dispersal mechanisms for coping with environmental disturbances. As a result, there may be a significant increase in local extirpations that may eventually lead to region-wide extirpations or even extinction of certain species.

Regarding oak forests, it is unclear if changes in fire regime will be beneficial or harmful. They would benefit from an increase in low to moderate intensity fire, which could serve to reverse the alteration of composition and structure that has been caused by fire suppression. Alternatively, severe fire during droughts would cause extensive canopy mortality, which would exacerbate the effects of increased wind damage and logging.

Wildfire could be a severe threat in high elevation rock outcrops and grass and heath balds. Natural vegetation in high elevation rock outcrops virtually never burns and is not thought to be adapted to fire, but fire does not carry well over rocks and sparse vegetation on high elevation rock outcrops. Wildfire, could possibly promote the expansion of some grassy bald ecosystems, however, the effects of more frequent

fire are uncertain.

Wind storms
Increased wind storm damage could affect canopy structure of many forest types across the state. For example, extensive wind damage in longleaf pine savannas would be detrimental to red-cockaded woodpeckers and other species that depend on older longleaf pine trees. Upland sites with significant wind damage may be more vulnerable to the establishment of invasive species populations.

Rising sea level
The most significant effects of climate change on coastal uplands, such as maritime grasslands and maritime upland forests, will be rising sea level and an increase in the frequency or intensity of storms. Most maritime grasslands occur on the narrower, less stable barrier islands that are most susceptible to storm surge and breaching. Many narrower areas of the Outer Banks could gradually erode, while the wider, higher, and more stable parts of barrier islands are likely to remain.

Much of the higher, wider areas of the barrier islands are currently occupied by maritime upland forests. Grasslands will likely expand in the more exposed areas, but, overall, maritime grasslands are likely to suffer losses. Grassland communities may also shift and change as the result of increased storm activity and its associated erosion, increased salt spray, overwash, and salt water intrusion. However, these communities are well adapted to overwash and this may or may not be harmful to them. Rising sea level and erosion of dunes can allow for increased inundation of maritime wetland forests, eventually converting them to marshes, wet grasslands, or open water. Rising water tables may allow wetlands to spread to higher elevations at the expense of maritime upland forests, and possibly even cause new examples to appear. But the net change is likely to be a loss of forest acreage. The largest expanses of maritime wetland forests are on the low-lying sound side of Currituck Banks, where they exist only because of the fresh water in Currituck Sound.

If the Outer Banks are severely breached by storms or rising sea level, much of the area of maritime wetland forests will likely be converted to salt or brackish marsh (Riggs and Ames 2003). Likewise, the extensive examples along the sounds (estuarine fringe loblolly pine forest) are low-lying and are very likely to be inundated or affected by increased salinity. The acreage lost from this system by shifts in community types and conversion to other land uses may be extensive. Any loss will be significant for these already-rare communities. New sites for these communities may be generated as the coastal landscape changes, but only in places that currently support natural habitats. Many maritime plants disperse readily and occur commonly in wetlands in the coastal plain, but the naturally and artificially fragmented distribution of wet maritime forests may limit such latitudinal movement.

Current Efforts

Many conservation agencies and organizations are currently working to reduce the vulnerability and promote resiliency of North Carolina ecosystems to climate change by protecting and managing surrounding wetlands, uplands and vegetative buffers from storm surge and flood damage, while providing wildlife habitat.

The Coastal and Estuarine Land Conservation Program (CELCP) protects important

coastal and estuarine areas that have significant conservation, recreation, ecological, historical, or aesthetic values, or that are threatened by conversion from their natural or recreational state to other uses. Priority is given to lands which can be effectively managed and protected and that have significant ecological value. An update to the NC CELCP Plan is in progress, and will take sea-level rise into account in evaluating potential acquisitions. The State's updated CELCP plan will provide guidance to grant applicants and allow them the flexibility to discuss the amount of sea-level rise they anticipate and how the conservation target might be affected. Applicants could also propose acquisition of lands that could serve a climate change adaptation purpose, e.g. corridors for habitat or species migration.

The Coastal Habitat Protection Program (CHPP) has developed a plan for long-term enhancement of coastal fisheries associated with coastal habitats. The plan includes recommendations for the environmental regulatory commissions (Marine Fisheries Commission, Coastal Resources Commission, Environmental Management Commission, and Wildlife Resources Commission), which must be implemented. The effects of climate change on each type of coastal habitat are discussed in the plan and several recommendations directly address it. The 2010 CHPP includes scientific information on expected impacts to fish habitat and water quality from rising sea level.

The National Oceanic and Atmospheric Administration's (NOAA) North Carolina Sea-Level Rise Research to Application Project is a pilot study intended to improve scientific understanding of the ecological effects of sea-level rise and storm surge on North Carolina coastal habitats and to develop better models and tools to forecast these effects. The project is funded by NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) through its Ecological Effects of Sea Level Rise (EESLR) Program. The project study area included the Neuse River and the Pamlico, Back, Bogue and Core Sounds. A cooperative network of multi-investigative projects were funded including: (1) forecasting the effects of different sea-level rise scenarios and/or storm surges on tidal shorelines, tidal conditions, and coastal inundation; (2) predicting the ecological effects of sea-level rise on coastal NC marshes; (3) modeling estuarine habitat response to sea-level rise and increased shoreline hardening; (4) predicting geomorphic change in the coastal system as a result of rising sea levels; and (5) using the Neuse Landscape Model to assess the quality and quantity of spatial and temporal coastal habitat change under diverse sea-level rise scenarios.

The North Carolina National Estuarine Research Reserve System (NERRS) sites are sentinel monitoring sites for climate change impacts on salt marsh habitat. This project involves creating a long-term ecological monitoring program to determine the effects of sea-level rise, warmer temperatures, and coastal storms on salt marshes.

A major project that is specifically addressing climate impacts to wetlands is the Alligator River National Wildlife Refuge/Albemarle-Pamlico Peninsula Climate Adaptation Project. This pilot project is a partnership between the N.C. chapter of The Nature Conservancy (TNC) and the U.S. Fish and Wildlife Service (USFWS) to evaluate the effects of different adaptation strategies on areas impacted (or likely to be impacted) by sea-level rise. This is an adaptive management study to determine how to make the shoreline more resilient to rising sea levels. The strategies include constructing oyster reefs to buffer shorelines from waves and storm surges,

restoring the natural hydrologic regime and associated wetland systems, and planting salt- and flood-tolerant species.

In addition to these current projects, there are many conservation partnerships in North Carolina that have formed to facilitate collaboration among multiple agencies for the purpose of conserving natural habitats and species within their focus areas. Many of these partnerships and agencies are considering climate change impacts while working together to promote resilient ecosystems. Some of these partnerships include the Greater Uwharrie Conservation Partnership, the Cape Fear Arch Conservation Collaborative, the Onslow Bight Conservation Partnership, the N.C. Sandhills Conservation Partnership, the Upper Tar River Collaboration, the South Atlantic and Southern Appalachian Landscape Conservation Cooperatives (LCC), Brook Trout Joint Venture, Appalachian Joint Venture, and Atlantic Coast Joint Ventures.

In addition, other activities that may help address climate change impacts to upland ecosystems are being addressed by the North Carolina Prescribed Fire Council and the N.C. Exotic Plant Pest Council. The N.C. Prescribed Fire Council is a group of resource professionals that promote prescribed fire as a land management tool. Prescribed fire promotes ecosystem health in fire-dependent habitats and minimizes the likelihood of catastrophic wildfires by reducing the fuel load. The N.C. Exotic Plant Pest Council (NCEPPC) works to facilitate solutions to problems caused by invasive plants, which are likely to spread in projected climate change conditions.

The Ecosystem Enhancement Program (NC EEP) restores, enhances and preserves streams, wetlands, and coastal marsh as mitigation for impacts to these resources from development activities. The program's projects are designed to produce self-sustaining improvements to and protection of hydrology, water quality, and habitat. EEP increases the resilience of watersheds through alterations to stream channels and wetlands, including planting native trees in buffer zones along streams and in wetlands that restore natural functions. Through watershed planning, EEP identifies the priorities for intervention to improve aquatic systems statewide, while involving and educating stakeholders at the local level.

Adaptive Response Options

Maintaining ecosystem integrity through protection and management:

Land managers may be able to implement actions to help maintain resilient habitats in the face of climate change. Adaptive responses may include maintaining or restoring natural shorelines and stream buffers, protecting floodplains and wetlands from extensive development, improving connectivity for species movement (bridge or culvert design considerations, removing dams, protecting migrations corridors), and managing invasive species.

It is important to protect and restore habitat connections to allow movement of species across the landscape as climate changes. Many species and habitats may be able to adapt and disperse as the climate changes, but only if there is an available path on the landscape, to allow for that.

In some situations, it may be necessary to propagate or implement translocation

projects for rare species that are unable to relocate naturally, as their habitat decreases or is lost entirely. This occurrence may be particularly true of species that have ranges restricted by current land uses or have naturally restricted ranges such as isolated wetlands, headwater streams, or mountain tops.

Additional adaptive responses may include managing the remaining examples of extremely rare wetland community types, so that they are not so vulnerable to potential changes, controlling invasive species, and maintaining landscape connections between wetland habitats to allow the migration of species.

It is also important, where it is feasible, to restore the natural hydrology or maintain the current hydrology in aquatic and wetland ecosystems and reduce groundwater extraction, which may exacerbate the negative impacts caused by climate change.

Consideration could be given to using available web-based tools and GIS programs to model options that evaluate population response to climate change and sea-level rise scenarios. These modeled results could be used to develop response plans that use monitoring to track the actual changes.

Monitoring

NERRS sentinel monitoring sites will collect data on the impacts of sea-level rise on representative coastal ecosystems and inform resource management decisions at both reserve sites and in N.C.'s coastal communities. The N.C. Coastal Reserve, part of the Division of Coastal Management, is currently working on aspects of the sentinel sites initiative at the Rachel Carson (Carteret County), the Masonboro (New Hanover), and Zeke's Islands sites (New Hanover and Brunswick Counties). It is anticipated that the N.C. Coastal Reserve will engage in adaptation planning for the individual reserve sites, nearby protected areas, and/or their local communities through partnerships. Adaptation strategies will be tailored to the unique risks in the local areas. Other aquatic ecosystems throughout the state, not just at the coast, will also need to be monitored for climate change impacts.

Policies and Plans

Integrated water management plans and policies could be developed to protect the ecological integrity of natural habitats. Coordinated policies and guidelines for management adaptations to increase the resiliency of fish habitats are developed from the Coastal Habitat Protection Plan, as led by the Division of Marine Fisheries. The N.C. Wildlife Resources Commission is working to incorporate potential climate change impacts and adaptive management into the revision of its Wildlife Action Plan. The Albemarle-Pamlico National Estuary Partnership, through its Comprehensive Conservation and Management Plan, can provide support for local governments that seek to incorporate climate considerations into their planning processes. NC EEP has completed River Basin Restoration Priority plans for every river basin in the state, as well as 29 Local Watershed Plans statewide which detail opportunities for integrated management of watershed systems, including opportunities to improve local ordinances and treat storm water. Other policies may result from efforts to promote green infrastructure and low impact development.

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Appendix F: Earlier Efforts to Address Climate-Related Threats in North Carolina

Since the turn of the 21st century, there has been a growing awareness of the need to address the climate-related threats to our state's health and safety. North Carolina's state government and elected officials have undertaken a series of efforts over the last few years to address these concerns. These include:
Climate Action Plan Advisory Group

In the 2002 Clean Smokestacks Act (Session Law 2002-4), the Division of Air Quality within the Department of Environment and Natural Resources (DENR) was directed to study issues related to carbon dioxide emissions. As a result of that study, DENR established a Climate Action Plan Advisory Group (CAPAG) in 2005 to identify and assess options that state policy makers could consider in reducing greenhouse gas emissions. In the 2008 final CAPAG report, 56 options were recommended for further study and potential adoption by the state. One of these options, CC-5, recommended the development of a State Climate Adaptation Plan; this option was not adopted. Some of the other CAPAG options related to climate mitigation have been implemented legislatively, or have been incorporated into state agency programs. http://www.ncclimatechange.us/capag.cfm

Legislative Commission on Global Climate Change

The Legislative Commission on Global Climate Change (Commission) was established in Session Law 2005-442 to conduct an in-depth study of issues related to global climate change. The Commission met 23 times, starting in February 2006 and ending in May 2010, when the final report was adopted.

One recommended legislative proposal was incorporated into Session Law 2010-180, requiring state agencies to determine whether the impacts of global climate change are being considered in state regulatory and planning programs. In a summary report, some programs reported that they currently consider global climate change impacts in their programs, while many others indicated that this could be considered in the future. Departments may use this information to evaluate when and how certain programs might be modified to enhance the safety and resiliency of our state to climate-related hazards.

The Commission report included another recommended legislative proposal, which would have tasked the Department of Environment and Natural Resources to develop the North Carolina Climate Change Adaptation Strategy, with the cooperation of other state and federal agencies. While this proposal was not adopted, many of its elements have been included in the climate resiliency strategy outlined in this report. http://www.ncleg.net/gascripts/DocumentSites/browseDocSite.asp?nID=14

Department of Environment and Natural Resources

In 2009 DENR recognized the need to begin developing a response to the potential impacts posed by our changing climate. The department's strategic plan prioritizes implementing both mitigation and adaptation strategies to reduce vulnerability,

increase adaptive capacity, and improve resiliency of climate-sensitive resources. A Climate Change Steering Committee provides oversight for implementation of DENR's initiative. This team is focused on climate policy actions at state, regional and federal levels, while coordinating strategies with other state, federal, and non-governmental partners. http://www.climatechange.nc.gov/

Appendix G: Climate Sensitivity Assessment Packet

1 **Scale (1)** *See Appendix 2* _____

2 **Sector (1)** *See Appendix 3* _____

3 **Sub-Sector (Planning Area) (1)** *See Appendix 3* _____

4 **Climate Condition (1)** *See Appendix 4* _____

5 **Impact (1)** *Refer to Appendix 5* _____

6 **System-based Resources, Services, and Assets (Values)** | **System Classification** *(Natural or Human/Built)*

_____ | _____

_____ | _____

_____ | _____

7 **Consequences to System-based Resources, Services, and Assets** | **Metric** | **Sensitivity** (High, Medium, Low)

_____ | _____ | _____

_____ | _____ | _____

_____ | _____ | _____

8 **Non-Climate Factors**

_____ | _____

_____ | _____

_____ | _____

9 **Stakeholders/Decision Makers** *(Multiple)* _____

10 **Assessment Summary** *(Narrative)*

What are the Stakeholder roles and responsibilities?

_____

_____

_____

Generally, what is the magnitude and severity of the Impact and how do these vary?

_____

_____

_____

Are the Non-Climate Factors more, less, or equally important as the impact and why?

_____

_____

_____

11	**Required Spatial Data** *(other than data already commonly available)*	**Required Non-Spatial Data** (other than data already commonly available)	**List Data and Information Gaps**
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____
	_____	_____	_____

Name/Agency: _____

Date: _____

Appendix 1: Guidelines for Completing the Climate Sensitivity Assessment Template

NOTE: Multiple Assessment forms per sector must be completed in order to assess all the variables in climate sensitivity for various sub-sectors.

1. **Scale:** Refer to Appendix 2. List only 1 Scale per Assessment template. Select one of the major Scale categories to list in the left column. Identify your specific Scale in the right column.

2. **Sector:** Refer to Appendix 3 to choose from one of the major NOAA Sector headings. List only 1 Sector per Assessment template.

3. **Sub-Sector/Planning Area:** Refer to Appendix 3 to choose from one of the North Carolina sub-sectors (or planning areas) that fall under the major NOAA Sector headings. List only 1 Sub-sector per Assessment template.

4. **Climate Condition:** Refer to Appendix 4 to choose from one of the major Climate-related Conditions designated by IPCC. List only 1 Climate-related Condition that might affect your Scale/Sector per Assessment template. If there is more than one Climate-related Condition that might affect your Scale/Sector, you will need to fill out an additional template.

5. **Climate Impact:** Refer to Appendix 5 for examples of climate impacts that might affect your Scale/Sector. Be specific in describing the impact to that sub-sector (or planning area). List only 1 Impact per Assessment template. If there is more than one Impact that might affect your Scale/Sector, you will need to fill out an additional template.

6. **System-based Resources, Services, and Assets (or Values):** List the Resources, Services, and Assets that are valued for the system, which would be affected due to the Impact listed in Box 5. Be specific. In the right column, indicate whether the System is a Natural or Human/Built environment.

7. **Consequences to the System:** In the left column, list the Consequences to the System identified in Box 7. In the middle column, list a metric that could be used to quantify the Consequence; this can be in general terms. In the right column, estimate the degree of sensitivity this System has to the Impact listed in Box 5.

8. **Non-Climate Factors:** List other Non-Climate variables that could combine with specified climate conditions to impact the resource being assessed or other variables to consider that could combine with specified climate conditions to cause an impact.

9. **Stakeholders and/or Decision Makers:** Based on the criteria you provided in Boxes 1–5, list the key groups of Stakeholders and/or Decision Makers that would need to be engaged in the Assessment.

10. **Assessment Summary:** Provide a summary narrative of information in Boxes 1–9. Include any other relevant information. Specifically, address the questions that have been provided for further thought.

11. **Data Needed for the Assessment:** List any required Spatial or Non-Spatial Data that may be needed for the Assessment, which is not already easily accessible through federal, state or local agencies. In the right column, list any other data or information that is not currently available, which you feel would add to the Assessment process.

Appendix 2: Scale

Major Scale Category	Specific Scale
National	
Regional	Choose from major Region of the U.S. (e.g. Southeast, Northeast, etc.)
State	North Carolina
State-Regional	Choose from one of three main regions of North Carolina (Mountains, Piedmont, Coast)
River Basin	Choose from 6, 8, or 10 HUC or one of the 17 major river basins used by NC for basin planning
NOAA Climate Division	Choose from one of the eight NC climate divisions
Planning Organization	Assumes a North Carolina planning organization
• *Council of Governments*	Choose from Region A–R
• *Rural Planning Organization*	Choose from one of the 20 RPOs across the state
• *Metropolitan Planning Organization*	Choose from one of the 17 MPOs across the state
Municipality	Choose from incorporated towns/cities/counties
Local	List and be specific.

Appendix 3: Sector and Sub-sector (Planning Area)

NOAA Sectors	North Carolina Sub-sectors (Planning Area)
Transportation	Land Transportation Operations Land Transportation Maintenance Marine Transportation Operations Marine Transportation Maintenance Air Transportation Operations Air Transportation Maintenance
Natural Environments	Ecosystems (aquatic and terrestrial)
Water Resources	Public water supply Industrial water supply Agricultural water use Water quality (including infrastructure, water/wastewater)
Coastal Resources	Public trust resources (use and access) Natural buffers—wetlands and barrier islands Public property and infrastructure Private property and development Marine and estuarine coastal habitats
Human Health and Welfare	Heat-related /weather-related morbidity and mortality Vectorborne/zoonotic, foodborne, and waterborne diseases Asthma, respiratory allergies, and airway disease Mental health and stress-related disorders Other diseases (cancer, cardiovascular disease and stroke, neurological diseases and disorders, human development effects)
Agriculture and Forestry	Agriculture Forest Resources
Energy Production and Use	Utilities—Power Generation (coal, gas, hydro, etc.) Utilities—Use (electricity, gas, liquid fuels) Energy Resources Development and Marketing Energy Conservation and Efficiency
Human Social Systems	Cultural Resources (cultural landscape resources, cultural archival resources) Insurance Emergency management (mitigation, preparedness, planning, response, recovery) Economic vitality (business and industry, tourism/recreation, community development)
Land Resources	Dams Mining Erosion and Sedimentation Control Geological hazards
Marine Resources	Fisheries
Air Quality	Ambient air quality planning Air quality permitting and compliance Air quality monitoring Sources of air pollution (stationary, mobile, other)

Appendix 4: Climate Conditions (or climate-related phenomena)

Temperature-Related
Precipitation-Related
Tropical/Severe Weather-Related
Sea-level rise-Related

Climate Conditions	Definition/Future Climate Concern(s)
Low-temperature days/nights and frost days	Decrease in number of annual cold days/frost days, defined as a percentage of days with temperature (max for days, min for nights) not exceeding some threshold. The future climate concern is a decrease in the frequency and intensity of these events.
High-temperature days/ nights	Increase in number of annual hot days, defined as percentage of days exceeding some threshold. The future climate concern is an increase in the frequency and intensity of these events.
Cold spells (cold snaps)	Episode of several consecutive low-temperature days/nights. The future climate concern is a decrease of this occurrence, though an increase could occur regionally.
Warm spells (heat waves)	Episode of several consecutive high-temperature days/nights. The future climate concern is an increase of this occurrence, both locally and regionally.
Cool seasons/warm seasons (annual temperature averages)	Increase or decrease in seasonal averages (as opposed to daily temperatures) exceeding some threshold. The future climate concern is shorter cool seasons and longer warm seasons, with an increase in average temperatures during both.
Heavy precipitation events (normal events that occur annually)	Increase in the number of days with heavy precipitation, where daily precipitation exceeds some threshold, either fixed or varying regionally. This also includes an increase in the amount and rate of precipitation during events. The future climate concern is that while total precipitation may decrease annually, the amount and rate at which precipitation occurs during an event may increase significantly.
Rare precipitation events (with return periods >-10 yr)	Increase in rare or extreme precipitation events, where precipitation would exceed a threshold based on a return interval of greater than 10 years. Such events would not necessarily be related to tropical events.
Drought (precipitation deficit) (severity/duration)	Drought severity classification (Drought Monitor D1–D4) and duration of 1–3 months (short-term) or 6–60 months (long-term), leading to lack of water supply. The future climate concern is that drought may increase both seasonally and/or annually, and seasonal changes could occur.
Tropical cyclones (tropical lows, tropical depressions, tropical storms, hurricanes, major hurricanes)	Tropical cyclones are measured by their strength (frequency, intensity, track, peak wind speed, precipitation, and storm surge). Hurricanes are classified as a category 1–5 (major = 3–5). The future climate concern is that tropical cyclone/hurricane occurrences may increase, and that the overall strength may increase as well.
Extreme extratropical storms (mid-latitude wave cyclones)	Intense low-pressure systems that occur throughout the mid-latitudes of both hemispheres fueled by temperature gradients. The future climate concern is that their occurrence, size, and strength could increase.
Small-scale severe weather phenomena	Includes extreme events, such as tornadoes, hail, thunderstorms, dust storms, high wind events, and other local severe weather (nor'easters, derecho winds). The future climate concern is in an increase in the frequency/intensity of these events.
Sea-level rise	The result of the warming-induced expansion of the oceans, accelerated melting of glaciers, and/or loss of ice in Greenland and Antarctica leading to a rise in sea-level. The future climate concern is the rate at which this may increase.

Reference: IPCC Fourth Assessment Report (AR4)—Climate Change 2007: Working Group I—The Physical Science Basis, Chapter 3, Table 3.7, pg 314.

Appendix 5: Possible Impacts to Sectors due to select Climate Conditions (Examples)

Climate Conditions	Sector		
	AGRICULTURE AND FORESTRY	WATER RESOURCES	HUMAN HEALTH & WELFARE
High-temperature days/ nights	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks	Effects on water resources relying on snow melt; effects on some water supplies	Reduced human mortality from decreased cold exposure
Warm spells (heat waves)	Reduced yields in warmer regions due to heat stress; increases danger of wildfire	Increased water demand; water quality problems	Increased risk of heat-related mortality, especially for the elderly, chronically sick, and very young
Heavy precipitation events (events that occur every year)	Damage to crops; soil erosion; inability to cultivate land due to waterlogging of soils	Adverse effects on quality of surface and groundwater; contamination of water supply; water shortage relief	Increased risk of death, injuries, and infectious/respiratory/skin disease
Drought (season/year)	Land degradation, lower yields/ crop damage and failure; livestock deaths; increased risk of wildfire	More widespread water stress	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of food/water shortage
Tropical cyclones (frequency, intensity, track, peak wind, peak precipitation	Damage to crops; uprooting of trees; damage to coral reefs	Power outages causing disruption of public water supply	Increased risk of deaths, injuries, water and food-borne diseases; post-traumatic stress disorders
Sea-level rise	Stalinization of irrigation water, estuaries and freshwater systems	Decreased freshwater availability due to saltwater intrusion	Increased risk of deaths and injuries by drowning infloods; migration related health effects

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Appendix I: Glossary

Accommodate: Designing development and property uses such that their function is not eliminated as sea level rises.

Adaptive capacity: The ability of the built, natural, and human systems within a given planning area to accommodate changes in climate with minimal disruption or cost.

Climate: Long-term average weather conditions over seasonal to millennial time periods

Climate condition: Global climate conditions that had been identified in the IPCC Fourth Assessment report fall into four major categories: temperature-related, precipitation-related, tropical/severe weather-related, and sea-level rise-related. Climate conditions include such things as warm and cold spells, heavy precipitation, drought, tropical cyclones, high and low temperature days, cool and warm seasons, and sea-level rise, among others. (See Appendix I, Climate Assessment Packet, for the IPCC detailed definitions of the climate conditions)

Climate impact: Climate conditions and non-climate factors may combine to cause a climate impact to a system, such as flooding, reduced water availability, inundation, reduced agriculture production, increased wildfire, or salt infiltration.

Conservation measure: Non-regulatory tool that can include easements, land acquisition, habitat restoration and similar measures.

Consequence: The result or effect that occurs when systems are affected by climate impacts.

Drought: A deficit in normal precipitation for a region over a period of time sufficient to cause impacts.

Likelihood: IPCC reports characterize the confidence in the validity of findings in relative terms (such as "low," "medium," and "high"), based on the assessment of underlying scientific evidence and agreement. The reports use common terms to quantify the probability of various outcomes, because without precise definitions, these terms could mean different things to different people. So when we say:

- Virtually certain we mean 99–100% probability
- Very likely we mean 90–100% probability
- Likely we mean 66–100% probability
- About as likely as not we mean 33 to 66% probability
- Unlikely we mean 0–33% probability
- Very unlikely we mean 0–10% probability
- Exceptionally unlikely we mean 0–1% probability

Non-climate factors: Circumstances such as population, topography, land use, soil type, governing policies, or the economy, that could interact with climate conditions to intensify an impact.

Planned adaptation: Taking a proactive and deliberate approach to promoting resiliency of communities, economies and ecosystems, by identifying hazards and vulnerabilities and designing and implementing measures to adjust to, or relocate from, rising seas.

Relative sea-level rise: An increase in the average surface height of the oceans over a long period of time that may be caused by an absolute increase in the water level, by sinking of the land at the water's edge, or by a combination of the two.

Resilience: The ability of communities, economies and ecosystems to withstand, recover from, or adjust to disruptive influences without collapse. Ability to prepare and plan for, absorb, recover from and more successfully adapt to adverse events.

Sea-level rise: A long-term increase in the average surface height of the oceans.

Sector: Eleven major categories were designated by NOAA for the National Climate Assessment. Each of these sectors was sub-divided; a total of 34 sub-sectors aligned with the state agencies involved in the process (See details in Chapter 1: Introduction.)

Sensitivity: The degree to which a built, natural, or human system is directly or indirectly affected by changes in climate conditions (e.g., temperature and precipitation) or specific climate change impacts (e.g., sea level rise, increased water temperature).

Shoreline erosion: The chronic or episodic landward migration of a shoreline caused by the loss or displacement of sediment.

Shoreline recession: The long-term landward migration of the average position of a shoreline.

Subsidence: The sinking or decrease in land elevation over time.

Systems: The built, natural, and human networks that provide important services or activities within a community or region.

Vulnerability: A function of a system's sensitivity to changes in climate and its ability to adapt to those changes.

Weather: Short- term atmospheric conditions during daily to weekly time periods