Resilient Fairfax

Climate Vulnerability and Risk Assessment (VRA)

2022

A Fairfax County, Virginia publication

Acknowledgments

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Project Management Team: Fairfax County Office of Environmental and Energy Coordination (OEEC)

Consultants: WSP USA Inc. and the Cadmus Group

Resilient Fairfax Planning Team: composed of technical leads and subject matter experts from 20 relevant county departments and agencies. The Planning Team is responsible for providing interdepartmental information and coordination, reviewing, and providing technical feedback on deliverables, developing recommendations, and assisting OEEC in coordinating between Resilient Fairfax and related initiatives of other county departments.

Department of Emergency Management and Security (DEMS)

Office of Environmental and Energy Coordination (OEEC)

Facilities Management Department (FMD)

Department of Family Services (DFS)

GIS and Mapping Services (GIS)

Health and Human Services (HHS)

Health Department (HD)

Department of Housing and Community Development (DHCD)

Land Development Services (LDS)

Neighborhood and Community Services (NCS)

Northern Virginia Soil & Water Conservation District (NVSWCD)

One Fairfax

Fairfax County Park Authority (FCPA)

Department of Planning & Development (DPD), Planning Division (PD)

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Fairfax County Public Schools (FCPS)

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Department of Transportation (FCDOT)

DPWES Urban Forest Management Division (UFMD)

Department of Vehicle Services (DVS)

Resilient Fairfax Infrastructure Advisory Group: composed of representatives from utilities and authorities, building industry groups, transportation commissions and authorities, and infrastructure partners at the local, regional, state, and federal levels. The IAG is responsible for reviewing and providing feedback on key deliverables.

American Society of Highway Engineers (ASHE)

Columbia Gas of Virginia

Cox of Northern Virginia

Dominion Energy

Engineers & Surveyors Institute

Fairfax County Department of Emergency Management and

Security (DEMS)Fairfax County Public Schools (FCPS)

Fairfax County Department of Public Works and Environmental Services (DPWES)

Fairfax County Department of Transportation (FCDOT)

Fairfax Water

Federal Emergency Management Agency (FEMA)

Metropolitan Washington Council of Governments (MWCOG)

National Association of Industrial & Office Properties (NAIOP)

Northern Virginia Building Industry Association (NVBIA)

Northern Virginia Electric Cooperative (NOVEC)

Northern Virginia Regional Commission (NVRC)

Northern Virginia Transportation Authority (NVTA)

United States Department of Defense (DOD)– Fort Belvoir Public Works

Verizon

Virginia Department of Conservation & Recreation (VDCR)

Virginia Department of Emergency Management (VDEM)

Virginia Department of Environmental Quality (VDEQ)

Virginia Department of Transportation (VDOT)

Washington Gas

Washington Metropolitan Area Transit Authority (WMATA)

WTS International

Resilient Fairfax Community Advisory Group: composed of representatives from each of the nine magisterial districts, environmental, religious, non-profit, and civil rights organizations, businesses, residential communities, and the county's boards, authorities, and commissions. The CAG is responsible for reviewing and providing feedback on key deliverables.

350 Fairfax

Board Appointed Residents from the following Districts: Braddock, Dranesville, Hunter Mill, Lee, Mason, Mount Vernon, Providence, Springfield, and Sully.

Cornerstones

EcoLatinos

Environmental Quality Advisory Council (EQAC)

Faith Alliance for Climate Solutions (FACS)

Federation of Citizens Associations

George Mason University (GMU)

League of Women Voters

Multicultural Advisory Council

National Association for the Advancement of Colored People (NAACP)

Northern Virginia Chamber of Commerce

Northern Virginia Soil & Water Conservation District (NVSWCD)

Resilient Virginia

Reston Association

Sierra Club, Great Falls Group

Small Business Commission

Tysons Partnership

Resilient Fairfax would also like to acknowledge the **National Aeronautics and Space Administration (NASA) DEVELOP** program for providing Urban Heat Island data and analyses for Fairfax County that are presented in this assessment.

Table of Contents

List of Tables

List of Figures

List of Acronyms

CBPO	Chesapeake Bay Preservation Ordinance
CEC	California Energy Commission
CFI	Covanta Fairfax Inc.
COG	Metropolitan Washington Council of Governments
CO-OP	Public Health Continuity of Operations
COPD	Chronic Obstructive Pulmonary Disease
Cox	Cox Communications
DAS	Distributed Antenna System
DEMS	Fairfax County Department of Emergency Management and Security
DFS	Fairfax County Department of Family Services
DHCD	Fairfax County Department of Housing and Community Development
DOD	United States Department of Defense
DPSC	Fairfax County Department of Public Safety Communications
DPD	Fairfax County Department of Planning & Development
DPWES	Fairfax County Department of Public Works and Environmental Services
DVS	Fairfax County Department of Vehicle Services
EAP	Emergency Action Plan
EPA	United States Environmental Protection Agency
EQC	Environmental Quality Corridor
ERRF	Energy Resource Recovery Facility
ESA	Environmentally Sensitive Area
FCDOT	Fairfax County Department of Transportation
FCFRD	Fairfax County Fire and Rescue Department
FCHD	Fairfax County Health Department
FCPA	Fairfax County Park Authority
FCPS	Fairfax County Public Schools
FEMA	United States Federal Emergency Management Agency
FMD	Fairfax County Facilities Management Department
GIS	Geographic Information Systems
H_2S	Hydrogen Sulfide
HHS	Fairfax County Health and Human Services
HOAs	Homeowners Associations
ICPRB	Interstate Commission on the Potomac River Basin
LDS	Fairfax County Land Development Services
LEED	Leadership in Energy and Environmental Design
LID	Low Impact Development
LiDAR	Light Detection and Ranging
MGD	Million Gallons per Day
MS4	Municipal Separate Storm Sewer System
MWCOG	Metropolitan Washington Council of Governments

NCR	National Capital Region
NCS	Fairfax County Neighborhood and Community Services
NESC	National Electric Safety Code
NFIP	National Flood Insurance Program
NOVEC	Northern Virginia Electric Cooperative
NVRC	Northern Virginia Regional Commission
NVSWCD	Northern Virginia Soil and Water Conservation District
NVTA	Northern Virginia Transportation Authority
OEEC	Fairfax County Office of Environmental and Energy Coordination
OES	Operational Energy Strategy
OPEH	Fairfax County Office to Prevent and End Homelessness
PPE	Personal Protective Equipment
psi	Pounds per Square Inch
PTSD	Post-Traumatic Stress Disorder
PV	Photovoltaic
RPA	Resource Protection Area
RTDS	Real Time Digital Simulators
SOPs	Standard Operating Procedures
TMDL	Total Maximum Daily Load
UFMD	Urban Forest Management Division of the Fairfax County DPWES
UHI	Urban Heat Island
USACE	United States Army Corps of Engineers
VCAP	Virginia Conservation Assistance Program
VDCR	Virginia Department of Conservation and Recreation
VDEM	Virginia Department of Emergency Management
VDEQ	Virginia Department of Environmental Quality
VDOT	Virginia Department of Transportation
VMRC	Virginia Marine Resources Commission
VRE	Virginia Railway Express
WMA	Washington, DC, Metropolitan Area
WMATA	Washington Metropolitan Area Transit Authority
WSCA	Water Supply Coordination Agreement

EXECUTIVE SUMMARY

Vulnerability and Risk Assessment Background

The climate is changing. Fairfax County, Virginia (the county), has already experienced rising temperatures, more frequent heat waves, stronger storms, heavier rainfall events, and rising sea levels. These hazards impact people, infrastructure, and services. In the coming decades, many of these climate hazards are projected to increase in frequency and intensity.

Fairfax County is committed to proactively working to address climate change and prepare for future impacts. In June 2020, the Board of Supervisors Environmental Committee resolved to develop a climate adaptation and resilience plan as part of the larger Resilient Fairfax program. The climate adaptation and resilience plan will identify how to better prepare and reduce risk to climate change impacts for county residents, businesses, and infrastructure.

This report, the Resilient Fairfax Vulnerability and Risk Assessment (VRA), was developed in parallel with other Resilient Fairfax analyses: the Climate Projections Report and the Audit of Existing Policies, Plans, and Programs. Taken together, these analyses help to identify and prioritize potential strategy areas to enhance Fairfax County's resilience to climate change effects.

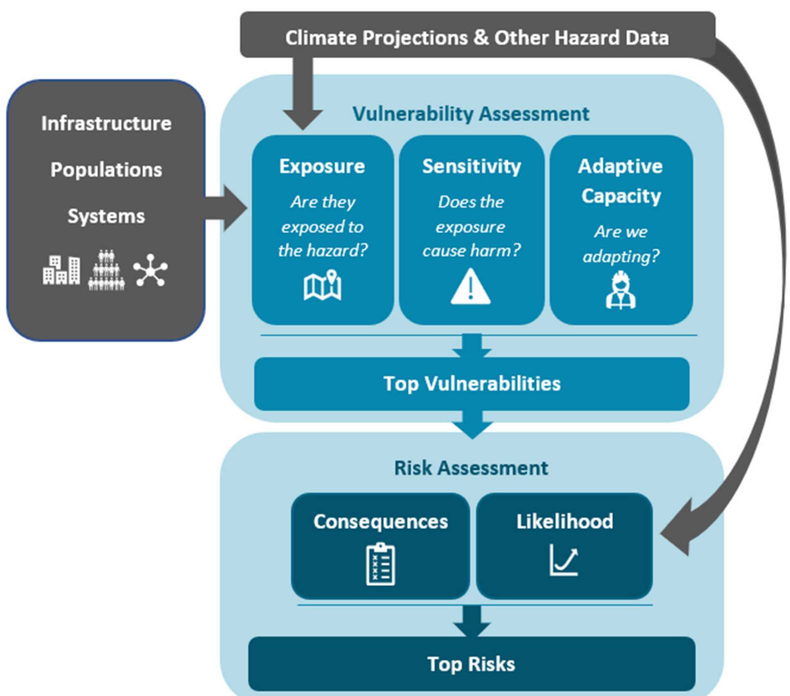
This VRA is a key step in the development of the Resilient Fairfax Climate Adaptation and Resilience Plan. The purpose of the VRA is to identify the vulnerabilities and risks associated with climate change. The VRA answers the question, "where are we vulnerable to climate hazards?"

The **Vulnerability Assessment** identifies which Fairfax County assets, systems, and populations are *most exposed, most sensitive, and least adaptive* to the projected climate hazards by mid-century. This assessment was used to help identify the county's top vulnerabilities.

Exposure measures whether an asset, system, or population may be exposed to a climate hazard.

Sensitivity measures how sensitive an asset, system, or population is to the climate hazard.

Adaptive Capacity measures capacity to enhance resilience to these hazards.



Each subsector was scored for exposure, sensitivity, and adaptative capacity. The scores were multiplied for a total vulnerability score.

Vulnerability = Exposure x Sensitivity x Adaptive Capacity

A score below 4 indicated very low or low vulnerability. A score of 5-9 indicated moderate vulnerability. A score of 12 indicated moderately high vulnerability. A score of 18 indicated high vulnerability. A score of 27 indicated very high vulnerability. Through this scoring system, the Vulnerability Assessment qualitatively identified the subsectors that may have the highest vulnerabilities to climate hazards.

The qualitative **Risk Assessment** further evaluated the top vulnerabilities to identify those that are the *most severe in consequence* and *most likely*. Vulnerabilities with a low likelihood of occurrence and low consequences were estimated to have a low risk. Vulnerabilities with higher likelihood of occurrence and higher consequences were estimated to have a higher risk rating.

Risk = Likelihood x Severity of Consequence

Sectors Analyzed

This VRA analyzed seven sectors and 21 subsectors for their vulnerability to six climate hazards:

Populations: General Population and Socioeconomically Vulnerable Populations

Public Services: Health and Community Services, Emergency Response and Management Services, Parks and Recreational Services, Waste Management Services

Buildings: Residential, Commercial, Industrial, Mixed-Use, Public Buildings, Parking Garage, and Other buildings

Water Infrastructure: Drinking Water, Stormwater, and Wastewater Infrastructure

Energy and Telecommunications Infrastructure: Electricity, Natural Gas, and Telecommunications Infrastructure

Transportation Infrastructure: Roadways and Bridges, Rail and Public Transit, and Bicycle and Pedestrian Infrastructure

Natural and Cultural Resources: Water Bodies, Wetlands and Environmentally Sensitive Areas, Trees and Forests, Agricultural and Farm Areas, and Cultural and Historic Resources

Climate Hazards

Based on best available science, the sectors and subsectors were evaluated for their vulnerability to the following six climate hazards of concern:

Extreme Heat: Extreme heat refers to temperatures above 90°F degrees with high humidity for at least two to three days. Very hot days (at or above 90°F) and extreme heat days (at or above 95°F and 100°F) are both projected to rise significantly.

Heavy Precipitation and Inland Flooding: Heavy precipitation can cause inland flooding in two major ways. First, urban flooding can occur when stormwater infrastructure is overwhelmed and/or there is excess impervious surface coverage. Second, riverine flooding can occur when streams and rivers overflow onto floodplains. Heavy precipitation events are projected to become more intense, amplifying flooding.

Severe Storm and Wind Events: Severe storms, including wind events, refers to events such as tropical storms, derechos, severe thunderstorms, and other storms. Tropical cyclones in the Atlantic basin are projected to become more intense with stronger winds and heavier precipitation. Storm events, in general, are projected to intensify.

Extreme Cold: Extreme cold in Fairfax County refers to temperatures below freezing. Days below freezing, freeze-thaw days, and snow days are all projected to decrease as the climate warms. This also extreme cold events such as snowfall and icing.

Coastal Flooding: Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. By 2050, coastal inundation due to sea level rise is projected along some of the southeastern county shoreline.

Drought: Drought refers to a long period of abnormally low rainfall that leads to a shortage of water. Over the coming decades, significant changes in drought conditions for the county were not detected based on meteorological drought analysis and review of the literature.

Key Findings and Outcomes

Severe storms and wind, heavy precipitation and inland flooding, and extreme heat were found to cause the highest vulnerabilities for Fairfax County. Populations, natural and cultural resources, and public services were found to be the most vulnerable sectors. A summary of vulnerability scores can be found in the list and *Table 1* below. These summaries are detailed in the Vulnerability Assessment.

Climate Hazards, Ranked by Total Vulnerability Scores

1. Severe Storms and Wind (291)
2. Heavy Precipitation and Inland Flooding (271)
3. Extreme Heat (243)
4. Coastal Flooding (145)
5. Extreme Cold (98)
6. Drought (94)

Sectors, Ranked by Average Total Vulnerability *(Total score divided by number of subsectors)*

1. Populations (76.5)
2. Natural and Cultural Resources (58.6)
3. Public Services (55.5)
4. Buildings (55)
5. Transportation (52.7)
6. Energy and Communications Infrastructure (46.7)
7. Water Infrastructure (40.3)

Subsectors, Ranked by Total Vulnerability

1. Vulnerable Populations (97)
2. Emergency Services (76)
3. Tree Canopy (73)
4. Electricity Infrastructure (72)
5. Agricultural Areas and Farms (70)
6. Roadways (60)
7. General Population (56)
8. Buildings (55)
9. Health and Community Services (54)
10. Parks and Recreation (54)
11. Drinking Water Infrastructure (53)
12. Public Transportation (52)
13. Water Bodies (51)
14. Wetlands and Environmentally Sensitive Areas (50)
15. Cultural and Historic Resources (49)
16. Bicycle and Pedestrian Infrastructure (46)
17. Communications Infrastructure (38)
18. Waste Management (38)
19. Wastewater Infrastructure (36)
20. Stormwater Infrastructure (32)
21. Natural Gas Infrastructure (30)

Top Climate Vulnerability Categories

1. Combined hazard stress on natural systems (275)
2. Heavy Precipitation causing inland flooding of communities (271)
3. Storms and wind causing debris, damage, and unsafe conditions (209)
4. Storms and wind causing power outage impacts (161)
5. Extreme heat causing health-related impacts (129)
6. Coastal flooding impacts (72)
7. Extreme heat causing damage to built systems (42)

Subsector Vulnerabilities That Scored "Very High"

- Extreme Heat | Vulnerable Populations (27)
- Heavy Precipitation/Inland Flooding | Vulnerable Populations (27)
- Severe Storms and Wind | Emergency Services (27)

Subsector Vulnerabilities That Scored "High"

- Drought | Trees and Forests (18)
- Extreme Heat | Agricultural (18)
- Extreme Heat | Electricity Infrastructure (18)
- Extreme Heat | Emergency Response (18)
- Extreme Heat | Public Transportation (18)
- Heavy Precipitation/Inland Flooding | Buildings (18)
- Heavy Precipitation/Inland Flooding | Cultural and Historic (18)
- Heavy Precipitation/Inland Flooding | General Population (18)
- Heavy Precipitation/Inland Flooding | Roadways (18)
- Severe Storms and Wind | Agricultural (18)
- Severe Storms and Wind | Buildings (18)
- Severe Storms and Wind | Drinking Water Infrastructure (18)
- Severe Storms and Wind | Electricity Infrastructure (18)
- Severe Storms and Wind | Health and Community Services (18)
- Severe Storms and Wind | Roadways (18)
- Severe Storms and Wind | Trees and Forests (18)
- Severe Storms and Wind | Vulnerable Populations

Subsector Vulnerabilities That Scored "Moderately High"

- Coastal Flooding | Cultural and Historic (12)
- Coastal Flooding | Water Bodies (12)
- Coastal Flooding | Wetlands and Environmentally Sensitive Areas (12)
- Drought | Agricultural (12)
- Extreme Cold | Vulnerable Population (12)
- Extreme Heat | Bicycle and Pedestrian (12)
- Extreme Heat | General Population (12)
- Extreme Heat | Health and Community Services (12)
- Extreme Heat | Parks and Recreation (12)
- Extreme Heat | Roadways (12)
- Extreme Heat | Trees and Forests (12)
- Extreme Heat | Waste Management (12)
- Extreme Heat | Wetlands and Environmentally Sensitive Areas (12)
- Heavy Precipitation/Inland Flooding | Agricultural (12)
- Heavy Precipitation/Inland Flooding | Emergency Services (12)

- Heavy Precipitation/Inland Flooding | Health and Community Services (12)
- Heavy Precipitation/Inland Flooding | Parks and Recreation (12)
- Heavy Precipitation/Inland Flooding | Public Transportation (12)
- Heavy Precipitation/Inland Flooding | Stormwater Infrastructure (12)
- Heavy Precipitation/Inland Flooding | Trees and Forests (12)
- Heavy Precipitation/Inland Flooding | Wastewater Infrastructure (12)
- Heavy Precipitation/Inland Flooding | Water Bodies (12)
- Severe Storms and Wind | Bicycle and Pedestrian (12)
- Severe Storms and Wind | Communications Infrastructure (12)
- Severe Storms and Wind | Cultural and Historic (12)
- Severe Storms and Wind | General Population (12)
- Severe Storms and Wind | Parks and Recreation (12)
- Severe Storms and Wind | Public Transportation (12)
- Severe Storms and Wind | Wetlands and Environmentally Sensitive Areas (12)

Table 1: Climate Vulnerability Results by Sector, Subsector, and Climate Hazard

Sector	Subsector	Extreme Heat	Heavy Precipitation and Inland Flooding	Severe Storms and Wind	Extreme Cold	Coastal Flooding	Drought
Water infrastructure	Drinking Water	8	8	18	9	4	6
	Stormwater	4	12	8	2	4	2
	Wastewater	8	12	4	4	6	2
Energy and Communication	Electricity	18	18	18	6	8	4
	Natural Gas	2	8	8	6	4	2
	Communication	8	8	12	4	4	2
Transportation	Roadways	12	18	18	4	6	2
	Public Transit	18	12	12	4	4	2
	Bicycle and Pedestrian	12	8	12	4	8	2
Buildings	Buildings	6	18	18	2	9	2
Populations	General Population	12	18	12	4	8	2
	Vulnerable Populations	27	27	18	12	9	4
Natural and Cultural Resources	Water Bodies	8	12	8	2	12	9
	Wetlands and Environmentally Sensitive Areas	12	6	12	2	12	6
	Trees and Forested Areas	12	12	18	9	4	18
	Agricultural and Farms	18	12	18	6	4	12
	Cultural and Historical Resources	4	18	12	2	12	1

Sector	Subsector	Extreme Heat	Heavy Precipitation and Inland Flooding	Severe Storms and Wind	Extreme Cold	Coastal Flooding	Drought
Public Services	Health and Community Services	12	12	18	4	6	2
	Emergency Response and Management Services	18	12	27	4	9	6
	Parks and Recreational Facilities	12	12	12	4	8	6
	Waste Management	12	8	8	4	4	2

The findings of the Vulnerability and Risk Assessment (along with the Climate Projections Report, the Audit of Existing Policies, Plans, and Programs, and intensive stakeholder engagement) helped to inform the development of the county's climate adaptation and resilience strategies. These analyses serve as a foundation for the Resilience Fairfax climate resiliency and adaptation initiative by the Fairfax County Office of Environmental and Energy Coordination (OEEC). It is anticipated that these data will need to be periodically updated.

INTRODUCTION & PURPOSE

Purpose

Climate change already has a significant impact on Fairfax County. Over the past several years, the county has seen rising average annual temperatures and more frequent heat waves, precipitation events, and extreme storms. Climate hazards impact the county's residents, infrastructure, and services. As climate hazards are projected to increase in frequency and intensity in the coming decades, it is important that Fairfax County understands and addresses its top vulnerabilities. The purpose of this Vulnerability and Risk Assessment was to identify 1) which Fairfax County assets, systems, and populations are *most exposed, most sensitive, and least adaptive* to the projected climate hazards, and 2) which of these top vulnerabilities is *most severe in consequence* and *most likely*.

How the VRA Fits into Resilient Fairfax

"Resilient Fairfax" is a climate resiliency and adaptation initiative led by the Fairfax County Office of Environmental and Energy Coordination (OEEC). Resilient Fairfax is envisioned to be a long-term program of iterative climate planning and implementation that will allow the county to better anticipate, prepare for, respond to, and cope with the changing climate. The following diagram shows how this report relates to the other Resilient Fairfax deliverables. This report is shown in green.

Resilient Fairfax Climate Adaptation and Resilience Plan

Climate Projections Report: *How has the climate changed? What will the future climate look like?*

- Will there be change in temperature?
- Will there be change in storm severity?
- Will there be change in precipitation and intensity of rain events?
- Will there be coastal flooding?
- Will there be drought?

Climate Vulnerability and Risk Assessment: *Where are we vulnerable? What are the top risks?*

- Which of our infrastructure, populations, and systems are *exposed* to climate hazards?
- Which are *sensitive* to these climate hazards?
- Which lack the *adaptive capacity* to handle changing conditions?
- What are our top vulnerabilities?
- Which are most likely? Which have the most severe consequences?

Audit of Existing Plans, Policies, and Programs: *Do our policies, plans, and programs include resilience?*

- How do our policies, plans, and programs compare to best practices?
- Which programs are working well and should be potentially expanded?
- Where are the gaps or opportunities to update policies and programs?

Strategies for Climate Adaptation & Resilience: *What should we do to enhance the county's resilience?*

- What strategies would help the county address our climate vulnerabilities and risks?
- Which of these strategies are top priority?

Implementation Roadmap: *What is the plan to implement the priority strategies?*

- What actions would be taken to implement the strategies?
- Who would be responsible for implementation?
- What is the timeframe for implementation?

Methodology Summary

This report contains two distinct assessments: a Vulnerability Assessment and a Risk Assessment. The scoring approach used in the Vulnerability Assessment was adapted from methodology developed by the Association of Climate Change Officers (ACCO) to identify levels of exposure, sensitivity, and adaptive capacity. The Risk Assessment then provides a qualitative analysis of the top vulnerabilities identified in the Vulnerability Assessment to identify likelihood and severity. Appendix 1 describes the detailed methodology for the Vulnerability and Risk Assessment.

The Vulnerability Assessment evaluates the following sectors for vulnerabilities to climate hazards:

- **Population Section**
- **Public Services**
- **Buildings**
- **Water Infrastructure**
- **Energy and Telecommunication Infrastructure**
- **Transportation**
- **Natural and Cultural Resources**

Assets under these seven sectors were evaluated under current and future (mid-century) climate conditions for the following hazards:

- **Extreme Heat**
- **Heavy Precipitation and Inland Flooding**
- **Severe Storms**
- **Extreme Cold**
- **Coastal Flooding**
- **Drought**

The Vulnerability Assessment qualitatively identified which sectors and subsectors were most exposed, sensitive to, and unable to adapt to climate hazards in Fairfax County. Exposure levels were based on geographic information systems (GIS) data for future hazard projections that are geographically mappable within the county, such as inland flooding, coastal flooding, and the Urban Heat Island effect. Exposure levels for hazards that apply countywide, such as severe storms, extreme cold, and drought, assumed full county exposure, unless assets were protected. For example, infrastructure located underground may be less exposed than infrastructure located above ground. Sensitivity and adaptive capacity were based on extensive stakeholder input and research. The results of the Vulnerability Assessment highlight qualitative vulnerabilities that may need additional county attention or analysis.

Vulnerability = Exposure x Sensitivity x Adaptive Capacity

The Risk Assessment provided additional analysis for the top vulnerabilities identified in the Vulnerability and Assessment. The Risk Assessment qualitatively identified the vulnerabilities that were most likely to occur and most severe in consequence. Likelihood was based on past and future projected event occurrence per year. Consequence was based on qualitative considerations of economic impact and service loss, costs to repair, public health and safety, and environmental impacts.

Risk = Likelihood of Occurrence x Consequence

For detailed methodology, please see Appendix 1.

How This Document is Organized

This VRA is organized into the following sections:

Front Matter: This section includes the Acknowledgements, Table of Contents, Executive Summary, and Introduction and Purpose.

Vulnerability Assessment: The Vulnerability Assessment evaluates the exposure, sensitivity, and adaptive capacity of seven key sectors and 21 subsectors to climate hazards. Each subsector is introduced and described in the context of Fairfax County. Then, descriptions of each subsector's exposure, sensitivity, and adaptive capacity to each climate hazard are included. Summary tables with total vulnerability scores are included for each section. Each sector is color-coded for easier navigation.

Risk Assessment: The Risk Assessment evaluates risk in the categories identified as highly vulnerable according to the Vulnerability Assessment. Risk was determined based on likelihood of occurrence and severity of consequence. Each section begins with a summary of the sectors being assessed, followed by descriptions of risk scores. Each section includes a summary table of risk scores.

Appendix 1: Provides detailed methodology for the Vulnerability Assessment and Risk Assessment.

Appendix 2: Provides maps that may assist with visualization of exposure scores.

Appendix 3: Provides full exposure data tables that were used for Vulnerability Assessment scores.

VULNERABILITY ASSESSMENT

1. POPULATIONS

As the county prepares for climate change effects, addressing potential vulnerabilities of the population is top priority. As of April 1, 2020, the population of Fairfax County was estimated to be over 1.15 million people, a 6% increase from April 1, 2010.[1] *Figure 1* shows areas within Fairfax County with denser populations. The population is projected to increase to over 1.38 million people by the year 2050. The majority of the population is between 20 and 65 years of age; nearly one quarter of the population is under the age of 18, and 13.5% is 65 or older.[2]

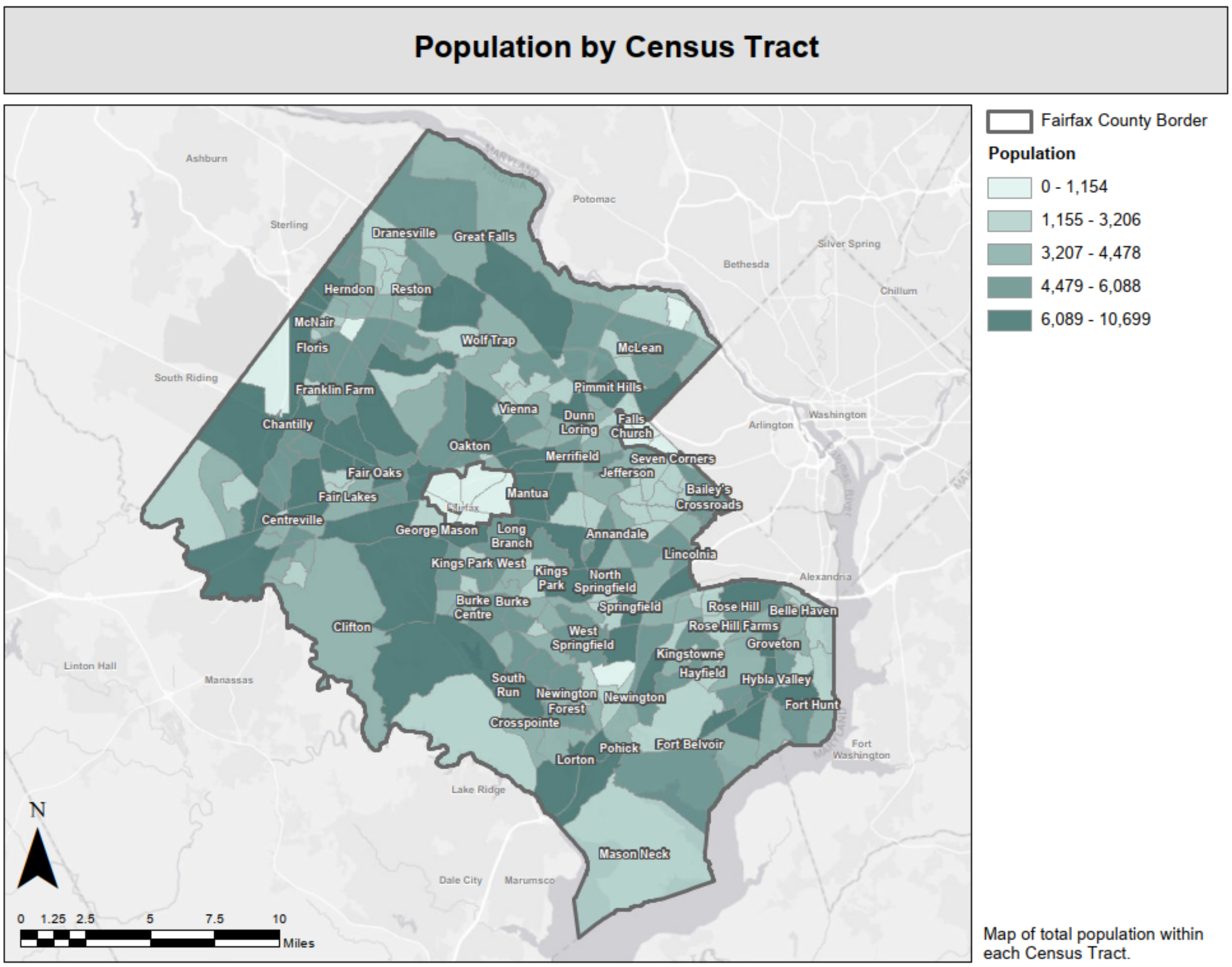


Figure 1: Population of Fairfax County by Census Tract

The population is diverse, with a range of racial and ethnic backgrounds including White (49.5%), Asian (20.4%), Two or More Races (11.3%), Black or African American (9.6%), American Indian and Alaskan Native (0.57%), Native Hawaiian and Other Pacific Islander (0.08%) and Other (8.6%). It should be noted that Fairfax County is home to many residents of Middle Eastern descent, which the United States Census classifies as “White.” Fairfax County is also home to nearly 200,000 Hispanic and Latino residents (17% of the population), which spans multiple racial groups defined by the United States Census. Asian Indians and Koreans make up a large percentage of the county’s Asian American population. Salvadorans make up a large percentage of the Latino population.[3] Within these groups, much of the population speaks English “very well” or “well,” although there is a notable portion of residents that are not comfortable speaking English. Almost 40% of residents at or over the age of five speak a language other than English at home. Fairfax County is one of the wealthiest counties in the United States, with a median household income of $127,866, which is nearly double the national average.[4]

Vulnerable Populations: One of the most important components of a climate vulnerability and risk assessment is the analysis of populations who may be highly exposed or sensitive to specific climate hazards, or who may lack the capacity to adapt to changing conditions. Exposure to the impacts of climate change can exacerbate existing vulnerabilities and disproportionately impact vulnerable populations within Fairfax County. In addition, when vulnerable populations are impacted by an event, they become more vulnerable to future events. Identification of impacts on the people of the county helps the county plan for potential strategies to assist these communities.

Inclusion of Equity in Decision-Making

The One Fairfax Policy establishes the consideration of equity in county decision making and planning. Resilient Fairfax actively seeks to promote racial equity and social justice by evaluating disproportionate climate burdens and planning for equitable implementation of resiliency strategies.

Some populations may be more vulnerable due to systemic inequities and historic underinvestment in their neighborhoods and the infrastructure they use. For example, those who live in a neighborhood with degrading infrastructure and frequent power outages may be more vulnerable to flooding and storms than those who live in a neighborhood that was provided with new, refurbished infrastructure. Due to systemic historic inequities, communities of color face long-standing inequality in income, health, and opportunity.[5] Other disadvantaged groups from a climate hazard perspective include low-income households, individuals with disabilities, individuals experiencing homelessness, those without access to healthcare, elderly residents, outdoor workers, and individuals with compromised health and preexisting conditions, among others.[6] Approximately 7.2% percent of the Fairfax County population, are identified as disabled due to access or functional needs.[7]

The One Fairfax Policy is a joint racial and social equity policy of the Fairfax County Board of Supervisors and School Board. It is a declaration that all residents deserve an equitable opportunity to succeed, regardless of their race, color, sex, nationality, sexual orientation, religion, disability, income, or where they live. To enable the county to consistently evaluate plans and programs for equity considerations, One Fairfax staff developed a Vulnerability Index that identifies Census Tracts in the county with high proportions of residents who may be more vulnerable due to both socioeconomic and individual characteristics.

The following tables and text provide an overview of estimated climate vulnerabilities for Fairfax County populations. To consider potential disproportionate burden on certain populations, the assessment includes analyses of both the general population and the populations identified in the One Fairfax Vulnerability Index. *Table 2* shows the climate vulnerability scores for the general population. *Table 3* shows the climate vulnerability scores for the populations identified by One Fairfax as especially vulnerable for socioeconomic or individual reasons. Each score is explained in detail in the following sections.

Table 2: Climate Vulnerabilities Summary – General Population

General Population – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total Vulnerability***
Extreme Heat	3	2	2	**12**
Inland Flooding	3	2	3	**18**
Severe Storms	2	3	2	**12**
Extreme Cold	1	2	2	**4**
Coastal Flooding	2	2	2	**8**
Drought	1	1	2	**2**
Total	-	-	-	**56**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

Table 3: Climate Vulnerabilities Summary – Vulnerable Populations

Vulnerable Populations – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total Vulnerability***
Extreme Heat	3	3	3	**27**
Inland Flooding	3	3	3	**27**
Severe Storms	3	3	2	**18**
Extreme Cold	2	3	2	**12**
Coastal Flooding	1	3	3	**9**
Drought	1	2	2	**4**
Total	-	-	-	**97**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information

1.a. Extreme Heat - Population Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Populations**	**Extreme Heat**	**General Population = 3** (High) **Vulnerable Population = 3** (High)

The Fairfax County population in general is highly exposed to extreme heat. Both the general population and the vulnerable populations received the maximum exposure score of three (3). Fairfax County residents are projected to experience an increase in intensity, frequency, and duration of heat events due to climate change. Future projections suggest that the county will experience a continued increase in extreme heat events.

While all county residents are highly exposed to increasing temperatures and extreme heat, certain populations live in areas with significantly hotter land surface temperatures than other areas because of the Urban Heat Island Effect (UHI). UHI refers to the phenomenon where roads, parking lots, dark-roofed buildings, and other infrastructure absorb and retain heat, creating “islands” where land surface recorded temperatures are significantly higher than other areas. In contrast, areas that have ample green space, trees, and lighter-colored roofs are significantly cooler in temperature. Urban heat islands can perpetuate environmental injustice and inequities. Approximately 74% of general households and 91% of vulnerable households are located in areas identified as having “significantly high” UHI.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Populations**	**Extreme Heat**	**General Population = 2** (Moderate) **Vulnerable Population = 3** (High)

Sensitivity summary: The general population is “moderately sensitive” to extreme heat effects, receiving a score of two (2). Moderate sensitivity means the hazard could cause harm to the population requiring emergency medical care. Vulnerable populations are “highly sensitive” to extreme heat, receiving the maximum score of three (3) for sensitivity to this hazard. High sensitivity means this hazard could cause mortalities for those populations. Heat can have both direct and indirect impacts on human health.

Populations most likely to be impacted by extreme heat include young children, older adults, outdoor workers, non-U.S. citizens, low-income families, pregnant women, and individuals with preexisting conditions including respiratory disease.[8, 9] In 2014, non-U.S. citizens in the United States aged 18 to 24 were 20 times more likely to die from heat exposure than were U.S. citizens, due to a number of factors such as healthcare access and exposure to extreme heat during employment.[10] Vulnerable groups such as those with lower income levels or those living in sub-standard housing[11,12] might not have access to air conditioning or cooling systems that could help to alleviate the effects of heat exposure. They may also be more likely to be employed in outdoor industries or spend significant amounts of time outdoors.

These groups include, but are not limited to, individuals waiting for transit, populations experiencing homelessness, individuals without affordable housing access,[13] undocumented immigrants,[14] construction workers, landscape workers, and factory workers. Undocumented immigrants may be at further risk due to lower access to health care. Community members who have lengthy commutes or who may need to use vehicles and roadways that are compromised by climate change may be even more vulnerable.[15] Heat exposure and inaccessibility of air conditioning or poor ventilation is especially a concern for those less able to effectively regulate body temperature, such as young children, pregnant women, and older adults. Specifically, older adults with co-morbid cardiovascular and respiratory issues may be particularly vulnerable, along with individuals with mild or severe incidences of asthma.[16]

Direct Sensitivities: As hot days become more typical in Fairfax County, populations will be at risk of heat-related illness such as heat stroke, dehydration, and cardiovascular, respiratory, and cerebrovascular disease.[17] Existing health conditions such as kidney disease, pulmonary disease, or cardiovascular disease can also be exacerbated in extreme heat. Heat-related illness can increase mortality among these groups. During extreme heat events, demand for air conditioning increases, leading to higher energy bills. This may be financially burdensome to lower income groups.

Indirect Sensitivities*:* During extreme heat events, all populations tend to spend more time indoors. More time spent in enclosed, poorly ventilated spaces can increase the spread of communicable diseases such as COVID-19.[18] Extreme heat can also interact with pollutants like car exhaust and power plant emissions to create ground-level ozone, resulting in an increase of unhealthy outdoor air quality days. Ground-level ozone decreases air quality and can have negative health effects including increased risk of disease and even death.[19] Warmer temperatures also prolong pollen season and facilitate mold growth, which reduces air quality, can prolong allergy seasons, and can worsen asthma conditions. Heat-related strain on homes and personal vehicles can cause additional maintenance costs. There may be economic impacts for outdoor and transit workers if heat reduces the ability to work. This would disproportionately impact the most vulnerable residents such as low-income communities and communities of color. Indirect effects of extreme heat, such as reduced outdoor activity, can also contribute to obesity and other sickness. Climate change impacts can also have a significant effect on stress and mental health[20] and may require additional wellness services be established. Excessive heat has also been linked to increased aggressive behavior, which may yield more incidences of crime.[21] Increased water temperatures, as seasonal temperatures begin to climb, can lead to harmful algae and coastal pathogens. When this is coupled with more frequent and intense rainfall events leading to runoff, recreational waters can be adversely affected.[22]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Extreme Heat**	**General Population = 2** (Moderate) **Vulnerable Population = 3** (Poor)

The general population in Fairfax County is estimated to have "moderate" adaptive capacity for extreme heat conditions. Vulnerable populations are estimated to have "poor" adaptive capacity for extreme heat conditions(Adaptive capacity is scored according to four criteria; please see Appendix for detailed methodology). Vulnerable populations may have worse adaptive capacity to extreme heat due to a number of factors such as less disposable income to run air conditioning, limited access to cooling resources or services (i.e. lack of transportation to cooling centers), or poor living conditions (e.g., poorly ventilated homes, neighborhoods with little tree canopy cover).

In terms of actions taken to increase adaptability, Fairfax County offers a number of programs to support residents' ability to cope with extreme heat, such as cooling centers, HVAC and weatherization upgrades for qualifying homes,[23] energy assistance programs,[24] and other forms of financial support. The county's Department of Emergency Management and Security (DEMS) also provides educational resources to the community on how to prepare for, respond to, and recover from extreme heat conditions.[25] The Fairfax County Health Department is developing a Climate Health Plan that will address extreme heat and other related topics such as vector-borne diseases, urban heat islands, and air quality. Most climate hazard-relevant county initiatives are specifically targeted to vulnerable populations, such as Fan Care, an electric fan distribution program for residents over 60 years of age,[26] and HomeWise,[27] a program that provides energy efficiency upgrades for low and moderate-income residents.

Additionally, because tree canopy coverage is one of the most effective heat mitigation strategies, the Fairfax County Tree Action Plan sets the strategic vision to grow and protect the urban tree canopy. The Urban Forest Management Division also advances urban forestry through its implementation of the Tree Conservation Ordinance, Public Facilities Manual, Zoning Ordinance Landscaping and Screening requirements, Chesapeake Bay Preservation Ordinance, Stormwater Management Ordinance, and other codes.[28] These actions to grow the urban tree canopy provide more cool, shaded areas and a slight cooling effect from evapotranspiration.[29]

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable are we to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Populations**	**Extreme Heat**	**General Population = 12** (Moderately High) **Vulnerable Population = 27** (Very High)

Total vulnerability considers exposure, sensitivity, and adaptive capacity. Based on available information available, the general population in Fairfax County is estimated to have a moderately high total vulnerability to extreme heat. The vulnerable populations are estimated to have very high total vulnerability to extreme heat.

1.b. Heavy Precipitation and Inland Flooding – Populations Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Populations**	**Inland Flooding**	**General Population = 3** (High) **Vulnerable Populations = 3** (High)

Both the general and vulnerable populations of Fairfax County have high exposure to inland flooding caused by heavy precipitation. (See Appendix 1 for methodology). There are two major types of inland flooding caused by heavy precipitation in Fairfax County. The first and most common is "urban flooding," when heavy precipitation overwhelms stormwater management systems. The county's flooding and drainage service requests indicate that urban flooding is a concern across many areas of the county; 97% of service requests are urban flooding requests (located *outside* of floodplains). In some Fairfax County older neighborhoods, storms are already overwhelming existing stormwater infrastructure and conveyance systems.[30] Based on a parcel-by-parcel analysis that evaluated properties for 10 flood-prone factors, an estimated 71% of general households and 65% of vulnerable households are located on parcels with two (2) or more flood-prone factors. Further, over 14% of general households and 10% of vulnerable households are located on parcels with four (4) or more flood-prone factors.

The second major type of inland flooding type is "riverine flooding," which occurs when heavy precipitation causes rivers and other water bodies to overflow into adjacent floodplains. Riverine or floodplain flooding is less common than urban flooding in Fairfax County. Approximately 5.5% of general households and 6.8% of vulnerable households are located on parcels that intersect a FEMA floodplain. In other words, over 90% of households are located away from floodplains.

Heavy precipitation events are projected to increase in intensity and frequency, producing greater exposure to inland flooding. Ensuring safety of the population both within and outside floodplains is a priority for the county as precipitation intensifies due to climate change.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Populations**	**Inland Flooding**	**General Population = 2** (Moderate) **Vulnerable Populations = 3** (High)

Sensitivity Summary: The general population is estimated to have moderate sensitivity to inland flooding. Vulnerable populations are estimated to have high sensitivity to inland flooding.

Direct Sensitivities: Heavy precipitation and flooding can lead to conditions that shut down normal operations within flooded neighborhoods until floodwaters recede and cleanup occurs. Heavy precipitation and flooding can result in reduced water quality from agricultural and sewage contamination.[31] Increased precipitation and flooding can have serious impacts on vulnerable communities[32] that might face additional obstacles and cost burdens in recovering from climate change events, including the cost of loss of production, repairs, emergency operations, and insurance claims. Heavy precipitation and flooding can lead to conditions that harm people to the extent that medical care and/or emergency rescues (i.e. swift water rescues) are required.

Indirect Sensitivities: Excessive moisture can also increase the survivability of water-borne vectors and pathogens that can increase sickness in at-risk populations.[33] Increased temperatures along with more frequent and intense extreme precipitation events can lead to conditions conducive to the movement of vector-borne diseases such as Lyme disease, West Nile, chikungunya, dengue, and Zika viruses, introducing these diseases into new geographic regions.[34] Increased moisture (in conjunction with extreme heat) creates ideal conditions for mold growth, which can worsen allergies and asthma for vulnerable individuals, including children. [35]

Adaptive Capacity: Are we able to adapt to this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Inland Flooding**	**General Population = 3** (Poor) **Vulnerable Populations = 3** (Poor)

Based on available information, Fairfax County populations are estimated to have poor capacity to adapt to inland flooding and heavy precipitation. Residents who live in older neighborhoods that were constructed prior to modern stormwater management policies and design standards may be living with insufficient or non-existent stormwater management infrastructure to handle flooding. Additionally, because flood retrofits are often complex, time consuming, and cost-prohibitive, lower income residents are likely less able to afford flood resilience upgrades and subsequently flood damage repair.

However, the county does have numerous maintenance activities to offset potential impacts from heavy precipitation and inland flooding. For example, the Department of Public Works and Environmental Services (DPWES) Stormwater Management identifies stormwater drainage system maintenance needs through its Infrastructure Inspection and Rehabilitation Program and response to customer service requests. Per the county's Municipal Separate Storm Sewer System (MS4) permit, the county must inspect 100% of the public storm drainage system, including pipes and manmade channels with MS4-designated outfalls, every five years and at least 15% annually. County-maintained stormwater management facilities are inspected annually or every other year depending on the facility type. Publicly maintained facilities are inspected by the county once every five years.

The county also has various efforts underway to reduce the risk of flooding. For instance, the Department of Emergency Management and Security (DEMS) provides resources to the community on how to prepare for, respond to, and recover from flooding. DPWES Stormwater Management has a flood mitigation plan that includes floodplain management, evaluation of flood-prone areas, and implementation of neighborhood stormwater improvement projects. DPWES, OEM, and Fire and Rescue, coordinate on the development and implementation of flood response plans and emergency action plans. Additionally, DPWES is currently leading a Flood Risk Reduction workgroup across multiple county departments to address the county's flooding issues more proactively. This effort is being conducted in coordination with Resilient Fairfax.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable are we to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Populations	Inland Flooding	**General Population = 18** (High) **Vulnerable Population = 27** (Very High)

Total vulnerability considers exposure, sensitivity, and adaptive capacity. Based on the information available, the general population in Fairfax County is estimated to have high total vulnerability to inland flooding and heavy precipitation. The vulnerable populations in Fairfax County are estimated to have very high total vulnerability to inland flooding and heavy precipitation.

1.c. Severe Storms – Population Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Populations	Severe Storms	**General Population = 2** (Moderate) **Vulnerable Population = 3** (High)

The Fairfax County general population is moderately exposed to severe storms and wind events, which are projected to increase in intensity and frequency with climate change. Vulnerable populations such as those experiencing homelessness, outdoor workers, those in sub-standard housing, and those who are reliant on walking or using public transit for transportation may face higher exposure to storms than others.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the impacts of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Populations	Severe Storms	**General Population = 3** (High) **Vulnerable Population = 3** (High)

The general Fairfax County and vulnerable populations are estimated to have high sensitivity to severe storms and wind events, which means that severe storms (such as tropical storms and derechos) could cause operational failure for more than 24 hours and/or mortalities in the population.

Direct Sensitivities: Severe storms can cause mortality and disrupt public health, healthcare, and services in ways that can affect population health.[36] Severe storms and wind can cause direct injuries from debris and property damage, and power and water outages.[37] Storms can impact sanitation and wastewater systems, which can increase water-borne illness including gastrointestinal disease, especially among young children with developing immune systems. [38]

Indirect Sensitivities: After effects of severe storms such as hurricanes or derechos can have lasting impact on mental health, including chronic stress and post-traumatic stress disorder (PTSD).[39] For populations with damaged neighborhoods and residences, recovery and rebuilding can take significant time, creating transient conditions. Low-income populations, communities of color living in areas of historic under-investment, and other disadvantaged groups may have a harder time and/or need more assistance with rebuilding and recovery.

Adaptive Capacity: Are we able to adapt to this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Severe Storms**	**General Population = 2** (Moderate) **Vulnerable Population = 2** (Moderate)

Both the general and vulnerable populations in Fairfax County are estimated to have a moderate capacity to adapt to severe storms and wind events. Fairfax County offers a number of resources and services to residents to enhance adaptive capacity. DEMS, for example, provides educational materials to the community on how to prepare for, respond to, and recover from thunderstorms, hurricane/tropical storms, winter weather, and tornados.[40] The Fairfax County Emergency Operations Plan states that the county may open a service and information center to assist residents after a disaster; that residents may receive loan or grant funding for damages from a disaster; and that an effort is made to meet unmet needs through nonprofit assistance.[41] Neighborhood and Community Services (NCS) and Fairfax County Park Authority (FCPA) also administer centers that may serve as safe places during emergency events. Ready Fairfax instructs residents on how to create an emergency plan, make an emergency kit, and sign up for emergency alerts.[42] However, these program are more focused on emergency response than on long-term climate resilience to changing conditions. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable are our populations to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Populations**	**Severe Storms**	**General Population** = **12** (Moderately High) **Vulnerable Population = 18** (High)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information available, the general population in Fairfax County is estimated to have a moderately high total vulnerability to severe storms and wind events. The vulnerable populations in Fairfax County are estimated to have a high total vulnerability to severe storms.

1.d. Extreme Cold - Population Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Populations**	**Extreme Cold**	**General Population = 1** (Low) **Vulnerable Population = 2** (Moderate)

Extreme cold is projected to decrease in frequency and intensity as temperatures warm. Therefore, overall exposure for this hazard is low and decreasing. However, for vulnerable populations, exposure is considered to be moderate, because, if and when extreme cold events do occur, the following populations may face higher exposure to these events: those experiencing homelessness, those living in sub-standard housing, those without the ability to afford heat, and those who rely on walking or public transit for transportation, among others. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Populations**	**Extreme Cold**	**General Population = 2** (Moderate) **Vulnerable Population = 3** (High)

Sensitivity Summary: The general population is estimated to have moderate sensitivity to extreme cold. Vulnerable populations are estimated to have high sensitivity to extreme cold.

Direct Sensitivities: Exposure to spells of cold indoor temperatures can lead to increased mortality, hospitalizations, and morbidity rates among residents. For populations unable to afford heat in their residences as well as those living in buildings with structural deficiencies such as lack of insulation and airtightness, extreme cold can lead to significant health concerns by inflaming lungs and inhibiting circulation, increasing asthma attacks, infections, and worsening chronic obstructive pulmonary disease (COPD).[43] Exposure to extreme cold can be highly dangerous for individuals with insecure housing or individuals without homes. If extreme cold is associated with ice, there can be associated risks of slipping or falling. Older adults or those with disabilities may be especially sensitive to this hazard.

Indirect Sensitivities: Long-term exposure to cold indoor temperatures (such as those experienced by those in sub-standard housing or without access to heat) can have long-term physical and mental health effects due to associated high stress.[44]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Extreme Cold**	**General Population = 2** (Moderate) **Vulnerable Population = 2** (Moderate)

Both the general and vulnerable populations in Fairfax County are estimated to have a moderate capacity to adapt to extreme cold. Fairfax County offers a number of programs to support vulnerable residents' ability to cope with extreme cold, such as heating centers, HVAC and weatherization upgrades for qualifying homes, energy assistance programs, and other forms of financial support. The county also provides educational resources to the community on how to prepare for, respond to, and recover from extreme cold. The Office to Prevent and End Homelessness (OPEH) provides dedicated hypothermia shelter space during winter months at several locations across the county. OPEH also partners with non-profits and places of worship to provide shelter for individuals at risk of hypothermia during the winter. Barriers that limit adaptation to extreme cold include lower income residents being less able to afford heating, home upgrades, or a back-up generator for heat during power outages. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable are our populations to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Populations**	**Extreme Cold**	**General Population = 4** (Low) **Vulnerable Population = 12** (Moderately High)

Total vulnerability considers exposure, sensitivity, and adaptive capacity. The general population is considered to have low total vulnerability to extreme cold because extreme cold is projected to continue to decrease, and there is low sensitivity and relatively good adaptive capacity for the general population. However, socioeconomically vulnerable populations are considered to have moderately high total vulnerability to extreme cold, because, if extreme cold events do occur, they may be more exposed and less able access safety from this hazard.

1.e. Coastal Flooding – Population Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Populations**	**Coastal Flooding**	**General Population = 2** (Moderate) **Vulnerable Population = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. The scores in this section apply only to the areas in the county where coastal flooding is a relevant hazard (defined as Census Tracts within one mile of the Potomac River shoreline). Most neighborhoods in the county are not projected to be affected by sea level rise and coastal flooding; approximately 0.9% of total general households and 0.07% of total vulnerable households would be exposed to projected coastal flooding. However, for the neighborhoods that are exposed to coastal flooding, the projected impacts could be significant. Of those Census Tracts located within one mile of the Potomac River shoreline, 7.3% of general households and 0.40% of vulnerable households are projected to be exposed to coastal storm surge flooding. Neighborhoods including Belle Haven and New Alexandria have high exposure to coastal flooding. The Woodlawn Area, Yacht Haven Area, and Gunston Cove area have neighborhoods with a few isolated locations that are also susceptible to changing shoreline. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Populations**	**Coastal Flooding**	**General Population = 2** (Moderate) **Vulnerable Population = 3** (High)

Sensitivity Summary: The general population is moderately sensitive to coastal flooding in specific areas within the county. Socioeconomically vulnerable populations in coastal areas are estimated to have high sensitivity to coastal flooding.

Direct Sensitivities: Coastal floods can damage residences, deplete financial savings, and affect physical and mental health. Further, the rising coastline may increase the extent inland of coastal flooding from storms. Socioeconomically vulnerable populations might face additional obstacles and costs in recovering from coastal flooding events, including the cost of loss of production, repairs, and medical bills.

Indirect Sensitivities: If residents are forced to relocate due to coastal flooding, they may lose long-held community ties.[45] The consequences of a rising coastline could impact some economic activities affecting populations that work in or near these locations and rely on visitors for income, such as the Fort Belvoir Marina and the Pohick Bay Regional Park along the Pohick Creek and Bay.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Coastal Flooding**	**General Population = 2** (Moderate) **Vulnerable Population = 3** (Poor)

The Fairfax County general population is estimated to have moderate adaptive capacity for coastal flooding, while vulnerable populations are estimated to have poor adaptive capacity. As with inland flooding, there are significant cost barriers associated with adaptation to coastal flooding. Elevation of homes, construction of floodwalls, flood-proofing of homes, and other flood risk reducing actions are expensive and not accessible to many residents, especially including low-income populations.

There is some existing ability to naturally accommodate sea level rise through wetland and marsh areas; however, the degradation of those wetlands and marshes limits this ability. Additionally, existing development in the shoreline area of presents a barrier that limits the ability to adapt through techniques such as managed retreat.

Fairfax County offers educational resources to the community on how to prepare for, respond to, and recover from hurricane/tropical storms and flooding. The Department of Planning and Development (DPD) is in the process of amending the Wetlands Zoning Ordinance in accordance with updates to the Virginia Code, which will encourage the use of living shoreline stabilization methods where suitable and protection of shorelines and sensitive coastal habitats. This update will encourage more nature-based shoreline stabilization methods, which will add climate change resiliency and long-term ecological benefits to tidal shorelines. Additionally, based on adopted amendments to the Chesapeake Bay Preservation Area Designation and Management Regulations, the county will be required to assess the impacts of climate change and sea-level rise on any proposed land development in Resource Protection Areas (RPAs) during the development review process.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable are our populations to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Populations**	**Coastal Flooding**	**General Population** = **8** (Moderate) **Vulnerable Population = 9** (Moderate)

Total vulnerability considers exposure, sensitivity, and adaptive capacity. Based on the information available, populations in Fairfax County located where coastal flooding is relevant have moderate total vulnerability to coastal flooding. Vulnerable populations have lower exposure but higher sensitivity to the projected coastal flooding in Fairfax County.

1.f. Drought - Population Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Populations**	**Drought**	**General Population = 1** (Low) **Vulnerable Populations = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County. The county is expected to experience an increase in precipitation rather than a decrease, although intermittent drought events may still occur. Therefore, for all Fairfax County populations, drought exposure is projected to be low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Populations**	**Drought**	**General Population = 1** (Low) **Vulnerable Populations = 2** (Moderate)

The general population in Fairfax County is estimated to have low sensitivity to drought, and vulnerable populations are estimated to have moderate sensitivity. Within the context of Fairfax County, populations typically do not face severe effects from drought. In extreme cases (largely elsewhere), drought can result in food and water shortages which can lead to water use restrictions, heightened food prices, and, in severe cases, dehydration and malnutrition. Younger children, older adults, and individuals of lower socioeconomic status may be particularly affected. Increased exposure to drought coupled with a heightened demand for potable water during heat events can raise serious public health concerns such as lack of access to drinking water, unsafe drinking water quality, and increases in instances of heat stroke.[46] Additional health concerns such as acute respiratory and gastrointestinal illness can occur through the need to conserve water, which can reduce proper sanitation and hygiene.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Populations**	**Drought**	**General Population = 2** (Moderate) **Vulnerable Populations = 2** (Moderate)

Little information was found to assess the adaptive capacity of the general and vulnerable populations to drought; therefore, both were assigned a moderate adaptive capacity. For drinking water infrastructure adaptive capacity to drought, please see the Water Infrastructure section. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable are our populations to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Populations**	**Drought**	**General Population = 2** (Very Low) **Vulnerable Populations = 4** (Low)

Total vulnerability considers exposure, sensitivity, and adaptive capacity. Based on the information available, the Fairfax County populations are estimated to have a low total vulnerability to drought.

2. PUBLIC SERVICES

Public services are services managed by the county and its partners to support the Fairfax community. These services are important to evaluate in the climate vulnerability and risk assessment for two major reasons. First, some public services are critical in the response to, long-term resilience to, and recovery from climate hazards. Second, these services themselves may be vulnerable to climate effects. Threats to public services that are key to resilience can create a compounding effect. For this analysis, the public services sector includes the following sub-sectors: health and community services, emergency response and management, parks and recreational facilities, and waste management services.

Table 4 provides the overall climate vulnerability scores for the four sectors of public services considered in this document, as detailed in the following sections.

Table 4: Climate Vulnerability Summary - Public Services

Public Services – Climate Vulnerability Summary					
Climate Hazards	**Health and Community Services**	**Emergency Response and Management Services**	**Parks & Recreation**	**Waste Management**	**Total**
Extreme Heat	12	18	12	12	**54**
Inland Flooding	12	12	12	8	**44**
Severe Storms	18	27	12	8	**65**
Extreme Cold	4	4	4	4	**16**
Coastal Flooding	6	9	8	4	**27**
Drought	2	6	6	2	**16**
Total	**54**	**76**	**54**	**38**	**222**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

2.1. Health and Community Services

Public health and community services are critical to the resilience of a community. Additionally, these services themselves may be hindered by climate hazards. Fairfax County government provides a range of these services through its Health and Human Services (HHS), a network of county agencies and community partners that provide climate-relevant programs and services for county residents, including cooling centers, health clinics, low-income services, disability services, emergency shelters, child and adult protective services, financial assistance for HVAC, and food services, among many other services. Health clinics for essential services are available in spaces including Joseph Willard Health Center and the District offices of Annandale, Springfield, Mount Vernon, and Herndon-Reston. Privately owned hospitals, including the INOVA Medical Campus, and rehabilitation centers are accessible to the community.

These services are particularly critical in responding to health impacts caused by climate change; climate impacts can significantly disrupt public health and have long-lasting implications for the physical and mental health of Fairfax County individuals. Preexisting or climate-induced health concerns can be worsened if events prohibit the ability to obtain necessary medical and emergency attention. If public services are themselves hindered by climate hazards, this can exacerbate vulnerabilities among the population. In addition to services that directly assist with health vulnerabilities, facilities such as libraries and community centers are critical to community well-being and can enhance resilience.

This section applies to the climate vulnerabilities of the *public services* themselves. For population vulnerabilities, please see the "Population" section of this document. For the purposes of this vulnerability and risk assessment, "health and community services" include community centers, hospitals and urgent care, libraries, and Health and Human Services (HHS) facilities. According to Fairfax County geospatial data, there are 51 community centers, 46 hospitals and urgent care centers, 23 libraries, and 95 HHS facilities (in 56 buildings) within county borders.

Table 5 summarizes the climate vulnerability scores for health and community services. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. The highest vulnerabilities to health and community services are severe storms and extreme heat. Each of the scores is explained in greater detail following the table.

Table 5: Climate Vulnerability Summary – Health and Community Services

Health and Community Services – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	2	**12**
Inland Flooding	3	2	2	**12**
Severe Storms	3	3	2	**18**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	3	2	**6**
Drought	1	1	2	**2**
Total	-	-	-	**54**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

2.1.a. Extreme Heat – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Extreme Heat**	**Exposure = 3** (High)

Health and community services and facilities in Fairfax County are highly exposed to extreme heat, which is projected to increase in intensity and frequency due to climate change. In addition to general county-wide warming, the majority of health and community services facilities in Fairfax County are located in areas with significantly higher land surface temperatures due to the Urban Heat Island Effect (UHI). Specifically, 98% of community centers, 100% of hospitals and urgent care facilities, 100% of libraries, and 98% of HHS facilities are located in areas with significantly high UHI effect. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have moderate sensitivity to extreme heat. In extreme heat conditions, facilities supporting public health and community services may become dangerous if they are poorly ventilated. In public health and community service facilities, older HVAC equipment may be insufficient to handle extreme heat events. During past heat events in Fairfax County, power outages and/or losses of air conditioning have created unsafe working conditions and staff have been sent home or to alternative work locations. When staff are sent home, this results in loss of or lowered access to public services for county residents. System failure is particularly dangerous in hospitals and urgent care centers[47] where medical services may be disrupted or compromised by heat-induced power outages or other events. Energy costs for cooling will likely increase, potentially straining budgets.

During this climate vulnerability and risk assessment process, Fairfax County departments noted certain specific public service buildings with existing heat-related issues. A comprehensive inventory of all county buildings has not yet been conducted, however, and is likely needed. The following issues have been reported:

- **The Embry Rucker Community Shelter**: has air conditioning issues during extreme heat events. However, staff have not turned anyone away during extreme heat events.
- **Kelly Square (Fairfax County Health Department Headquarters)**: has frequent loss of air conditioning, resulting in staff being sent home or to a different area to work due to elevated temperatures.
- **Health Department outreach team:** has had to discourage staff from outdoor health-related outreach activities during extreme heat events.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have a moderate capacity to adapt to extreme heat. This score considers both the adaptive capacity of physical buildings and infrastructure, as well as operations (including staff and programs).

The Facilities Management Department (FMD) conducts regular maintenance of all county facilities, including those related to health and community services. This building maintenance can assist with adaptive capacity, such as efficiency of air conditioning during extreme heat. Through the Capital Renewal Program, critical facilities are provided with a backup generator and necessary upgrades to minimize potential for system failure and risk to public safety. Fairfax County Health and Human Services (HHS) departments work ardently to provide continued public service despite extreme heat.

Fairfax County has designated cooling centers for extreme heat available to the public. Most of the health and community services infrastructure fall within areas where land surface temperatures are significantly higher due to the Urban Heat Island effect. This suggests that these facilities are located in proximity to exposed populations experiencing enhanced heat during heat events and services that can support these populations, reducing potential harm if these services are operational during the heat event (in both staffing and infrastructure operations). The county does not turn people away at shelters during extreme heat events. Therefore, the public service itself has not historically been denied due to extreme heat, although capacity is strained.

The county is also working to reduce this strain on facilities by expanding the opportunities for residents to safely stay in their homes during extreme temperatures. Through the Department of Family Services (DFS), residents have access to numerous energy assistance programs that offer financial support to help low-income residents to help purchase equipment or pay high energy bills for both heating and cooling. DFS also offers Fan Care, an electric fan distribution program for residents over 60 years of age. The county's Strategic Plan (2021)[48] includes a priority action to expand the Department of Housing and Community Development (DHCD's) Home Repair for the Elderly Program (HREP),[49] which supports minor home repairs for low and moderate-income, elderly, and disabled individuals. Some of these repairs, such improved weatherization, may help individuals remain at home more comfortably during extreme heat events.[50] Similarly, the Office of Environmental and Energy Coordination (OEEC) program "HomeWise" provides energy-efficiency improvements for low- and moderate-income residents, which may make homes more livable during extreme heat events.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Extreme Heat**	**Vulnerability = 12** (Moderately High)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information available, Fairfax County's health and community services are estimated to have moderately high total vulnerability to extreme heat events.

2.1.b. Heavy Precipitation and Inland Flooding – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Inland Flooding**	**Exposure = 3** (High)

Heavy precipitation and inland flooding refers to both "urban flooding," when heavy precipitation overwhelms stormwater management infrastructure, and "riverine/ floodplain flooding," when heavy precipitation causes overflowing of water bodies into floodplains. Urban flooding exposure is higher than riverine or floodplain flooding exposure. Health and community service facilities in Fairfax County are generally not located in floodplains; less than 2% of facilities are located on parcels that intersect floodplain areas. However, urban flooding exposure is estimated to be high. Based on a parcel-by-parcel analysis of properties for 10 flood-prone factors, significant percentages of health and community service facilities have two (2) or more flood-prone factors. Specifically, 45% of community centers, 63% of hospitals and urgent care facilities, 9% of libraries, and 58% of HHS facilities are located on parcels with two (2) or more flood-prone factors. When parcels are filtered to those with four (4) or more flood-prone factors, community centers appear to be the most exposed; 10% of community centers, 4% of hospitals and urgent cares, 4% of libraries, and 1% of HHS facilities are located on parcels with four (4) or more flood-prone factors. Heavy precipitation is projected to increase in intensity and quantity due to climate change. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have moderate sensitivity to inland flooding. Flooding can cause physical damage to health and community service buildings and contents, hindering the county's ability to provide services. Excessive moisture produces an increased risk of mold, which thrives in wet and warm conditions, particularly in buildings that are not properly maintained. Flooding can also impact access of travelers to public health and community services facilities. Similarly, flooding can impact the ability of service provider staff such as Child Protective Services and Adult Protective Services to access homes of those needing services.

During this climate vulnerability and risk assessment process, Fairfax County departments have noted certain specific public service buildings that currently have flooding-related issues. A comprehensive inventory of all county buildings is likely needed. The following issues have been reported:

- **Embry Rucker Community Shelter**: water enters through the lobby door during heavy precipitation events.

- **New Hope Housing Mondloch House**: water enters through the front of the building during heavy precipitation events.
- **Fairfax County Historic Courthouse, which includes DFS offices**: there is a history of flooding in this building.
- **Annandale District Office of the Health Department:** has consistent leaks during heavy precipitation events. These leaks are typically inside the administrative work areas and cubicles.
- **Herndon Harbor Adult Day Health Care:** has consistent flooding in the patio area during heavy precipitation events.
- **Burkholder Building:** recently experienced severe flooding and has a history of flooding due to first floor leaks from the ground.
- **Roadway flooding:** Fairfax County DFS notes that roadway flooding could prevent residential services such as Child Protective Services or Adult Protective Services from reaching their destinations. Health Department notes that any road closure due to flooding has the potential to interrupt the work function of health inspectors from being able to reach a destination.
- **Health Department Inspection Services:** onsite staff are not able to perform to outdoor inspections during inclement weather. Work functions include assessment of property septic system installations for contaminated water and inspections of water recreational facilities. Soggy or soft soil affects the ability to adequately assess these systems and also causes interruptions in workflow.

Adaptive Capacity: Are we able to adapt to this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Health and community services in Fairfax County have an estimated moderate adaptive capacity for heavy precipitation and inland flooding. To date, the Department of Housing and Community Development (DHCD) has not encountered disruption in its ability to provide service during heavy precipitation events. Existing county initiatives contribute to the adaptive capacity of the county's health and community services, including flood risk reduction work being led by the Department of Public Works and Environmental Services (DPWES), the county's Emergency Operations Plans and Emergency Action Plans (EAPs), the Northern Virginia Hazard Mitigation Plan (HMP), and the county's Continuity of Operations Plans, among others. However, inland flooding remains an issue. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Inland Flooding**	**Vulnerability = 12** (Moderately High)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information available, Fairfax County health and community services facilities are estimated to have moderately high total vulnerability to heavy precipitation and inland flooding.

2.1.c. Severe Storms – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Severe Storms**	**Exposure = 3** (High)

Health and community service facilities in Fairfax County are highly exposed to severe storms and wind events such as severe thunderstorms, tropical storms, and derechos. Severe storm events are projected to increase in frequency and severity with climate change. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Severe Storms**	**Sensitivity = 3** (High)

Fairfax County health and community services are estimated to have high sensitivity to severe storms and wind events such as severe thunderstorms, tropical storms, and derechos. Severe storm events can disrupt public health, healthcare, and community services both during and after the event.[51] Severe storms can lead to unsafe travel conditions, structural damage, increased debris, and power outages. Certain Fairfax County service providers, such as Department of Family Services, the Health Department, and the Department of Housing and Community Services, have staff that need to travel to residential areas to provide services. These services include domestic violence and sexual assault services, inspection services, health clinics, and housing assistance services, among others. Severe storms may limit the ability of the county to provide these services during and after such events. Similarly, residents may be limited in their ability to access service provider buildings. Restricted access to essential services like food distribution centers,[52] child daycare, adult care facilities, or mental health facilities can result in added risk for the Fairfax County population.[53]

During this climate vulnerability and risk assessment process, Fairfax County departments have noted certain specific public service buildings and services that currently have severe storm-related issues. A comprehensive inventory of all county buildings is likely needed. Prior to such an inventory, the following issues have been reported:

- **Public Health Lab**: experiences regular power outages, which requires the HVAC to be manually reset each time. Due to the sensitive conditions of the lab, the lab automatically shuts itself down and seals itself during power outages. Each reset requires a long and intensive process by a specialty contractor. This happens regularly, and no work can be performed until the reset is completed.
- **New Hope Housing Mondloch House**: experiences regular power outages during severe storms.

- **New Hope Housing Mondloch Place**: experiences regular power outages during severe storms.
- **Patrick Henry Family Shelter:** experiences regular power outages during severe storms.
- **Eleanor U. Kennedy Shelter**: surrounding trees can cause power outage issues during severe storms.
- **Health Department Clinic and Vaccine Services:** have been shut down or halted by severe storm events, delaying or hindering treatment and vaccination of residents. On one notable occasion, a substantial and expensive amount of medical supply was lost due to a power outage.
- **Health Department Inspection Services:** onsite staff are not able to perform their job duty of outdoor inspections during inclement weather. Work functions include assessment of property septic system installations for contaminated water and inspections of water recreational facilities. Soggy or soft soil affects the ability to adequately assess these systems and also causes interruptions in workflow.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have a moderate adaptive capacity to severe storms and wind events.

The distribution of backup generators is inconsistent across facilities. The Department of Family Services (DFS) notes that its facilities do include backup generators. The Department of Housing and Community Development (DHCD) notes that only one of its housing or shelter sites has a small generator for backup power. The Health Department (FCHD) notes that most of its buildings include generators, but some do not. The Health Department reports that Public Health Continuity of Operations (CO-OP) plans are in place for sensitive materials such as vaccines in the event of power outages.

The county does have a variety of ways that it adjusts its programs during severe storms. For example, the Fairfax County Emergency Operations Plan specifies that the county may open a service and information center to assist residents after a disaster, provide temporary shelter if needed, facilitate loans or grants for damages from a disaster, and meet unmet needs through nonprofit assistance. Additionally, during declared disasters, DFS may be authorized to administer the Disaster Supplemental Nutrition Assistance Program (DSNAP) which allows modifications to the ordinary SNAP program. These modifications help eligible low-to-moderate income households who do not normally receive SNAP benefits with help buying or replacing groceries due to lost income or damages following a disaster such as a hurricane. SNAP clients are also eligible for food replacement due to loss of power.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Severe Storms**	**Vulnerability = 18** (High)

Based on the information available, Fairfax County's health and community services are estimated to have high vulnerability to severe storms and wind events such as tropical storms, derechos, and severe thunderstorms.

2.1.d. Extreme Cold – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Extreme Cold**	**Exposure = 1** (Low)

Health and community service facilities may be exposed to extreme cold events when they occur. However, cold events are projected to decrease in frequency and intensity, making overall exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Fairfax County's health and community services are estimated to have moderate sensitivity to extreme cold, which means the hazard could cause temporary operational failure of the service. Health and community services that are provided outdoors, such as outdoor health inspection services, Housing and Community Development property maintenance services, services by the Office to Prevent and End Homelessness, or services by the Department of Family Services for domestic violence or sexual abuse, can be hindered by extreme cold conditions. Additionally, loss of heat within health and community service buildings during extreme cold events can result in staff being sent home, limiting the availability of service. Uninsulated water pipes and fire sprinkler systems in buildings can burst, causing flooding.

During this climate vulnerability and risk assessment process, Fairfax County departments have noted certain specific public service buildings that currently have issues related to extreme cold. A comprehensive inventory of all county buildings has not yet been conducted and is likely needed. Prior to such an inventory, the following issues have been reported:

- **Embry Rucker Community Shelter**: has heating issues during extreme cold events.
- **Kelly Square Health Department Headquarters**: In the past, has lost heat during extreme cold events, resulting in staff being sent home or to another area.

Adaptive Capacity: Are we able to adapt to and address these impacts?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have a moderate adaptive capacity to heavy precipitation and inland flooding.

The Facilities Management Department (FMD) conducts regular maintenance of all county facilities, including those related to health and community services. Through the Capital Renewal Program, critical facilities are provided with a backup generator and necessary upgrades to minimize potential for system failure and risk to public safety.

Fairfax County directs the public to hypothermia centers (for extreme cold). There are also many community centers, recreation centers, senior centers, libraries, shopping centers, and other facilities operated by Neighborhood and Community Services and other departments across the county that effectively serve that purpose even if not the intent. The Office to Prevent and End Homelessness (OPEH) provides dedicated hypothermia shelter space during winter months at several locations across the county. OPEH also partners with nonprofits and places of worship to provide shelter for individuals at risk of hypothermia during the winter.

The Department of Housing and Community Development (DHCD) notes that they do not turn anyone away requesting shelter during extreme cold events. However, there are current capacity challenges, and there is a need for additional space, especially during the Covid-19 pandemic or other transmissible disease spreading periods. During the pandemic, churches, places of worship, hotels, and commercial buildings such as a former Container Store were used to secure additional space for shelter sites. The county is proficient in finding additional space when needed, but the process is costly and additional capacity is needed.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Extreme Cold**	**Vulnerability = 4** (Low)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information available, Fairfax County's health and community services are estimated to have low total vulnerability to extreme cold.

2.1.e. Coastal Flooding – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River that occurs due to sea level rise, tidal flooding, or coastal storm surge. There are no known Fairfax County health and community services facilities that are exposed to current or future coastal flooding, so exposure is scored as "low." However, because certain Fairfax County service staff provide services throughout the community and within homes, such staff could be exposed to coastal flooding effects if services are needed in coastal flooding-prone areas. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Coastal Flooding**	**Sensitivity = 3** (High)

If health and community services were to be exposed to coastal flooding, those services would be highly sensitive to the hazard. Flooding can cause physical damage to buildings and contents, can impact access of travelers to public health and human service facilities, and can impact traveling service providers in their ability to reach residents. For additional flooding sensitivity notes, please see the "inland flooding" section.

Adaptive Capacity: Are we able to adapt to and address these impacts?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Health and community services in Fairfax County are estimated to have a moderate adaptive capacity for coastal flooding. Fairfax County is in the process of updating its ordinances and guidelines in accordance with state code updates relating to climate-related coastal flooding. Additionally, at the time of writing, at the state level, the Virginia Coastal Resilience Master Plan is in development. The goal of this plan is to improve the Commonwealth's resilience and ability to adapt to rising seas, increased nuisance flooding, and more frequent and intense storms that result from climate change. Further, the county's Hazard Mitigation Plans, Emergency Operations Plans, and Emergency Action Plans, address flooding. For example, the Huntington Response Plan (2021) creates an interagency coordination and communications structure for emergency response to severe flooding conditions in the Huntington community. However, barriers to coastal flooding adaptation exist, including cost, technical feasibility, and multiplicity of shoreline property ownership and governing bodies.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Coastal Flooding**	**Vulnerability = 6** (Moderate)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information provided, Fairfax County's health and community services are estimated to have moderate total vulnerability to coastal flooding.

2.1.f. Drought – Health and Community Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**HCS**	**Drought**	**Exposure = 1** (Low)

Health and community services in Fairfax County are estimated to have low exposure to drought. Drought is not projected to increase with significant frequency and intensity in Fairfax County, however intermittent drought events may still occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**HCS**	**Drought**	**Sensitivity = 1** (Low)

Health and community services in Fairfax County are estimated to have low sensitivity to drought.

Adaptive Capacity: Are we able to adapt to and address these impacts?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**HCS**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Information was not found to describe the four adaptive capacity factors this study considered in assessing adaptive capacity. Therefore, adaptive capacity for drought was assigned a moderate score of two (2). For drinking water adaptive capacity during drought, please see the "Water Infrastructure" sector. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**HCS**	**Drought**	**Vulnerability = 2** (Very Low)

Based on the information available, Fairfax County's health and community services are estimated to have very low total vulnerability to drought conditions.

2.2. Emergency Response and Management Services

Extreme weather from climate change can increase the need for emergency response and services to serve the Fairfax County population. Additionally, emergency responders and emergency facilities themselves can be put at risk during climate hazard scenarios. The Fairfax County Department of Emergency Management and Security (DEMS) is responsible for the coordination of recovery and resiliency efforts in response to emergencies. Higher demand can place strain on first responders such as the Fairfax County Fire and Rescue Department (FCFRD), the Fairfax County Police Department (FCDPD), DEMS and the Fairfax County Department of Public Safety Communications (DPSC).

To ensure adequate funding for emergency response and management, the county participates in several state and federal funding programs, including Hazard Mitigation Assistance (HMA), Hazard Mitigation Grant Program (HMGP), Emergency Management and Performance Grants (EMPG), Staffing for Adequate Fire and Emergency Response Grants (SAFER), and others.

Table 6 summarizes the climate vulnerability scores for Fairfax County's emergency response and management services. This is an assessment of vulnerabilities *to the emergency services and facilities themselves,* not the population. For population vulnerabilities, please see the "population" section. This section assessed vulnerabilities of police stations, fire stations, emergency management facilities, and associated services. Emergency facilities and services were screened for their vulnerability to the six hazards below.[54] For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. The highest vulnerabilities to emergency response and management services and facilities are heavy precipitation and inland flooding, severe storms, and extreme heat. Each of the scores is explained in greater detail following the table.

Table 6: Climate Vulnerability Summary - Emergency Response and Management Services

Emergency Response and Management Services – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	3	2	**18**
Inland Flooding	2	3	2	**12**
Severe Storms	3	3	3	**27**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	3	3	**9**
Drought	1	2	3	**6**
Total				**76**

2.2.a. Extreme Heat – Emergency Management and Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Extreme Heat**	**Exposure = 3** (High)

Emergency services in Fairfax County are estimated to have high exposure to extreme heat. In addition to general countywide warming conditions due to climate change, certain areas are exposed to significantly higher land surface temperatures due to the Urban Heat Island (UHI) effect. 100% of the counties police stations, fire stations, and emergency management facilities are located in areas with significantly high UHI. Additionally, emergency responders are highly exposed to extreme heat while on the job. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Extreme Heat**	**Sensitivity = 3** (High)

Fairfax County's emergency facilities and services are estimated to have high sensitivity to extreme heat. There are heat-related sensitivities to both the facilities and the personnel. On the facilities side, FCFRD and FCPD have reported experiencing issues where radio and IT rooms at some facilities overheat during hot weather. While this damage is not permanent, it can be disruptive. Additionally, many stations do not have air conditioning when power is lost, and the facility and staff are exposed to extreme heat without relief.

During periods of extreme heat, emergency responders themselves are at risk of heat-related illnesses and injuries. Emergency responders may also be inundated with increased number of response calls for extreme heat medical attention, which may in turn put a strain on local emergency response capacity. Specifically, during periods of extreme heat, FCFRD sees notable increases in calls for service for heat emergencies. Additionally, during periods of extreme heat, a fire or event requiring personal protective equipment (PPE) has a corresponding increase in the need for additional staff, increased rehabilitation times, and an increase in heat-related employee injuries/illnesses.

Additionally, extreme heat can increase demand for emergency planning such as cooling centers and services during excessive heat watches, warnings, and advisories.[55]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Fairfax County emergency services are estimated to have moderate capacity to adapt to extreme heat. Adaptive capacity is scored based on four factors. (See methodology in Appendix 1 for more information).

The Facilities Management Department conducts regular maintenance of all county facilities, including buildings associated with emergency response services and emergency management services. However, there is no data on the extent to which emergency management facilities have been retrofitted specifically to address extreme heat. Emergency response staff have noted that certain facilities lack air conditioning during heat-related power outages.

Emergency responders have established standard operating procedures (SOPs) to address instances of extreme heat, including increased rehabilitation time, modified shifts, and increased staff. Many emergency responders are required to wear protective clothing. It may be challenging to adapt uniforms for extreme heat weather conditions.[56]

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Extreme Heat**	**Vulnerability = 18** (High)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on the information available, Fairfax County emergency response and management services and facilities are estimated to be highly vulnerable to extreme heat conditions.

2.2.b. Heavy Precipitation, Inland Flooding – Emergency Management & Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Inland Flooding**	**Exposure = 2** (Moderate)

Heavy precipitation and inland flooding refers to both "urban flooding," when heavy precipitation overwhelms stormwater management infrastructure, and "riverine flooding," when heavy precipitation causes overflowing of water bodies into floodplains. Heavy precipitation and inland flooding are projected to increase. Emergency response and management services are moderately exposed to this hazard. This exposure is largely due to urban flooding rather than riverine or floodplain flooding. There is only one known fire station that intersects a floodplain. However, there are six fire stations located on parcels with two or more flood-prone factors, and four fire stations located on parcels with four or more flood-prone factors. There is one police station located on a flood-prone parcel (containing four or more flood-prone factors). (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Inland Flooding**	**Sensitivity = 3** (High)

Emergency services are highly sensitive to heavy precipitation. Flash flooding of roads and properties results in a significant increase in call volume for swift water rescues by FCFRD, FCPD, and Virginia Department of Transportation (VDOT). This greatly reduces available resources for other emergency events. Additionally, roadway flooding can significantly hinder and delay the ability to emergency services to access those who need assistance. Increased flooding, especially of roads and essential infrastructure, may require emergency planning for road redundancies and alternate routes. In terms of physical facilities, there are no known fire or police stations with existing flooding issues. However, Station 16 in Clifton has moisture issues and was built on top of an underground stream.[57]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's emergency services have an estimated moderate capacity to adapt to heavy precipitation and inland flooding. The Department of Public Works and Environmental Services (DPWES), Fairfax County Department of Transportation (FCDOT), and Virginia Department of Transportation (VDOT) actively work to address stormwater management issues and flooded roadways. Roadway and stormwater management improvements have historically been successful in mitigating these issues. In 2019, the Huntington Levee and Storm Water Pump station was completed to protect from up to 100-year flood events. Regular maintenance of county emergency services and management facilities help to mitigate the risk associated with heavy precipitation and inland flooding. There are no known fire or police stations with flooding issues. However, there are notable barriers to adaptation for increasing inland flooding, including staff capacity and technical feasibility and cost of mitigating flood risk. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Inland Flooding**	**Vulnerability = 12** (Moderately High)

Total vulnerability is based on exposure, sensitivity, and adaptive capacity. Based on available information, the emergency services in Fairfax County are estimated to have moderately high vulnerable to inland flooding.

2.2.c. Severe Storms – Emergency Management and Services

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Severe Storms**	**Exposure = 3** (High)

Emergency response services and facilities are highly exposed to severe storms and wind events such as tropical storms, severe thunderstorms, and derechos, which are projected to intensify. Emergency responders are responsible for rescue operations during such storm events, and, as such, are highly exposed to these hazards themselves. Operations may also be impacted during and after storm events as power, travel, and communications may be affected. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Severe Storms**	**Sensitivity = 3** (High)

DEMS notes that the biggest risk to emergency response in Fairfax County is currently severe storms and wind events. When severe storms strike, emergency responders are at high risk. They can also be hindered by the storm effects in responding to the emergency at hand. There is a policy in place for permitted response protocols during high wind events, which establishes when emergency responders can be safely deployed. When wind speeds are very high, emergency responders are not permitted to respond to emergencies (for their own safety) until wind speeds decline. This can create a backlog of emergency calls. High winds also pose a risk to towers used for 911 systems, emergency response vehicles such as fire trucks, and evacuation centers. DEMS notes that the county's evacuation shelters currently are not storm-hardened or safe room type structures. An increase in the frequency of severe storms and weather can place strain on DEMS and first responders and can require more staff to ensure proper emergency communication and response. In terms of power outages, during major storms, fire stations such as Station 20 (Gunston), Station 16 (Clifton), and others routinely lose power, often for extended periods. Additionally, DEMS notes that many shelters designated for severe storm evacuation do not have onsite generators. Very few of these existing facilities would be able to fully operate in the event of a power outage.[58]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Severe Storms**	**Adaptive Capacity = 3** (Low)

Fairfax County's emergency services have an estimated low capacity to adapt to increasing severe storm and wind events, based on the four factors used to score this metric.

The existing architecture of fire stations and other emergency response facilities can limit the resilience of those buildings. For example, the bay door frames of some fire stations in Fairfax County are not reinforced, so if a building were to significantly shift during a severe storm such as a hurricane or derecho, fire trucks may not be able to exit the bay door. Facilities are upgraded on a set refurbishment cycle according to standardized procedures that may not take climate change into account.

Severe storms may lead to more frequent power outages. FCFRD notes that the county's shift towards electrification of buildings to meet Operational Energy Strategy (OES) goals, while a positive move for emissions reduction, also increases county buildings' dependence on electricity and vulnerability to power outages. As a result, the size of generators and backup power distribution will need to increase significantly to ensure that areas such as apparatus bays are still able to be heated by the generators.

Certain critical facilities have backup generators in case of power outages. However, in many cases, these generators are insufficient to operate the full facility. Additionally, when buildings are updated or renovated, emergency generators and onsite power are often the first item to be deleted from budgets. There is a need to reclassify such onsite power as essential during these renovation cycles, so that they are adequately funded. In some cases, FCFRD has trailer-drawn generators to support tower sites, but these resources are limited and outdated.

On the positive side for adaptive capacity, Fairfax County is designated as a StormReady community, which includes robust public education and training related to multiple hazards, including severe storms. The county also partners with local schools for the Student Tools for Emergency Planning (STEP) program. Additionally, DEMS uses Hazus, a FEMA tool, to map out damage and potential impacts from natural disasters, including severe storms. For severe storm situations, DEMS has pre-designated evacuation or shelter sites. The sites used for the storm at hand are selected based on the conditions at the time including the storm path, power outages, need, and availability. Sites used for such purposes include community centers, recreation centers, and schools. All sites have been surveyed by the American Red Cross, and DEMS keeps these surveys on file. However, there is currently a capacity issue because none of the sites currently designated as severe storm shelters (community centers, recreation centers, and schools) are able to hold more than 500 people.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Severe Storms**	**Vulnerability = 27** (Very High)

Total vulnerability is scored based on exposure, sensitivity, and adaptive capacity. Based on the available information, it is estimated that emergency response and management services in Fairfax County have very high vulnerability to severe storms such as tropical storms, hurricanes, and derechos.

2.2.d. Extreme Cold – Emergency Management and Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Extreme Cold**	**Exposure = 1** (Low)

Emergency management facilities and emergency response staff are exposed to cold events when they occur. However, as temperatures warm, cold events in Fairfax County are projected to decrease in frequency and intensity, so overall exposure will be low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Extreme cold can stress the capacity of emergency management services by increasing the need for hypothermia centers and response to brittle and breaking infrastructure, including communication lines. Emergency response personnel themselves can be exposed to extreme cold while responding to emergencies.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's emergency services have an estimated moderate adaptive capacity for extreme cold. The Facilities Management Department has SOPs for extreme cold conditions. Adaptive measures noted in previous sections, including backup generators and EAPs, are also relevant in extreme cold conditions. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Extreme Cold**	**Vulnerability = 4** (Low)

Based on the available information, the overall vulnerability of Fairfax County emergency response and management services to extreme cold is estimated to be low.

2.2.e. Coastal Flooding – Emergency Management and Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River that occurs due to sea level rise, tidal flooding, or coastal storm surge. Fairfax County's emergency management and response facilities are not projected to be exposed to coastal flooding. However, DEMS staff note that exposure to coastal storm surge flooding depends on the track of the storm at hand. The worst-case scenario is a storm that travels up the Chesapeake Bay, causing welling of water that is trapped at the top of the bay, and associated coastal flooding. Emergency management services may be affected by coastal flooding if travel is impaired. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Coastal Flooding**	**Sensitivity = 3** (High)

If emergency management and response services were to be exposed to coastal flooding, such services would have high sensitivity to the hazard. Emergency management and response may be needed to coordinate evacuation and provide resilience efforts to regions impacted by coastal flooding, reducing the capacity of emergency services in other parts of the county. Additionally, under severe flooding circumstances such as those caused by coastal storm surge, emergency response personnel may themselves be at risk while responding to rescue cases.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Coastal Flooding**	**Adaptive Capacity = 3** (Low)

Fairfax County's emergency services have an estimated low adaptive capacity to coastal flooding and storm surge. There are existing barriers that limit the ability of emergency services to adapt to increasing coastal storm surge hazards, including existing SOPs, facility architecture and locations, and response vehicles. However, on the positive side, DEMS uses Hazus, a FEMA tool, to map out damage and potential impacts from natural disasters, including coastal storm surge. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Coastal Flooding**	**Vulnerability = 9** (Moderate)

Based on the information available, Fairfax County's emergency response services are estimated to have moderate total vulnerability to coastal flooding.

2.2.f. Drought – Emergency Management and Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Emergency**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County, making overall exposure low. However, intermittent drought events may still occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Emergency**	**Drought**	**Sensitivity = 2** (Moderate)

Drought may require that new emergency services be put in place to ensure food and water availability to Fairfax County residents and critical services. Emergency services are not highly sensitive to drought apart from fire response. FCFRD's ability to utilize natural water sources (ponds and streams) for firefighting purposes may be reduced during periods of drought.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Emergency**	**Drought**	**Adaptive Capacity = 3** (Poor)

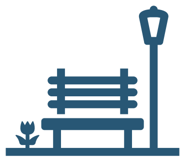
Fairfax County's emergency services are estimated to have a poor capacity to adapt to drought. Firefighters rely on large amounts of water for firefighting and training exercises. Periods of drought and water conservation would present a significant challenge. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Emergency**	**Drought**	**Vulnerability = 6** (Low-Moderate)

Despite a poor adaptive capacity to drought, the total vulnerability of Fairfax County emergency services to drought is relatively low because both exposure and sensitivity to drought are low or moderate.

2.3. Parks and Recreational Services



It is important to evaluate the climate vulnerabilities of the county's parks and recreational services for two primary reasons. First, the county's parklands provide significant natural resilience for the county, by absorbing floodwaters and mitigating heat, among other benefits. Second, parks and recreational services themselves can be vulnerable to climate hazards, and should be protected due to the critical public services they provide.

The Fairfax County Park Authority (FCPA) is responsible for an essential system within Fairfax County, operating 427 parks that span over 23,000 acres of land.[59] Park Authority land protects expansive and biodiverse forests, wetlands, tidal freshwater marshes, nearly all of Fairfax County's stream valleys, and historical sites.[60] The county also provides many opportunities for entertainment, exercise, and public health, including indoor RECenters, 715 athletic fields, 11 dog parks, 10 lakefront parks, golf courses, accessible playgrounds, and an extensive 334-mile trail system. In addition to park land, Neighborhood and Community Services (NCS) provides teen and senior centers and public-private Community Resource Centers for personal development.[61] (For community center vulnerabilities, please see the "health and community services" sub-sector). In addition to county parks, Fairfax County is home to numerous prized state and national parks, such as Mason Neck State Park, Great Falls Park, Wolf Trap National Park, Fort Hunt National Park, and Turkey Run Park, among many others. These are described as "non-county" parks in this assessment.

Table 7 summarizes the climate vulnerability scores for parks and recreational services. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. These scores are general and qualitative in nature; they are intended to identify high-level vulnerabilities that may need additional county attention and analysis. The highest climate hazard vulnerabilities to parks and recreational services are estimated to be extreme heat, heavy precipitation and inland flooding, and severe storms.

Table 7: Climate Vulnerability Summary - Parks and Recreational Services

Parks and Recreational Services – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	3	2	**12**
Inland Flooding	3	2	2	**12**
Severe Storms	3	2	2	**12**
Extreme Cold	1	2	2	**4**
Coastal Flooding	2	2	2	**8**
Drought	1	2	3	**6**
Total				**54**

2.3.a. Extreme Heat – Parks and Recreation Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Parks & Rec**	**Extreme Heat**	**Exposure = 2** (Moderate)

The county's parks and recreation services are moderately exposed to extreme heat. County parks are projected to experience an increase in intensity and frequency of heat events due to climate change. In addition to general countywide warming, some parks and recreation facilities are located in areas with significantly higher land surface temperatures due to the Urban Heat Island (UHI) effect. Specifically, 24% of county trails, 44% of non-county trails, 14% of county parks, and 9% of non-county parks are located within significant UHIs. However, parks themselves (especially those with ample green space and tree canopy) serve to dissipate heat, making overall exposure to heat within parks slightly lower than other areas in the county. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Parks & Rec**	**Extreme Heat**	**Sensitivity = 3** (High)

Extreme heat can have several detrimental impacts on parks and recreational services. Extreme heat can increase the risk of heat-related illnesses for those engaged in outdoor activities like walking, running, or biking in Fairfax County parks. Increased and pervasive high heat days, especially when paired with poor air quality alerts, can necessitate outdoor park closures and restrictions to protect public health. FCPA closures follow Fairfax County Government closures.[62] Even without closures, extreme heat may reduce visitation and use of outdoor areas and recreation facilities. FCPA notes that such reduction in visitation and revenue-generating activities could have serious financial impacts for FCPA. Extreme heat can also have maintenance implications and associated costs. Extreme heat can cause degradation of trail pavements, negative ecological effects on natural resources present in parks, and increased need for field maintenance. These maintenance needs may have additional financial implications for park facilities. Additionally, extreme heat can cause power blackouts or brownouts, which may affect the power at certain facilities.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Parks & Rec**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Fairfax County parks and recreation services have an estimated moderate capacity to adapt to extreme heat conditions.

To a certain extent, there is an ability to naturally accommodate increases in extreme heat. Parks themselves provide heat mitigation and dissipation. Use of native plants and heat-resistant species in parks may render the ecological conditions more adaptable to local conditions. However, if the native plants are not accustomed to extreme heat, their adaptability may be limited. Maintaining and increasing tree canopy can naturally assist with heat mitigation.

FCPA has taken several actions to address climate vulnerabilities. For example, FCPA conducted a review of RECenters for possible installation of backup generators. Generator projects have included installation of an emergency generator sized to provide standby power for the three high-flow submersible pumps and critical building systems, including security, HVAC, lighting, and incidentals. Additionally, FCPA is working diligently to provide energy efficient buildings and renewable power generation, which can enhance resilience.

The Fairfax County Tree Action Plan sets the strategic vision to grow and protect the urban tree canopy in Fairfax County residential and commercial properties, public lands, and parks, and adjacent to streams, streets, and trails. Expanding the urban tree canopy would provide more cool, shaded areas for those recreating at Fairfax County parks. In addition, a larger and more mature urban tree canopy would increase Fairfax County's albedo while providing a slight cooling effect as a result of evapotranspiration.[63]

FCPA conducts robust and regular maintenance of parks and recreational facilities, which helps to provide general resilience to climate effects. However, FCPA is the largest landowner in the county, so keeping up with this maintenance is a challenge. The majority of FCPA revenue-generating activities are located outdoors, and the largest revenue-generating periods are during the hottest months of the year. Therefore, there may be funding limitations for FCPA while maintenance and adaptation costs are increasing. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Parks & Rec**	**Extreme Heat**	**Vulnerability = 12** (Moderately High)

Total vulnerability is scored based on exposure, sensitivity, and adaptive capacity. Based on the information available, Fairfax County parks and recreation services are estimated to have moderately high overall vulnerability to extreme heat conditions.

2.3.b. Heavy Precipitation and Inland Flooding– Parks and Recreational Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Parks & Rec**	**Inland Flooding**	**Exposure = 3** (High)

Heavy precipitation that causes inland flooding refers to both "urban flooding," when heavy precipitation overwhelms stormwater management infrastructure, and "riverine flooding," when heavy precipitation causes overflowing of water bodies into floodplains. For the park system, "riverine" flooding is more relevant. In Fairfax County, a significant portion of parks are located within Resource Protection Areas (RPAs) and floodplains that are adjacent to water bodies and are therefore vulnerable to flooding. This is intentional and is a largely positive thing for the county's overall resilience. To protect these RPAs and to prevent development in flood-prone areas, Fairfax County implemented "stream valley parks" and "stream valley trails" throughout the county. In addition to the many parks and trails located in stream valleys, Fairfax County supports three lakefront parks including Lake Fairfax, Lake Accotink, and Burke Lake.[64] Several Fairfax County park lands are former bogs and are particularly exposed to extreme precipitation events.[65] These stream valley parks and protected park land adjacent to water bodies enhance the resilience of the county by absorbing floodwaters naturally, and protecting residential areas from such flooding. However, it also means that the parks themselves score high for exposure to flooding. Specifically, 31% of county trails, 11% of non-county trails, 29% of county parks, and 19% of non-county parks are located in FEMA floodplains. Heavy precipitation is projected to increase in intensity and quantity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Parks & Rec**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Parks and recreational services in Fairfax County are moderately sensitive to heavy precipitation and inland flooding. Flooding and associated debris in outdoor parks can create safety hazards for the public. Indoor parks and recreation facilities can also become flooded; for example, the basement of the Visitor Center at Riverbend Park has been known to flood during heavy precipitation. Additionally, heavy precipitation and inland flooding can cause degradation of parks and trails. Park lands located in former bogs that can no longer support excessive moisture are particularly vulnerable to extreme precipitation. FCPA reports[66] sensitivities including severe erosion of stream channels, trail sections that are frequently flooded, low spots that pond water, erosion of trail surface material and base material, widened trail areas due to high volumes of users walking around flooded trail areas, and loss of vegetation and habitat. Some of these trails are at risk of total loss. Heavy precipitation and inland flooding can cause increased maintenance requirements and therefore increased agency operation costs.[67] Simultaneously, flooding may reduce park usage, which may reduce revenue generated from the facilities.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Parks & Rec**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Fairfax County parks and recreational services have moderate adaptive capacity to heavy precipitation and inland flooding.

A significant portion of Fairfax County park lands naturally provide accommodation of inland flooding effects. The location of these park lands in stream valleys, adjacent to lakes and other water bodies, and in environmentally sensitive areas, provides a natural buffer between water bodies and developed land. With low impervious surface amounts, park lands are better able to naturally absorb heavy precipitation and floodwater than surrounding developed areas.

Fairfax County conducts regular maintenance activities to offset the sensitives associated with inland flooding and heavy precipitation. These activities include stream restorations, armoring trails, and other flood mitigation activities.

However, the majority of FCPA revenue-generating activities are located outdoors. Therefore, if flooding results in lower visitation of these sites, there may be funding limitations for FCPA while maintenance and adaptation costs are increasing. Additionally, there are existing workforce barriers both within and external to county governance that hinder the implementation of flood-resilient facilities such as pervious pavers or recreational courts. County staff, including NCS and DPWES, report that certain recreational facilities have been designed to be pervious to better absorb floodwater. However, the construction of those facilities has been limited by lack of local qualified contractors and lack of county staff construction project managers with green infrastructure skillsets.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Parks & Rec**	**Inland Flooding**	**Vulnerability = 12** (Moderately High)

Based on the information available, Fairfax County parks and recreational services are estimated to have moderate overall vulnerability to heavy precipitation and inland flooding.

2.3.c. Severe Storms – Parks and Recreational Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Parks & Rec	Severe Storms	**Exposure = 3** (High)

Fairfax County parks and recreational facilities and services are highly exposed to severe storms that are projected to intensify due to climate change. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Parks & Rec	Severe Storms	**Sensitivity = 2** (Moderate)

Figure 2: Eroded trails in Stream Valley parks. Credit: Fairfax County Park Authority.

Severe storms and wind events such as tropical storms, severe thunderstorms, and derechos can make use of outdoor parks unsafe to both the public and staff by increasing debris and exposure to lightning or other hazards. Additionally, severe storms can cause damage or degradation of parks, trails, and associated facilities. FCPA has reported significant damage to stream valley parks and trails due to large storms. FCPA notes that, because stream valley trails by nature run parallel to associated streams, during severe storms, the entire floodplain area is often inundated with fast-moving water. This fast-moving water quickly removes gravel of stream valley trails, and severely erodes the underlying soils (*Figure 2*). These trails require significant costs to repair, and result in loss of use of the trail for patrons. Furthermore, severe storms can result in power outages to parks and recreation facilities.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Parks & Rec	Severe Storms	**Adaptive Capacity = 2** (Moderate)

Fairfax County's parks and recreational services have an estimated moderate capacity to adapt to severe storms.

To address power vulnerabilities associated with severe storms, FCPA conducted a review of RECenters for possible installation of backup generators. Generator projects have included installation of an emergency generator sized to provide standby power for the three high-flow submersible pumps and critical building systems, including security, HVAC, lighting, and incidentals. Additionally, FCPA is working diligently to provide energy efficient buildings and renewable power generation, which can enhance resilience. The county's Debris Management Plan has also designated park sites for temporary storage of debris during severe storm.

Fairfax County's parks and recreational facilities are diligently and actively maintained to remove debris and other effects of severe storms. However, the sheer size of park land and recreational facilities in Fairfax County can make it challenging to keep up with maintenance for all facilities simultaneously.

The majority of FCPA revenue-generating activities are located outdoors. Therefore, if severe storms result in lower visitation of these sites, there may be funding limitations for FCPA while maintenance and adaptation costs increase.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Parks & Rec**	**Severe Storms**	**Vulnerability = 12** (Moderately High)

Fairfax County's parks and recreational facilities are estimated to have moderately high total vulnerability to severe storms and wind events such as tropical storms, severe thunderstorms, and derechos.

2.3.d. Extreme Cold – Parks and Recreational Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Parks & Rec**	**Extreme Cold**	**Exposure = 1** (Low)

Parks and recreational facilities are exposed to extreme cold when such events. However, cold events are projected to decrease in frequency and intensity, making overall future exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Parks & Rec**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Parks and recreational facilities are moderately sensitive to extreme cold. Extreme cold can make outdoor spaces unsafe for use. During extreme cold events, use of parks and recreational facilities may decrease, which may affect revenue for FCPA. If extreme cold is paired with ice, trails may create a safety hazard for users. However, extreme cold does not usually cause significant damage to parks and recreational facilities. Use of parks and recreational facilities is also usually lower during the winter, so revenue impacts may not be as significant as they would be during other times of the year.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Parks & Rec**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's parks and recreational services have moderate adaptive capacity for extreme cold. FCPA actively maintains and upgrades their buildings for energy efficiency, which can increase resilience to extreme cold. Further, the use of native plants on park lands may be more resilient to local climate conditions. However, as previously noted, the majority of FCPA revenue-generating activities are located outdoors. If extreme cold events are less frequent and intense, there is potential for increased visitation of these sites in cold weather months. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Parks & Rec**	**Extreme Cold**	**Vulnerability = 4** (Low)

Based on available information, Fairfax County's parks and recreational facilities have a low overall vulnerability to extreme cold.

2.3.e. Coastal Flooding – Parks and Recreational Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Parks & Rec**	**Coastal Flooding**	**Exposure = 2** (Moderate)

Coastal flooding in Fairfax County refers to flooding of the Potomac River that occurs due to sea level rise, tidal flooding, or coastal storm surge. Because Fairfax County is geographically large and only a portion of the land area is located in areas where coastal flooding is relevant, coastal flooding exposure considers two different denominators. The first denominator is the county as a whole. The second denominator is the "coastal area" of the county, or Census Tracts that fall within one mile of the Potomac River shoreline. Parks and recreational facilities within the county have a moderate exposure to coastal flooding, largely due to protected park areas located along the shoreline. Specifically, 3.89 miles of county trails (1.2% of total or 12.1% of coastal), 8.91 miles of non-county trails (2.9% of total of 12% of coastal), 0.44 square miles of county parks (1.2% of total or 9.3% of coastal), and 4.36 square miles of non-county parks (14.2% of total and 25% of coastal) are exposed to projected coastal storm surge flooding. There are lower projected exposure rates for sea level rise alone. The park areas with most significant exposure rates are operated by entities other than Fairfax County. However, Huntley Meadows Park is one example of a county-operated park that may be exposed to such flooding. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Parks & Rec	Coastal Flooding	**Sensitivity = 2** (Moderate)

Parks and recreational facilities that are exposed to coastal flooding may have moderate sensitivity to such flooding effects. These flooding sensitivities are similar to those detailed previously in the "heavy precipitation and inland flooding" section.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Parks & Rec	Coastal Flooding	**Adaptive Capacity = 2** (Moderate)

Fairfax County parks and recreational facilities have an estimated moderate adaptive capacity for coastal flooding. Open space, including park land, is better able to absorb flooding than surrounding developed area. However, recreation facilities and buildings do not have an existing ability to naturally accommodate coastal flooding. There are barriers to adaptation for this hazard, including cost, feasibility, staff capacity, and multiplicity of land ownership and authority. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Parks & Rec	Coastal Flooding	**Vulnerability = 8** (Moderate)

Based on the information available, the overall vulnerability of parks and recreation facilities in Fairfax County to projected coastal flooding is estimated to be moderate.

2.3.f. Drought – Parks and Recreational Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Parks & Rec**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County, making overall projected exposure low. However, intermittent drought events may still occur. Parks and recreation facilities are exposed during periods of drought. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Parks & Rec**	**Drought**	**Sensitivity = 2** (Moderate)

Parks and recreation facilities in Fairfax County are moderately sensitive to drought. Vegetation on park land can suffer from sustained periods of drought. Playing fields throughout the FCPA require frequent watering to maintain playing conditions. Sustained periods of drought could result in loss or lower quality of playing space for sports and other recreational activities.[68] However, drought conditions are unlikely to cause full operational shutdown of parks and recreational areas.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Parks & Rec**	**Drought**	**Adaptive Capacity = 3** (Poor)

Fairfax County parks and recreational facilities have poor adaptive capacity to drought conditions, based on the information available. Parks and recreational facilities rely on water to maintain the quality of both park land and playing fields. This limits the ability to adapt to this hazard. Planting drought-resilient and native plants may naturally increase the resilience of park land ecology to this hazard. However, recreational facilities and buildings do not have the same ability to naturally accommodate drought conditions. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Parks & Rec**	**Drought**	**Vulnerability = 6** (Moderate)

Based on the information available, parks and recreational facilities in Fairfax County are estimated to have a moderate total vulnerability to drought.

2.4. Waste Management Services

It is important to evaluate the vulnerability of waste management services to climate change for several reasons. In the face of climate change, frequent disasters and exposure to extreme climate stressors can create situations wherein hazardous waste storage facilities are damaged, creating a potential risk to the community. Climate hazards can also produce larger quantities of waste, including hazardous waste, which may overwhelm existing facilities.[69] Hazardous storage can vent under extreme heat conditions which can be dangerous to workers and nearby environments. Additionally, waste management services and personnel may themselves be at risk of climate hazards.

Fairfax County's I-66 Transfer Station and the I-95 Landfill Complex provide facilities to discard waste.[70] Hazardous waste collection is also available at these facilities to residents and businesses to promote safety. These facilities are transfer stations, which means that the waste is temporarily dropped off at the facilities before being transferred outside of the county. There are no active municipal solid waste landfills in the county; the previously active landfills have been closed, and all landfill gas is monitored on a continual basis. All trash is burned or transferred out of the county. In addition to these facilities, the private Covanta Fairfax Inc. (CFI) I-95 Energy Resource Recovery Facility (ERRF), located next to the county landfill, is a waste-to-energy facility. This waste-to-energy facility uses municipal solid waste as the fuel that is burned to produce heat, which creates steam that spins turbine generators to produce energy.

Fairfax County DPWES oversees and monitors waste collection services in Fairfax County to ensure that all services comply with policies but the majority of waste collection service itself is provided by private contractors. About 10% of Fairfax County waste and recycling is collected by the Fairfax County Government, and the remaining 90% is conducted by private collection companies that are often individually hired by homeowner associations (HOAs).[71] Fairfax County also participates in the "Purple Can Club" program, which collects glass to be processed at the county's glass crusher at the I-95 Landfill. This glass is then reused in a variety of construction projects.

Table 8 summarizes the climate vulnerabilities of the waste management system in Fairfax County. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. The highest vulnerability to waste management services is extreme heat. Each of the scores is explained in greater detail following the table.

Table 8: Climate Vulnerability Summary - Waste Management Services

Waste Management Services – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	2	**12**
Inland Flooding	2	2	2	**8**
Severe Storms	2	2	2	**8**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	2	2	**4**
Drought	1	1	1	**2**
Total	-	-	-	**38**

2.4.a. Extreme Heat – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Extreme Heat**	**Exposure = 3** (High)

Waste management facilities and staff are highly exposed to heat events, which are projected to increase in severity and frequency due to climate change. In addition to county-wide warming due to climate change, certain areas are exposed to significantly higher land surface temperatures due to the Urban Heat Island (UHI) effect. Approximately 76% of the county's landfill acreage is located in areas with significantly high UHI. Additionally, waste management staff are highly exposed to extreme heat when working outdoors. Waste management service routes and other facilities vary in heat exposure. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Waste management services and facilities have an estimated moderate sensitivity to extreme heat. Extreme heat at waste management facilities and on service routes can place site workers at risk, especially given that landfills themselves are generally hot and operate in direct sunlight.[72] Some waste management personnel with DPWES are outdoor workers (providing compliance monitoring) who may be exposed to extreme heat conditions while performing their job duties. Additionally, hazardous storage may require venting under extreme heat conditions, which can be dangerous to workers and nearby environments. Furthermore, extreme heat can result in power outages that can affect the operation of waste management facilities. However, it is unlikely that extreme heat events would cause complete operational failure of waste management services, rendering the sensitivity "moderate."

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Waste management services in Fairfax County have an estimated moderate ability to adapt to changing heat conditions.

Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County; instead there is a transfer station and an incineration station. Waste management services in Fairfax County are provided by numerous separate private entities that are often individually hired by HOAs. These services are monitored for compliance by Fairfax County.

This system can create complexities and barriers to adaptation when compared with a consolidated system of waste management.

There are backup generators at all waste management facilities in Fairfax County to offset risks of power outages. Fairfax County DPWES coordinates with all private waste management groups to mitigate risk. To prevent possible combustion, waste facilities engage in additional turning of woody debris. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The county is also exploring the use of automated trucks for trash pickup, which would reduce personnel exposure to climate hazards.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Extreme Heat**	**Vulnerability = 12** (Moderately High)

Overall, Fairfax County's waste management services have an estimated moderately high vulnerability to increasing extreme heat conditions.

2.4.b. Heavy Precipitation and Inland Flooding – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Inland Flooding**	**Exposure = 2** (Moderate)

Heavy precipitation that causes inland flooding refers to both "urban flooding," when heavy precipitation overwhelms stormwater management infrastructure, and "riverine flooding," when heavy precipitation causes overflowing of water bodies into floodplains. Waste management facilities and staff are projected to be exposed to increased heavy precipitation and potential inland flooding. A small portion of the county's landfill acreage (2-3%) intersects FEMA and county floodplains. However, urban flooding exposure is estimated to be higher. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Intense precipitation and flooding of waste facilities can increase debris, potentially including hazardous materials. The county's Debris Management Plan designates Park sites that serve for temporary storage of debris. If the Parks themselves are exposed to increased flooding, they may be unable to serve their role within the Debris Management Plan. Washout and leachate leakage from extreme precipitation have the potential to transport litter and contaminants to downstream locations,[73] depositing toxic particles into the soil and waterways,[74] which is a public health concern. Additionally, flooding can affect site facilities such as weighbridges and leachate collection systems along with supporting roads, limiting or fully preventing proper functionality.[75] There is a culvert that conveys Mill Branch under the landfill. There may be an increased chance of blockage and an increased flooding potential from overland flow. Finally, trash may not be able to be collected in flooded locations.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Waste management services in Fairfax County have a moderate ability to adapt to inland flooding.

Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County. Waste management services in Fairfax County are provided by numerous separate private entities that are often individually hired by HOAs. These services are monitored for compliance by Fairfax County. This system can create complexities when compared with a consolidated system of waste management.

Fairfax County's DPWES partners with the Office to Prevent and End Homelessness (OPEH) to deliver a program called Operation Stream Shield.[76] This program employs individuals experiencing homelessness to keep streams clean through the removal of litter and by providing assistance to the I-66 Transfer Station and the I-95 Landfill Complex. Removal of litter in water bodies such as streams helps to prevent waste and debris issues from spreading after heavy precipitation and inland flooding. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The county is also exploring the use of automated trucks for trash pickup, which would reduce personnel exposure to climate hazards.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Inland Flooding**	**Vulnerability = 8** (Moderate)

Based on the information available, Fairfax County's waste management services are estimated to have moderate vulnerability to increasing heavy precipitation and inland flooding conditions.

2.4.c. Severe Storms – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Severe Storms**	**Exposure = 2** (Moderate)

Waste management facilities and staff are moderately exposed to severe storms, which are projected to intensify due to climate change. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Severe storms can exacerbate creation and accumulation of debris, potentially including hazardous debris. As a result, facilities may experience decreased waste capacity, and there may be increased debris management requirements for waste management personnel. Additionally, such events can put waste management personnel and outdoor workers at risk during provision of collection services. For particularly severe events such as tropical storms, the ability of waste management services to operate normally can be hindered, which may result in a temporary buildup of waste in residential areas.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Waste management infrastructure and services in Fairfax County have moderate adaptive capacity for severe storms.

Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County. Waste management services in Fairfax County are provided by numerous separate private entities that are often individually hired by HOAs. These services are monitored for compliance by Fairfax County. This system can create complexities when compared with a consolidated system of waste management.

The county has a Debris Management Plan to mitigate the sensitivities associated with severe storm and wind hazards. The county also has contracts in place with private waste management service providers to provide oversight and management. Additionally, there are backup generators at all facilities to mitigate the potential for power outage issues. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The county is also exploring the use of automated trucks for trash pickup, which would reduce personnel exposure to climate hazards.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Severe Storms**	**Vulnerability = 8** (Moderate)

Based on the information available, Fairfax County's waste management services are estimated to be moderately vulnerable to increasing severe storms.

2.4.d. Extreme Cold – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Extreme Cold**	**Exposure = 1** (Low)

Waste management facilities and staff are exposed to extreme cold. However, extreme cold events are projected to decrease in frequency and intensity as the weather warms, making overall future exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Extreme cold can create dangerous working conditions for site workers and waste collection workers. Fairfax County Solid Waste staff are involved in county cold weather emergency response efforts.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Waste management infrastructure and services in Fairfax County have moderate adaptive capacity for extreme cold.

Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County. Waste management services in Fairfax County are provided by numerous separate private entities that are often individually hired by HOAs. These services are monitored for compliance by Fairfax County. This system can create complexities when compared with a consolidated system of waste management.

There are backup generators at all waste management facilities in Fairfax County to offset risks of power outages. Fairfax County DPWES coordinates with all private waste management groups to mitigate risk. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The county is also exploring the use of automated trucks for trash pickup, which would reduce personnel exposure to climate hazards.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Extreme Cold**	**Vulnerability = 4** (Low)

Based on the information available, Fairfax County's waste management services are estimated to have low vulnerability to extreme cold overall.

2.4.e. Coastal Flooding – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River that occurs due to sea level rise, tidal flooding, or coastal storm surge. The two primary waste management facilities and staff are not projected to be exposed to increases in coastal flooding. However, waste pickup routes may be affected. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Waste management has moderate sensitivity to coastal flooding. When sumps are over-filled with leachate and other liquids, hydraulic control is complicated, and pumping wells may become necessary.[77] Storm surges can increase the potential of littering debris that can both damage infrastructure and require removal efforts.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Waste management infrastructure and services in Fairfax County have moderate adaptive capacity for coastal flooding.

Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County. Waste management services in Fairfax County are provided by numerous separate private entities that are often individually hired by HOAs. These services are monitored for compliance by Fairfax County. This system can create complexities when compared with a consolidated system of waste management. Fairfax County DPWES coordinates with all private waste management groups to mitigate risk. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The county is also exploring the use of automated trucks for trash pickup, which would reduce personnel exposure to climate hazards.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Coastal Flooding**	**Vulnerability = 4** (Low)

Based on the information available, Fairfax County's waste management services are estimated to have low vulnerability to coastal flooding overall.

2.4.f. Drought – Waste Management Services Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Waste Mgmt.**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County, making overall future exposure low However, intermittent drought events may still occur. If drought conditions do occur, waste management facilities and staff will be exposed. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Waste Mgmt.**	**Drought**	**Sensitivity = 1** (Low)

Waste management services in Fairfax County have low sensitivity to drought conditions. The private CFI waste-to-energy facility relies on water (steam produced through the heat from burning of waste) to generate energy. Other waste services are largely unrelated to water availability.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Waste Mgmt.**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Fairfax County waste management services have moderate adaptive capacity to drought conditions. Fairfax County regularly monitors closed landfill sites for safety. There are no active municipal solid waste landfill sites in Fairfax County. Fairfax County's Zero Waste Initiative is designed to lead to less waste overall, which will reduce associated risks. The CFI waste to energy plant is privately operated. It is not owned or operated by Fairfax County. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this service to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Waste Mgmt.**	**Drought**	**Vulnerability = 2** (Very Low)

Overall, waste management services in Fairfax County are estimated to have very low vulnerability to drought conditions.

3. BUILDINGS

Buildings are one of the most critical considerations in the assessment of the county's vulnerability to climate hazards. Building vulnerabilities translate to vulnerabilities where we live, work, learn, recreate, shop, and obtain services. Buildings can be physically damaged by climate hazards such as severe storms and flooding. Additionally, buildings can be impacted through their connections to other vulnerable infrastructure systems, such as water and energy infrastructure.[78] This section of the VRA covers the vulnerabilities of buildings as physical structures specifically. For public services, please see the "Public Services" section. For population effects, please see the "Populations" section. For energy, please see the "Energy" section.

There are approximately 260,000 buildings within county borders, according to 2017 planimetric GIS data. Fairfax County's building portfolio is primarily residential (93%), followed by commercial buildings (2%), public buildings (2%), other buildings (2%), industrial (<1%), multi-story garage (<1%), and mixed-use (<1%)*(Figure 3)*. "Public buildings" in the county's GIS database include airport terminals, general public buildings, community and recreation centers, education facilities, government or military facilities, health or medical facilities, historic sites and points of interest, and transportation facilities.

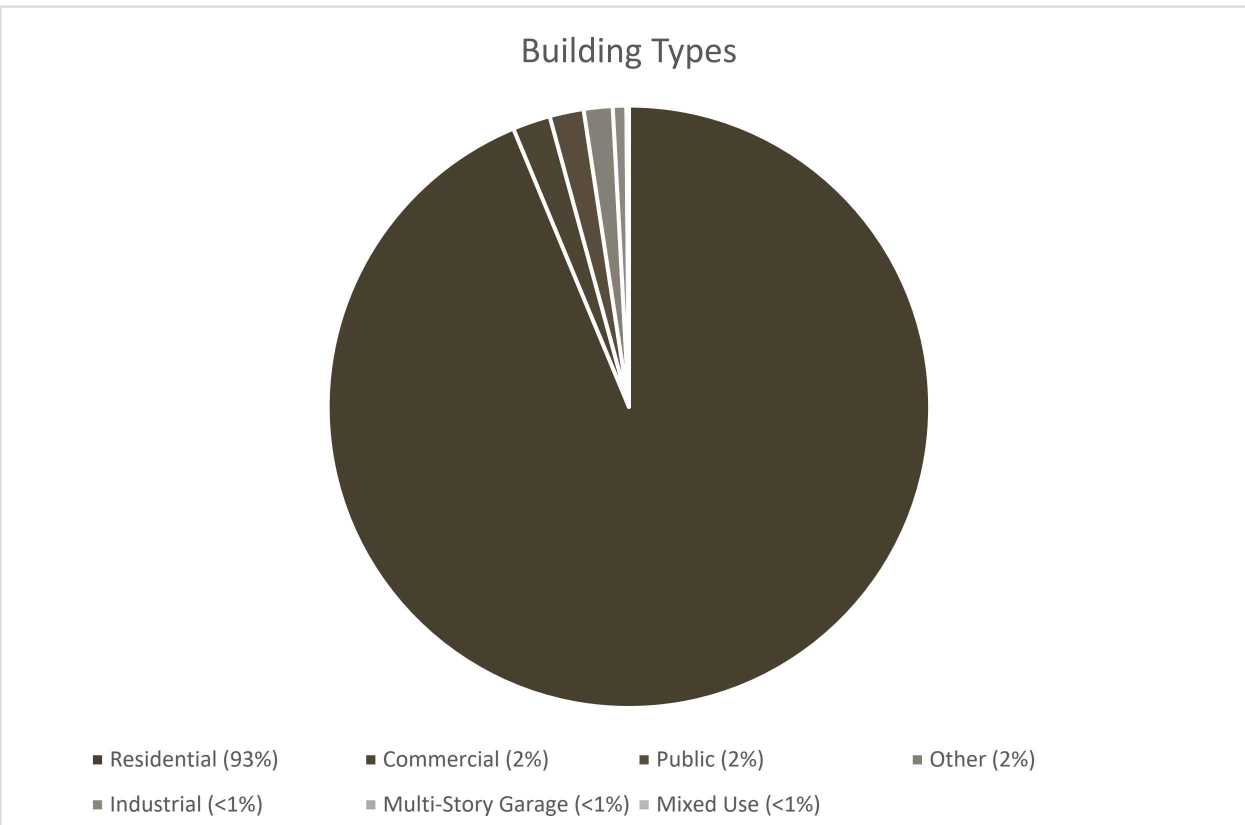


Figure 3: The Building stock by category
(Source: developed from Fairfax County GIS data)

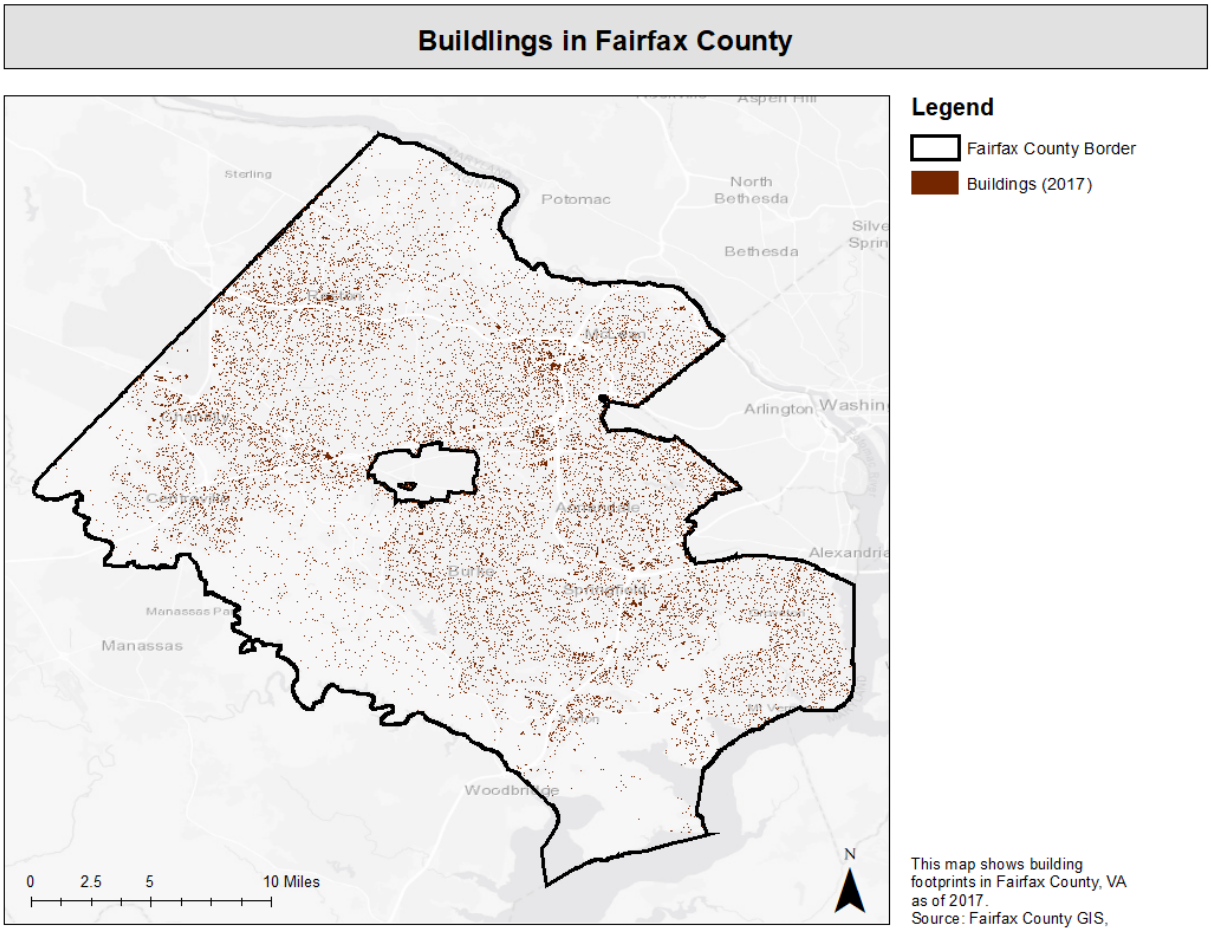


Figure 4: Buildings in Fairfax County. Source: Fairfax County GIS.

Table 9 summarizes the climate vulnerability scores for the buildings sector. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. These scores are general and qualitative in nature; they are intended to identify high-level vulnerabilities that may need additional county attention or analysis. Based on this assessment, the highest climate vulnerabilities to buildings in the county are heavy precipitation and inland flooding, and severe storms. Each of the scores is explained in greater detail in the sections below.

Table 9: Climate Vulnerability Summary - Buildings

Building Sector – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	1	2	**6**
Inland Flooding	3	3	2	**18**
Severe Storms	3	3	2	**18**
Extreme Cold	1	1	2	**2**
Coastal Flooding	1	3	3	**9**
Drought	1	1	2	**2**
Total	-	-	-	**55**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

3.a. Extreme Heat – Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Extreme Heat**	**Exposure = 3** (High)

All building assets in Fairfax County are projected to be exposed to increasing annual and monthly temperatures and increasing intensity and duration of heat events due to climate change, regardless of their location in the county. In addition to these general warming trends, approximately 99% of the building stock is located in areas where the Urban Heat Island effect (UHI) intensifies land surface temperatures either moderately or significantly. Approximately 67% of buildings are located in areas with "significant" UHI effect, and over 9% of buildings are located in areas with average land surface temperatures above 100 degrees F during the summer months. This is logical, because the Urban Heat Island effect itself is created when dark-colored surfaces such as asphalt and densely-built buildings absorb and retain heat. By building category, the breakdown of "significant" Urban Heat Island effect exposure is as follows: 66% of residential buildings, 96% of industrial buildings, 98% of commercial buildings, 100% of mixed-use buildings, 81% of public buildings, 98% of parking structure buildings, and 81% of other buildings. Extreme heat conditions are projected to increase over the coming decades.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Extreme Heat**	**Sensitivity = 1** (Low)

Buildings have low sensitivity to extreme heat. Structurally, buildings are generally able to withstand heat up to 110°F without impact.[79] Most sensitivities for extreme heat within buildings are related to the people within the buildings rather than the buildings themselves. Buildings subject to extreme heat can become dangerous if they are poorly ventilated. Increased internal temperature can not only compromise comfort but can jeopardize human health. Additionally, higher demand for cooling can result in heightened energy costs. Older HVAC equipment may be insufficient to handle extreme heat events. For more information on population-related sensitivities, please see the "Populations" section of this VRA.

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Buildings in Fairfax County have an estimated moderate adaptative capacity to extreme heat. Adaptive capacity is scored according to four factors. (Please see Appendix 1 for methodology).

The county and state have various programs and policies that indirectly assist with the adaptive capacity of buildings in extreme heat. When buildings are more energy-efficient, they have more temperature stability and may have a more stable energy load demand during heat events. For example, government buildings in Fairfax County are required to use the Leadership in Energy and Environmental Design (LEED) framework, which includes credits related to energy efficiency and some related to resilience. Low impact development (LID) and green infrastructure techniques, which can help mitigate extreme heat, are embraced by the Department of Public Works and Environmental Services (DPWES) Building Design and Construction Division (BDCD) designs for all Capital Improvement Program projects. To enhance residents' adaptive capacity, the county offers home improvement programs such as HomeWise that support energy-efficiency improvements for low- and moderate-income residents. The Zoning Ordinance regulates impervious cover in multiple ways, which can reduce impervious surfaces that lead to the Urban Heat Island effect, although that is not the purpose of those regulations. The county encourages green infrastructure concepts (i.e., rain gardens, green roofs, permeable pavement) for new development in urban areas as a mitigation strategy for extreme heat. Additionally, the county provides financial and technical assistance for those living in buildings without air conditioning during hot months. The county also has numerous tree conservation and tree planting codes and programs through the Urban Forest Management Division, Fairfax County Park Authority, and Northern Virginia Soil and Water Conservation District.

There are numerous barriers to adaptation for this hazard, including the large volume of building stock and the lack of local authority to update the Building Code (e.g. Virginia is a Dillon Rule state). Additionally, policy and code changes that are enacted (such as Building Code updates) apply only to new buildings, and do not retroactively apply to existing buildings. The county does not currently have adaptive capacity to mitigate heat through albedo changes such as cool roofs.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Extreme Heat**	**Total Vulnerability = 6** (Moderate)

Based on the information available, the building sector in Fairfax County is estimated to have moderate overall vulnerability to extreme heat.

3.b. Heavy Precipitation and Inland Flooding – Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Inland Flooding**	**Exposure = 3** (High)

Inland flooding in Fairfax County occurs in two main ways. "Riverine" flooding occurs when buildings located in floodplains are exposed to flooding because heavy precipitation causes water bodies to overflow. For this riverine flooding, the exposure of buildings in the county is relatively small. Only 0.8% of buildings in Fairfax County are located in 100-year floodplains, and only 1.1% are located in 500-year floodplains. Of these structures in floodplains, many are small sheds or storage structures rather than livable space. The second type of inland flooding, "urban flooding," is more common and occurs throughout the county. Urban or pluvial flooding occurs when buildings are exposed to flooding because heavy precipitation overwhelms stormwater management infrastructure, causing roads and properties to flood. Heavy precipitation and inland flooding are projected to intensify and become more frequent, and exposure to this hazard is considered high. Approximately 50% of buildings in the county are located on parcels with two (2) or more flood-prone factors. Approximately 7% of buildings in the county are located on parcels with four (4) or more flood-prone factors. Neighborhoods with known inland flooding issues include but are not limited Bel Air, Chesterbrook, Chesterfield, Virginia Hills, and Harmony Place, a mobile home community in the Route 1 corridor.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Inland Flooding**	**Sensitivity = 3** (High)

Buildings are highly sensitive to inland flooding. Flooding can cause physical damage to buildings and their contents. During severe flooding, many contents within flooded structures that are inundated with water are contaminated and unsalvageable. This is especially the case when flooding effects include sanitary sewer overflows that backup into and flood buildings.[80] Structurally, severe flooding of buildings often requires removal of all contents and dry wall, treatment of the studs, and rebuilding. Excessive moisture produces an increased risk of mold which thrives in wet and warm conditions. This is especially an issue for renters if their buildings are not properly maintained. Commercial, mixed use, industrial, governmental, medical, and other service provider buildings can experience shutdown if precipitation and flooding (or other weather conditions) become extreme. This can lead to delay or disruption of services and production until damage is assessed and safety is ensured. If heavy precipitation occurs in the form of snow rather than rain, heavy snow on a roof or building can cause a collapse.

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of buildings in Fairfax County with respect to heavy precipitation is estimated to be moderate. The county has implemented numerous measures to reduce exposure of buildings to flooding and/or reduce the sensitivity of the building if flooding occurs. However, there remain significant barriers to protecting all buildings across the county.

Fairfax County has numerous policies, programs, and regulations in place to manage stormwater and reduce the likelihood or impact of flood damage. For example, the county regulates and restricts development in the 100-year floodplain including minor floodplains that have drainage areas greater than or equal to 70 acres and major floodplains that start at 360 acres of drainage. This includes many smaller stream valleys that are not included in FEMA defined flood hazard areas. FCPA continues to acquire land in undeveloped floodplain areas adding to the stream valley park system that started in the 1970s. The Building Code and county Zoning Ordinance meet or exceed the National Flood Insurance Program (NFIP) standards and require structures to be elevated above base flood elevation and setback from the floodplain boundary.[81]

Additionally, the Fairfax County Floodplain Management Plan identifies the county's mitigation actions to reduce the impacts of flooding in county floodplains, including a voluntary buyouts program for Repetitive Loss properties[82], funding opportunities to replace vulnerable or undersized culverts, armoring stream banks and constructing flood walls to reduce flood/erosion risk, and providing emergency utility capabilities in critical facilities.[83] As feasible, the county acquires Repetitive Loss and Severe Repetitive Los properties; as of October 2015, 76 residential and one non-residential building have been purchased through these programs. The county also has dedicated staff to process permits for building repairs in the event of storm damage and inspect and maintain public stormwater facilities. The Department of Public Works and Environmental Services (DPWES) is conducting countywide regulatory floodplain mapping updates and assessing future rainfall estimates and climate change impacts. DPWES is working on a Flood Risk Reduction program to more proactively address flooding issues throughout the county.

The county also provides various services, such as flood mitigation assistance, to support individual owners and neighborhoods experiencing flooding. The Northern Virginia Soil and Water Conservation District also provides support to individual property owners on how to address drainage problems. In addition, NVSWCD administers the Virginia Conservation Assistance Program (VCAP) that currently offers technical assistance, training, and financial incentives in the form of cost sharing to property owners in Fairfax County who are experiencing detrimental impacts from stormwater, are not addressing stormwater management requirements already imposed by the jurisdiction in which the property is located, and have not had any site-disturbing construction activities within the past three years.

There are numerous barriers to adaptation for this hazard, including the cost prohibitive nature of flood improvements, existing levels of impervious surface, large feasibility challenges for the county in addressing flooding of neighborhoods that were constructed prior to current regulations and without stormwater conveyance systems, reluctancy of residents to report repetitive loss or drainage issues, and the lack of local authority to update the Building Code (e.g., Virginia is a Dillon Rule state).

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Inland Flooding**	**Total Vulnerability = 18** (High)

Based on the information available, the overall vulnerability of buildings to heavy precipitation and inland flooding in Fairfax County is estimated to be high.

3.c. Severe Storms – Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Severe Storms**	**Exposure = 3** (High)

Buildings are highly exposed to severe storms such as tropical storms, derechos, and severe thunderstorms when they occur. Storm events are projected to intensify in Fairfax County under future climate conditions. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Severe Storms**	**Sensitivity = 3** (High)

Buildings are highly sensitive to severe storm events such as hurricanes, tropical storms, derechos, tornados, severe thunderstorms, and other severe storm events. Severe storm events can inflict damage and reduce the lifetime of buildings and their functionality if they are not designed to withstand the impacts of climate change. Major storms, such as hurricanes, can cause severe breakage to buildings such as damage to roofs and can result in structural failure. Extreme storms can also greatly reduce property value and jeopardize human life. Additionally, severe storms can cause power outages to buildings, which creates additional associated sensitivities.

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Buildings in Fairfax County are estimated to have moderate adaptive capacity to handle severe storms.

For flooding-related factors associated with severe storms, please see the "Heavy Precipitation and Inland Flooding" discussion on buildings.

The Virginia Building Code accounts for wind associated with severe storms, although it does not consider how storms and high wind events may intensify as a result of climate change.[84] The Department of Emergency Management and Security (DEMS) provides guidance to residents on disaster mitigation for severe storms including reinforcing doors, installation of hurricane shutters, securing roofs and doors, anchoring outdoor fuel tanks and other outdoor items, and tree trimming near buildings. While maintenance activities can reduce storm damages, they do not provide full adaptation to these events.

After extreme storm events, the Fairfax County Department of Land Development Services (LDS) deploys building inspectors to assess structural damage and dedicates staff to process permits for storm damage repair. Fairfax County DEMS hosts a Disaster Damage Database that allows residents to report damage caused by disasters, which can help the county secure federal disaster assistance and funding for county residents.

There are numerous barriers to adaptation for this hazard, including the large volume of the county building stock and the lack of local authority to update the Building Code (e.g. Virginia is a Dillon Rule state).

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Severe Storms**	**Total Vulnerability = 18** (High)

Based on the information available, buildings in Fairfax County are estimated to have high total vulnerability to increasing storm severity.

3.d. Extreme Cold - Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Extreme Cold**	**Exposure = 1** (Low)

Buildings are exposed to extreme cold when it occurs. However, in Fairfax County, cold events are projected to decrease in frequency and intensity as temperatures increase, making overall projected exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Extreme Cold**	**Sensitivity = 1** (Low)

Buildings generally have low sensitivity to extreme cold. However, buildings with lower energy efficiency (or more air leaks and less insulation) may be more sensitive to extreme cold. Uninsulated water pipes and fire sprinkler systems in buildings can burst, causing flooding and building damage. Some insulated water pipes may also freeze during extreme cold events depending on the pipe location within the building (such as in unoccupied spaces). The longer the duration of the cold event, the more potential for damage. Repeated freeze and thaw cycles can cause structural damage.

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Buildings in Fairfax County are estimated to have a moderate adaptive capacity to extreme cold. The county has enacted several initiatives to protect buildings against extreme cold; however, numerous adaptation barriers persist.

To enhance residents' adaptive capacity, the county offers programs such as HomeWise, Home Repair for the Elderly Program (HREP), and C-PACE that support weatherization improvements. However, these programs are limited. Uninsulated pipes in older buildings may be challenging to access or cost prohibitive to insulate without incentives. In addition, energy costs may be too high for residents or businesses to maintain appropriate indoor temperatures, particularly in older, draftier buildings. The application of insulation is based on the average temperature range for the area. As these temperatures rise, the amount of insulation required will change in response.

Building codes require temperatures to be maintained at or above 65°F during the months of October through May.[85] Currently, building developers are not required to consider future climate conditions for new or modified existing properties in the Virginia Uniform Statewide Building Codes.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Extreme Cold**	**Total Vulnerability = 2** (Very Low)

Based on the information available, the overall vulnerability of the Fairfax County building sector to extreme cold is estimated to be very low, largely because of low exposure and relatively low sensitivity.

3.e. Coastal Flooding – Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. A small portion of the total building stock in Fairfax County is projected to be exposed to sea level rise inundation and coastal flooding. Specifically, a total of 699 building structures out of 259,440 could be exposed to coastal storm surge flooding, 24 structures could be exposed to flooding with 1 foot of sea level rise, and 122 buildings could be exposed to flooding with 3 feet of sea level rise. This exposure amounts to less than 0.3% of all buildings, 0.24% of residential buildings, 1.5% of public buildings, 0.6% of commercial buildings, and 0.6% of other buildings. (No industrial, mixed-use, or parking garage buildings were found to be exposed). However, because coastal flooding is relevant to a specific area of the county, and may be a serious concern for that area, exposure overlays were also conducted for the "coastal area" specifically, defined as the area within one mile of the Potomac River. (Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps. Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Coastal Flooding**	**Sensitivity = 3** (High)

Buildings are highly sensitive to flooding. Flooding can cause physical damage to buildings and their contents. Commercial, mixed use, industrial, public service, governmental, and other buildings can experience shutdown if flooding becomes extreme, which can lead to delay or disruption of service, operations, and production until damage is assessed. For additional building-related flooding sensitivities, please see the "inland flooding" discussion within this "Buildings" section. For additional population sensitivities, please see the "Populations" section. For additional public service sensitivities, please see the "Public Services" section.

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Coastal Flooding**	**Adaptive Capacity = 3** (Low)

Buildings in Fairfax County are estimated to have moderate adaptive capacity to handle coastal flooding. Cost can present a significant barrier to adaptation for building owners and occupants, especially those with lower financial capacity. Adaptation of buildings to coastal flooding may require elevation of structures or expensive flood-proofing upgrades. Because Virginia is a Dillon Rule state, the Building Code presents an additional barrier to adaptation, because the county lacks local authority. However, the county continues to advocate for updates to the Building Code. For additional detail, please see the "adaptive capacity" section of "heavy precipitation and inland flooding." Many of the items listed for inland flooding are applicable also to coastal flooding.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Coastal Flooding**	**Total Vulnerability = 9** (Moderate)

Based on the information available, the vulnerability of the buildings sector in Fairfax County to coastal flooding is estimated to be moderate. A small percentage of the county's total buildings are projected to be exposed to coastal flooding of the Potomac River and associated water bodies. However, such flooding could present a serious concern for those few neighborhoods affected.

3.f. Drought – Building Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Buildings**	**Drought**	**Exposure = 1** (Low)

Projected exposure to future drought in Fairfax County is low. As precipitation rates increase, drought is not projected to increase with significant frequency and intensity. However, intermittent drought events may still occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Buildings**	**Drought**	**Sensitivity = 1** (Low)

Buildings have low sensitivity to drought conditions. In extreme conditions, prolonged drought can contribute to the shrinking of clay-rich soils, resulting in potential impacts to buildings and infrastructure built on top of these soil types through subsidence.[86]

Adaptive Capacity: Are we able to adapt to and address impacts from this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Buildings**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Information was not found to describe the adaptive capacity of buildings to drought in Fairfax County, likely because drought conditions have not posed significant enough issues to buildings to warrant intervention. Due to this lack of information, adaptive capacity for drought is assigned a default moderate score of two (2).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Buildings**	**Drought**	**Total Vulnerability = 2** (Very Low)

Based on the information available, the overall vulnerability of buildings to drought in Fairfax County is estimated to be very low.

4. WATER INFRASTRUCTURE

The section describes water infrastructure vulnerabilities to climate change. Water infrastructure in this assessment includes infrastructure associated with drinking water, stormwater, and wastewater systems. *Table 10* summarizes the vulnerability scores of each of the water infrastructure subsectors for each climate hazard. These scores are general and qualitative in nature; they are intended to identify high-level vulnerabilities that may need additional county attention and analysis. This table shows that the water infrastructure sector as a whole is most vulnerable to heavy precipitation/inland flooding, severe storms, and extreme heat. The drinking water infrastructure subsector appears to be more vulnerable than the other subsectors. The sections below detail how each of these scores were calculated.

Table 10: Climate Vulnerability Summary - Water Infrastructure

Water Infrastructure Sector – Climate Vulnerability Summary				
Climate Hazards	**Drinking Water**	**Stormwater**	**Wastewater**	**Total**
Extreme Heat	8	4	8	**20**
Inland Flooding	8	12	12	**32**
Severe Storms	18	8	4	**30**
Extreme Cold	9	2	4	**15**
Coastal Flooding	4	4	6	**14**
Drought	6	2	2	**10**
Total	**53**	**32**	**36**	**121**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

4.1. Drinking Water Infrastructure

Drinking water in Fairfax County is provided by the Fairfax County Water Authority, also known as "Fairfax Water." Fairfax Water is a public, non-profit water utility. Fairfax Water is not directly operated by Fairfax County government, but the two entities work in partnership.

The source of drinking water provided by Fairfax Water comes from the Potomac River or Occoquan Reservoir and is treated by four treatment plants as shown on *Figure 5*. Fairfax County's Frederick P. Griffith and James J. Corbalis Jr. treatment plants treat about 345 million gallons of drinking water each day (MGD).[87] The Frederick P. Griffith treatment plant is connected to a pumping station that takes water from the Occoquan Reservoir and has a capacity of 120 MGD.[88] The James J. Corbalis Jr. treatment plant treats water from the Potomac River with a capacity of 225 MGD.[89] Fairfax Water also buys water from the Washington Aqueduct that is owned and operated by the U.S. Army Corps of Engineers. The Washington Aqueduct draws water from the Potomac River that is treated at two plants, the McMillan and Dalecarlia treatment plants, located outside of Fairfax County. The Fairfax Water system supplies about two million individuals in Northern Virginia with potable water.[90] Water supply also supports golf course irrigation and manufacturing/industrial uses.[91]

The portion of the Occoquan Reservoir watershed within Fairfax County is designated within a Water Supply Protection Overlay District. Regulations within this overlay district are established to prevent water quality degradation.[92]

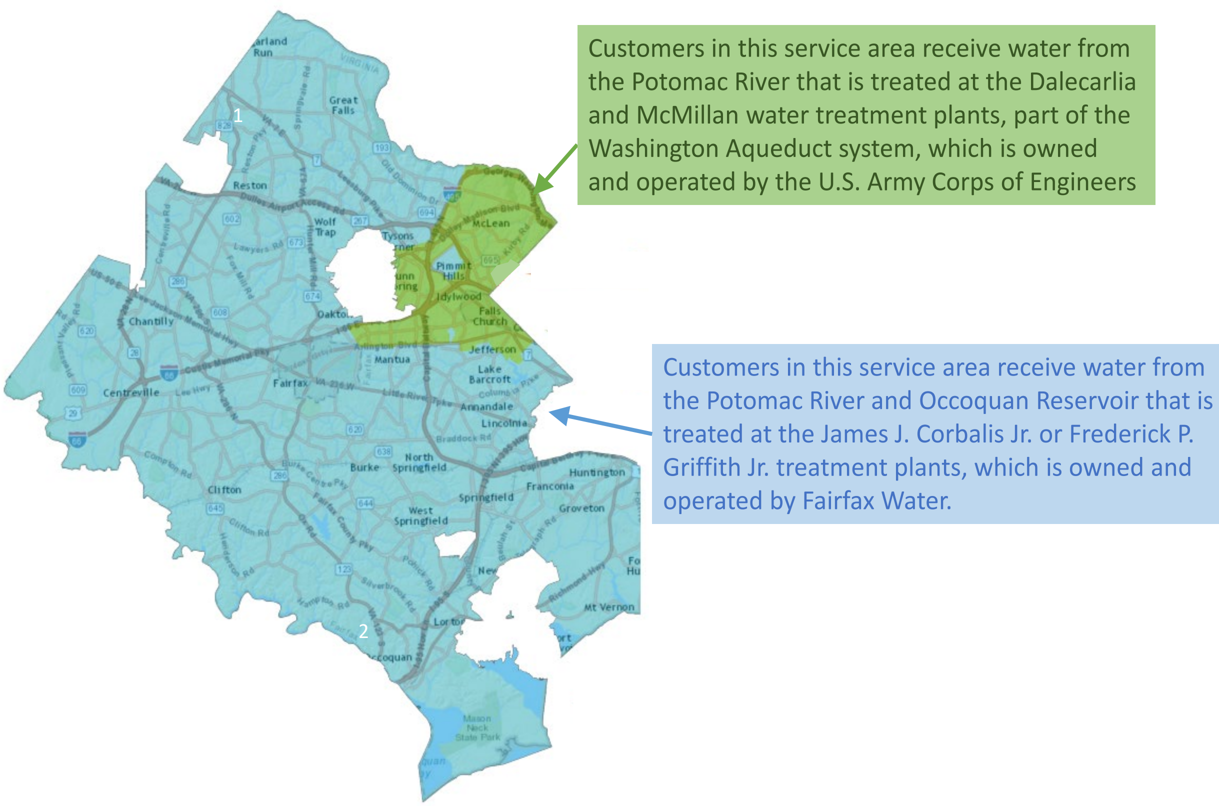


Figure 5: Identifies the source of potable water by customer location
(Source: adapted from Fairfax Water 2021 Annual Water Quality Report)[93]; James J Corbalis Jr Water Treatment Plant location added to image using a "1" marker; Griffith Water Treatment Plant location added to image using a "2" marker.

Private drinking water wells also provide potable water for some Fairfax residents. The Commonwealth of Virginia has established statewide drinking water well regulations and standards. The Fairfax County Health Department, Division of Environmental Health, manages the Onsite Sewage and Water Program, which oversees the implementation of local and state regulations pertaining to private wells.[94] Under Code of Virginia §62.1-258, certified water well system providers are required to submit water well completion reports.[95] The heaviest reliance on private wells tends to be in rural, non-agricultural areas, particularly where new growth occurred beyond the existing public water lines.[96] A 2019 analysis suggests Fairfax County's total groundwater withdrawal was less than 1 MGD or 0.3% of the total drinking water used by the county, where private wells support approximately 15,000 homes and businesses.[97,98]

Every five years since 1990, the Interstate Commission on the Potomac River Basin (ICPRB) Cooperative Section for Water Supply Operations (CO-OP) has conducted a water demand and resource availability forecast for the Washington, DC, metropolitan area (WMA). These studies assess whether the current water supply system will be able to meet the needs of the region at least 20 years into the future. The most recent study forecasts water demands for the WMA throughout the planning horizon, considering projected demographic and societal changes that may affect future water use, forecasts of water availability, potential impacts of changing climate and upstream water use on system resources, and an evaluation of the ability of current and planned system resources to meet the forecasted demands.[99] The ICPRB analysis includes an analysis of the water supply reliability for the Washington metropolitan area including Fairfax Water's service area for a range of climate change projection scenarios. The ICPRB modeling and analysis is intended to capture the range of uncertainty in global climate precipitation and temperature forecasts for future global carbon emissions scenarios, downscaled to the Potomac River basin area.[100]

Table 11 summarizes the overall climate vulnerability scores for drinking water. The discussion following the table provides vulnerability scores broken down by six hazard areas. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard.

Table 11: Climate Vulnerability Summary - Drinking Water

Drinking Water Infrastructure – Climate Vulnerabilities				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	2	2	**8**
Inland Flooding	2	2	2	**8**
Severe Storms	2	3	3	**18**
Extreme Cold	1	3	3	**9**
Coastal Flooding	1	2	2	**4**
Drought	2	3	1	**6**
Total	-	-	-	**53**

4.1.a. Extreme Heat - Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Drinking Water**	**Extreme Heat**	**Exposure = 2** (Moderate)

Drinking water infrastructure is moderately exposed to extreme heat, which is projected to increase significantly. In addition to county-wide general warming due to climate change, certain areas are exposed to higher land surface temperatures due to the Urban Heat Island (UHI) effect. The Griffith Water Treatment Plant, the James J Corbalis Jr Water Treatment Plant, Fairfax Water Headquarters, and 16 other Fairfax Water-owned structures are all located in areas that have been identified as significantly high Urban Heat Islands. In addition to treatment plants, Fairfax Water drinking water infrastructure and buildings include numerous pump stations, storage tanks, transmission facilities, and distribution facilities. Reservoirs that are the primary source of drinking water for the county will also be exposed to projected extreme heat during the summer. Underground pipes or private wells are not as exposed to extreme heat.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Drinking Water**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Drinking water infrastructure is moderately sensitive to extreme heat. Extreme heat can jeopardize quality and availability of these potable water systems, specifically the water quality of the Occoquan Reservoir and the Potomac River. Warmer temperatures promote stagnation, which can facilitate algae growth of harmful species such as blue-green algae that thrive in warm water environments.[101] Increased absorption of sunlight by algal blooms can cause additional warming of the water, which creates optimal conditions for further growth.[102] Unmediated algal bloom is concerning given that algae can release toxins and waterborne pathogens that are dangerous to human health. Increased treatment costs could become necessary to preserve water quality. Fairfax Water has the option to use copper sulfate to treat algae blooms in the Occoquan.

Additionally, long-term durations of extreme temperatures may have the potential to impact groundwater recharge rates which can limit infiltration of water into aquifers that support private well water, decreasing water availability.[103]

Further, extreme heat in Fairfax County has been known to lead to loss of power through blackouts and/or brownouts. Fairfax County drinking water infrastructure is dependent on power to function, so loss of power means loss of drinkable water. For residents who rely on well water rather than public water, loss of power could affect the water well pumps that are driven by electric motors, depending on the resident's source of energy and backup energy. There also may be intermittent summertime heat events that increase water demand to such an extent that supply capacity could be strained.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Drinking Water**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Drinking water infrastructure in Fairfax County has an estimated moderate adaptive capacity to handle extreme heat. Fairfax Water conducts regular maintenance activities that effectively enhance resilience to extreme heat, even if not the primary purpose of those maintenance activities. For example, Fairfax Water coordinates with Dominion Power to address power lines that are sagging due to heat. In addition, Fairfax Water has evaluated water treatment capacity to ensure that maximum-day demands can be met throughout the water supply planning forecast period (currently 2050). The assessment of water demand and reliability conducted by the ICPRB for Fairfax Water's service area includes an assessment for a range of climate change scenarios, including extreme heat.[104]

However, there are existing barriers to adaptation to extreme heat. For example, algae growth and water quality issues cannot be easily controlled at the source of the issue (heat), and instead must be addressed through increased treatment and use of chemicals. Backup generators for adaptation to power outages also present barriers, as described in greater detail in the "severe storms" section below.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Drinking Water**	**Extreme Heat**	**Total Vulnerability = 8** (Moderate)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have has moderate vulnerability overall to extreme heat.

4.1.b. Heavy Precipitation and Inland Flooding - Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Drinking Water**	**Inland Flooding**	**Exposure = 2** (Moderate)

Drinking water infrastructure components in Fairfax County are moderately exposed to heavy precipitation. By necessity and design, water supply intakes and related infrastructure are located directly in waterbodies and adjacent floodplains. Other drinking water distribution systems including pipes and pumps are located in stream valleys or other low-lying areas that are susceptible to flooding or stream bank erosion. Specifically, 64 miles (or 1.6%) of Fairfax Water's pipes are located in FEMA 100-year or 500-year floodplains. However, the two Fairfax Water treatment plants are not located in floodplain areas, nor are any other Fairfax Water-owned buildings that were included in this analysis. Heavy precipitation is projected to increase in intensity and quantity in the coming decades.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Drinking Water**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Drinking water infrastructure in Fairfax County is estimated to be moderately sensitive to heavy precipitation and flooding. This means that serious operational issues can occur, but the hazard does not cause complete shutdown of the infrastructure. Heavy precipitation and inland flooding refers to both "riverine" flooding, which is caused by water bodies overflowing, and "urban" flooding, which is caused by heavy precipitation overwhelming stormwater management infrastructure. While many components of drinking water infrastructure are, by design, insensitive to water, other components can be seriously vulnerable to flooding conditions.

Inland flooding can cause stress to the intake, treatment, and conveyance of drinking water through overwhelming of infrastructure, exposure of underground lines due to flooding-related erosion, damage to necessary structures, and reduction in water quality. Fairfax Water notes that they have experienced flooding of their intake structures, where water levels rose high enough to overtop the parapet wall, creating a risk of electrical facility impacts. Electrical power for drinking water infrastructure has also been threatened due to flooding-related downed trees onto power lines. Water infrastructure pipes are also vulnerable to stream erosion associated with heavy precipitation events. For example, at the time of writing, there is an exposed water main pipe along Route 7 due to flooding-related stream erosion. Similarly, previous large storm events have washed out section of bridge, leaving water main sections exposed. Underground drinking water infrastructure such as pipes may be exposed to rising pressures as the groundwater table rises in response to the projected heavy precipitation. If cracks, joint failures, or other problems with the pipes exist, then seepage from groundwater and during heavy precipitation events can occur, affecting water quality. Heavy precipitation and inland flooding causes water turbidity and increases debris in the water supply, which creates a need for higher chemical doses and operational cost to treat the water. Additionally, though future conditions suggest a shifting of precipitation from snow to rain events, the snowstorms that do occur are projected to become more intense and may require more intervention such as salting. Salting of impervious surfaces, such as roads and sidewalks results in salt load runoff into the river system, causing higher concentrations of salt in the Potomac River and Occoquan Reservoir. [105] Staff that support drinking water facilities may also be hindered in their ability to access facilities during severe flooding. Fairfax Water notes that in the past, flooding has blocked access to the intake facility.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Drinking Water**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Drinking water infrastructure in Fairfax County is estimated to have a moderate adaptive capacity for heavy precipitation and inland flooding. Adaptive capacity is scored according to four measures. (See Appendix 1 for methodology).

Fairfax Water's staff conduct regular maintenance activities that enhance resilience to flooding hazards. Their staff include skilled operators and treatment plant staff who know the facilities well and are trained to correctly respond when heavy precipitation and flooding impact water quality. Fairfax Water has worked to obtain more than one power source of water pumping stations where practical.[106] Fairfax Water has also evaluated water treatment capacity to ensure that maximum-day demands can be met throughout the water supply planning forecast period (currently 2050). The assessment of water demand and reliability conducted by the ICPRB for Fairfax Water's service area includes an assessment for a range of climate change scenarios, including future changes to precipitation applied to projected changes in stream flows).[107]

However, there are also barriers to adaptation to increased inland flooding. From a water treatment perspective, reduced water quality from flooding creates a need to purchase additional chemicals and for increased hauling of residuals off site, both of which translate to added cost for Fairfax Water. As a non-profit public utility, Fairfax Water keeps rates low, follows a strict process to determine water rates, and cannot increase them as easily as a private utility would.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Drinking Water**	**Inland Flooding**	**Total Vulnerability = 8** (Moderate)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have moderate overall vulnerability to projected heavy precipitation and inland flooding.

4.1.c. Severe Storms – Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Drinking Water**	**Severe Storms**	**Exposure = 2** (Moderate)

Drinking water infrastructure in Fairfax County is moderately exposed to severe storms, such as tropical storms, derechos, and severe thunderstorms. The infrastructure used for conveyance of drinking water is largely underground, and therefore less exposed to severe storm effects. However, the water treatment facilities are located above ground, and the distribution of water is enabled by over 30 pump stations distributed throughout the county. Additionally, the electricity lines used to power the water system are largely above-ground and exposed to storm and wind effects. Severe storms are projected to become more intense, which could translate to facilities being exposed to high wind speeds and potential damage. Flooding-related exposures are captured in the other sections concerning inland and coastal flooding. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Drinking Water**	**Severe Storms**	**Sensitivity = 3** (High)

According to Fairfax Water, drinking water infrastructure is highly sensitive to severe storms. Drinking water infrastructure is dependent on electricity, so loss of power can translate to loss of access to drinkable water during and after severe storm events. Water treatment plants are the most sensitive component of the drinking water infrastructure system in terms of power outage impacts. However, Fairfax Water notes that there are many other sensitive components of the drinking water system between the river intake and the tap, including pump stations, transmission facilities, distribution facilities and storage tanks. Additionally, loss of water (through loss of power) creates additional severe sensitivities such as loss of water availability for fire and rescue operations. Further, severe storms have created water quality issues including total organic carbon levels in the Occoquan Reservoir, which is the source of drinking water supply. These water quality issues translate to increased challenges for operators, increased cost to Fairfax Water, and increased use of chemicals.[108]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Drinking Water**	**Severe Storms**	**Adaptive Capacity = 3** (Poor)

The drinking water infrastructure in Fairfax County has an estimated poor adaptive capacity for severe storms. There are significant barriers to adaptation for drinking water facilities impacted by severe storms including cost, community impacts, and logistical operations of resilience measures.

Fairfax Water conducts regular maintenance activities that enhance resilience to the impacts of severe storms and has implemented specific actions to increase resilience. For example, Fairfax Water has installed an oxygenation system to the bottom of the Occoquan Reservoir to oxygenate water that may be of poor quality following storm events.

Fairfax Water has taken measures to reduce the risk of power outages and improve electrical system reliability at its drinking water treatment facilities.[109] However, treatment plants and some pumping stations do not have back-up generators. Fairfax Water reports that generators capable of providing power to facilities as large as drinking water facilities can cost tens of millions of dollars. The size of such generators (and associated sound enclosures) has impacts on the surrounding community. Additionally, such generators rely on substantial amounts of fuel, which may already be scarce during a severe storm event.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Drinking Water	Severe Storms	**Total Vulnerability = 18** (High)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have high vulnerability to severe storm events.

4.1.d. Extreme Cold - Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Drinking Water	Extreme Cold	**Exposure = 1** (Low)

Extreme cold is projected to decrease as the temperature increases, making overall projected future exposure to this hazard low. However, intermittent extreme cold may still occur, and drinking water infrastructure and facilities are exposed to extreme cold during such events. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Drinking Water	Extreme Cold	**Sensitivity = 3** (High)

Drinking water infrastructure is highly sensitive to extreme cold. The river ices over after a period of 5-7 days below freezing. When the river freezes, small ice forms that can blind the intake facilities. Having ice on the river also renders maintenance infeasible without employment of divers and ice cutting techniques. Certain treatment processes like flocculation and sedimentation basins and filtering practices that are not enclosed are susceptible to extreme cold. Further, water pipes that aren't well insulated can freeze and burst during extreme cold conditions. Water meters in Fairfax County have also frozen, impacting water supply. Extreme cold when combined with ice can also slow down response times, rendering it more difficult for maintenance officials to respond to drinking water infrastructure issues.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Drinking Water	Extreme Cold	**Adaptive Capacity = 3** (Poor)

Fairfax County drinking water infrastructure has an estimated poor adaptive capacity for extreme cold events.

Fairfax Water conducts maintenance activities such as winterization of equipment and sub-systems that enhance resilience to winter cold, but extreme cold continues to be a significant concern. When water meters have frozen, Fairfax Water has installed insulation within the water meters. However, because there are 100,000s of water meters, they have only been able to address meters on a case-by-case basis. Fairfax Water has also installed heaters and garage doors at the intake facility. Further, Fairfax Water's public affairs group conducts outreach during extreme cold events encouraging residents to take actions that reduce risk, including letting their water drip.

There are significant barriers to adaptation for extreme cold. For example, if the electrical grid is affected by an extreme cold event, some of the hazard mitigation actions taken by Fairfax Water would no longer work. As noted above, generators capable of providing power to facilities as large as drinking water facilities can cost tens of millions of dollars.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Drinking Water	Extreme Cold	**Total Vulnerability = 9** (Moderate)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have a moderate overall vulnerability to extreme cold. The vulnerability is scored as "moderate" rather than "high" because projected future exposure to extreme cold events is low.

4.1.e. Coastal Flooding – Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Drinking Water	Coastal Flooding	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. Drinking water treatment facilities and other Fairfax Water-owned buildings in Fairfax County are not projected to be exposed to coastal flooding. However, underground drinking water infrastructure such as pipes may be exposed if coastal erosion occurs. Specifically, 18.5 miles (or 0.5%) of Fairfax Water pipes are projected to be exposed to coastal storm surge. In the past 90 years, the Potomac and Anacostia Rivers have already experienced 11 inches of sea level rise.[110] (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Drinking Water**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Drinking water infrastructure is moderately sensitive to coastal flooding. Depending on the location of underground pipes, coastal erosion could expose underground water pipes. For additional flooding impacts, please see the "inland flooding" section. Coastal flooding sensitivities are much less prevalent than inland flooding sensitivities in Fairfax County.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Drinking Water**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Fairfax County drinking water infrastructure has an estimated moderate adaptive capacity for coastal flooding hazards. Fairfax Water's staff conduct regular maintenance activities that enhance resilience to coastal flooding hazards and through monitoring activities can identify and address erosion concerns and pipe exposure.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Drinking Water**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have low overall vulnerability to coastal flooding.

4.1.f. Drought - Drinking Water Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Drinking Water**	**Drought**	**Exposure = 2** (Moderate)

Drought is projected to be a comparatively lower future concern for Fairfax County, as precipitation on average is projected to increase rather than decrease. However, episodic drought may still occur in the future, and drinking water sources would be highly exposed to those events. Therefore, exposure for this hazard for this infrastructure is deemed to be "moderate." Future climate change-related impacts to the water supply and demand (including drought) are assessed and documented in greater detail in the ICPRB report.[111] Fairfax County, located in the Potomac River basin, has experienced drought watches during 2002, 2007, and 2010. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Drinking Water**	**Drought**	**Sensitivity = 3** (High)

Drinking water infrastructure is highly sensitive to drought. Drinking water availability is dependent on drinking water supply, which is heavily threatened by drought conditions. Long-term hydrologic drought can impact public water supplies, forcing local governments to enact water conservation restrictions.[112] Drought can also lead to increased algae growth, which creates the need for higher use of chemicals for water treatment. Decreased rainfall can lead to polluted groundwater and surface waters with contaminants that cause acute infectious disease, requiring increased water treatment and higher risk to using water from private wells.[113] Groundwater storage may be not replenished at a fast enough rate to support well water demand.[114]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Drinking Water**	**Drought**	**Adaptive Capacity = 1** (Good)

Drinking water infrastructure systems in Fairfax County are estimated to have good or strong adaptive capacity for drought. Measures have been taken to reduce the worst of potential drought impacts on the drinking water system.

There are numerous regional drinking water supply plans and planning activities in case of drought, including the Northern Virginia Regional Water Supply Plan,[115] the Metropolitan Washington Water Supply and Drought Awareness Response Plan,[116] and reports by the Interstate Commission on the Potomac River Basin (ICPRB),[117] among others. ICPRB has also established technical drought operations.[118] Fairfax Water is a public, non-profit water utility and a party to the Water Supply Coordination Agreement (WSCA) of 1982. As specified in the WSCA, the ICPRB CO-OP assumes a direct role in managing water supply resources and withdrawals during Potomac River drought periods. Every five years since 1990, the CO-OP has conducted a water demand and resource availability forecast for the WMA. Fairfax Water has evaluated water treatment capacity to ensure that maximum-day demands can be met throughout the water supply planning forecast period (currently 2050). These studies assess whether the current water supply system will be able to meet the needs of the region at least 20 or more years into the future. The most recent study forecasts water demands for the WMA throughout the planning horizon, considering potential impacts of changing climate and upstream water use on system resources. [119] Additionally, Fairfax County's Code of Ordinances gives authority for the restriction of water use or the absolute curtailment of water use.[120] These plans and activities help to increase preparedness and capacity to address drought conditions.

Additionally, in anticipation of a prolonged regional drought event as well as population growth, Fairfax County's Vulcan Quarry Project has been undertaken to provide storage of up to 17 billion gallons of water.[121,122] The reservoir will provide significant additional storage for use in the event of a prolonged regional drought. This new reservoir will be used to supplement water supply to ensure the success of Fairfax Water's mission to provide reliable, high-quality drinking water well into the future. The northern part of the quarry will be transferred to Fairfax Water by the end of 2035, and the remainder of the quarry will be transferred to Fairfax Water in 2085.[123]

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Drinking Water**	**Drought**	**Total Vulnerability = 6** (Moderate)

Based on the information available, drinking water infrastructure in Fairfax County is estimated to have a moderate overall vulnerability to drought. However, additional research is needed on this topic.

4.2. Stormwater Infrastructure

The Fairfax County Department of Public Works and Environmental Services (DPWES) is responsible for the maintenance of the county's network of stormwater infrastructure.[124] The county maintains the public storm drainage system within dedicated storm drainage easements, while the Virginia Department of Transportation (VDOT) maintains storm systems in public street rights-of-way. The county maintains over 1,350 miles of pipes, almost 65,000 structures, and 200 miles of manmade channels. VDOT maintains over 1,370 miles of stormwater infrastructure.[125,126] The storm drainage easements provide the county access and use rights to property for stormwater management purposes. These easements are generally located in residential areas, commercial, industrial, and institutional properties (for through-drainage), and county-owned property. [127] There are also private drainage systems that are not maintained by the county. All stormwater ultimately drains to the Potomac River, the Occoquan River, and the Chesapeake Bay.

According to the Department of Emergency Management and Security (DEMS), there are 45 dams located in Fairfax County, 26 of which are classified as "High Hazard" because of the consequences that would be associated with potential failure of the dam structure[128]. Based on information provided by DPWES, DEMS maintains an inventory of all dams, including dam locations, ownership, pool volume, impoundment capacity, and use.

The Fairfax County Public Facilities Manual (PFM) defines a stormwater conveyance system as the combination of manmade and natural drainage components used to convey stormwater discharge.[129] Per Chapter 6 of the Fairfax County PFM, a minor drainage system is, "normally designed for the 10-year storm, and consist of storm sewer appurtenances and conduits such as inlets, manholes, street gutters, roadside ditches, swales, small underground pipe and small channels which collect stormwater runoff and transport it to the major system." [130] A major drainage system is, "designed for the less frequent storm up to the 100-year level, and consists of natural waterways, large man-made conduits, and large water impoundments." In addition, a major system includes some less obvious drainageways such as overland relief swales and infrequent temporary ponding at storm sewer appurtenances. A major system includes not only the trunk line system which receives the water from the minor system, but also the natural backup system which functions in case of overflow from or failure of the minor system." [131]

Stormwater retention and detention facilities, such as wet and dry ponds, reduce the peak rate of discharge of the drainage system, reduce downstream erosion problems, and reduce environmental problems associated with increased stormwater runoff. [132] The stormwater management system in Fairfax County is separate from the wastewater system; Fairfax County does not have a combined sanitary and storm sewer system like older cities and counties like Washington D.C. and Arlington County.

The stormwater conveyance systems are designed to capture and convey stormwater runoff from precipitation during a specific storm event (i.e., the design storm). It is not designed to capture and carry away all stormwater from large storm events, and the capacity could be exceeded, resulting in localized flooding.[133]

There are new policies and changing practices that will help better prepare stormwater management infrastructure for future climate conditions. Based on 2020 legislation adopted by the Virginia General Assembly in 2020 and the State Water Control Board adopted amendments to the Chesapeake Bay Preservation Area Designation and Management Regulations, the county is required to amend their ordinances to consider climate change. The amendment also mandates incorporation of natural features or measures such as the planting of vegetation or trees, preservation of existing natural vegetation and trees, and reduction of land disturbance and impervious cover to the maximum extent practicable consistent with the applicable best management practices. This is applicable to all adaptive capacity sections presented below. In 2021, VDOT revised its specific requirements of the Structure and Bridge Division for the design of structures for climate change and coastal storms (Chapter 33). In addition, VDOT revised its Drainage Manual Chapter 12, Riverine Analysis, to include additional analysis of larger storms for projects associated with stream crossings, flood plain encroachments and other projects in certain size streams and rivers.

Table 12 summarizes the climate vulnerability scores for stormwater infrastructure. The discussion following the table provides vulnerability scores broken down by six hazard areas. For each hazard, vulnerability was scored through consideration of the stormwater infrastructure's exposure, sensitivity, and adaptive capacity to that hazard.

Table 12: Climate Vulnerability Summary - Stormwater Infrastructure

Stormwater Infrastructure – Climate Vulnerability				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	1	2	**4**
Inland Flooding	3	2	2	**12**
Severe Storms	2	2	2	**8**
Extreme Cold	1	1	2	**2**
Coastal Flooding	1	2	2	**4**
Drought	1	1	2	**2**
Total	-	-	-	**32**

4.2.a. Extreme Heat - Stormwater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**SWM Infrastructure**	**Extreme Heat**	**Exposure = 2** (Moderate)

Stormwater infrastructure is collectively moderately exposed to extreme heat conditions. In addition to general county-wide warming, there are certain areas of the county with hotter land surface temperatures than other areas due to the Urban Heat Island (UHI) effect. Certain above-ground components of stormwater infrastructure, such as stormwater infrastructure ponds, meadows, and green roofs, are highly exposed to extreme heat conditions. Over 81% of stormwater management facilities and 77% of stormwater nodes mapped technically fall within areas with significantly high UHI. However, some of these components are underground, reducing exposure. Most components of the stormwater system, such as underground conveyance pipes, have little to no exposure to extreme heat. Extreme heat conditions are projected to increase. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**SWM Infrastructure**	**Extreme Heat**	**Sensitivity = 1** (Low)

Though stormwater infrastructure can be impacted by extreme heat, the impacts are not significant in affecting operations; stormwater infrastructure is considered minimally sensitive to this hazard. Stormwater management infrastructure can be classified into two major types: (1) infrastructure that handles water quality, and (2) infrastructure that handles water quantity. Extreme heat mostly affects the *quality* side. Water quality of wet ponds may be affected during extreme heat conditions if algae becomes an issue. In addition, wet ponds may "heat up" during the summer months acting as a heat sink between storm events. Stormwater infrastructure may be further impacted by warm or hot stormwater runoff conditions due to runoff draining across hot pavement before entering the system (note that storm drains lead to streams, not a wastewater treatment facility). Wet pond water and runoff temperatures may increase, and higher temperatures can impact the ecological health of the receiving stream and other waterbodies. Extreme heat during dry conditions can impact the health of vegetation in other BMPs such as bioretention filters, green roofs, and meadows, reducing their capacity to serve as water storage during heavy rainfall events. Potential power outages during heat events may affect pump operations if backup power is not available.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County is estimated to have moderate adaptive capacity to handle extreme heat. Fairfax County DPWES routinely monitors its system for potential impacts. DPWES has staff capacity to conduct monitoring and skills to evaluate data. The Stormwater Management Program supports implementation of policies and actions that protect water quality in streams that might be affected by hot stormwater runoff. There are numerous policies in place that support natural landscaping and encourage the reduction of impervious surfaces or protection of natural resources. Certain aquatic vegetation may help to regulate pond water temperatures.[134] There are, however, barriers to adaptation, including cost and logistics of removing impervious surfaces and increasing tree canopy.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Extreme Heat**	**Total Vulnerability = 4** (Low)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have low overall vulnerability to extreme heat, largely due to low sensitivity.

4.2.b. Heavy Precipitation and Inland Flooding -Stormwater Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	SWM Infrastructure	Inland Flooding	**Exposure = 3** (High)

"Heavy precipitation and inland flooding" refer to both "riverine flooding," which is caused by water bodies overflowing onto floodplains, and "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Stormwater infrastructure will be highly exposed to the projected heavy precipitation, inland flooding, and rising groundwater table, because such infrastructure has an inherent purpose of conveying such water. DPWES has noted that some stormwater conveyance infrastructure, by design, is located in low-lying flood prone/plain areas, making it more vulnerable to flood damage.[135]

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	SWM Infrastructure	Inland Flooding	**Sensitivity = 2** (Moderate)

The focus of this section is to evaluate whether the stormwater management infrastructure *itself* is sensitive to heavy precipitation and inland flooding. Generally speaking, because stormwater management infrastructure has an inherent purpose of handling heavy precipitation, the infrastructure itself is not highly sensitive or prone to damage by precipitation. However, heavy precipitation can overwhelm stormwater infrastructure and dams. Stormwater infrastructure in older neighborhoods, such as stormwater conveyance pipes, may be undersized and in deteriorating condition compared to today's design standards, and experiencing increased runoff due to an increased number of impermeable surfaces. Debris can accumulate in catch basins, facilitating or increasing overload of drainage systems[136]. Extreme precipitation can also inflict structural damage on stormwater systems reducing their capacity to protect the built environment. Structures are also at risk from overcapacity during intense precipitation events. Continued changes in precipitation patterns can cause expansion and alteration of flood prone areas, placing additional strain on stormwater infrastructure. These hazards may also result in more dam overtopping and activated emergency spillways. Finally, flooding caused by storms and heavy precipitation may impact the functionality of the water quality stormwater infrastructure, such as bioretention ponds, which would adversely affect the county's ability to meet the Municipal Separate Storm Sewer System (MS4) and Chesapeake Bay Total Maximum Daily Load (TMDL) requirements.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County has an estimated moderate adaptive capacity to handle heavy precipitation and inland flooding. As described below, there are maintenance activities, policies, and actions being taken by the county to counteract inland flooding. However, these measures alone will not eliminate the current and future impacts associated with heavy precipitation and inland flooding on stormwater infrastructure.

Older subdivisions in the county that were constructed prior to stormwater management regulations (e.g., with insufficient or no conveyance systems) are especially susceptible to inland flooding. The concept of retroactively building or retrofitting stormwater systems in already-built communities has significant feasibility barriers.

Excess and increased runoff can put undue strain on stormwater management infrastructure itself. The Fairfax County PFM requires stormwater systems to move stormwater runoff from development sites to natural streams or manmade drainage facilities with enough capacity to ensure no adverse impacts.[137, 138] Increased and preventative maintenance can help to reduce blocks in the system and reduce the impacts of runoff on the stormwater management infrastructure during flooding events. Assessments have been done and are ongoing to determine appropriate infrastructure upgrades and flood mitigation strategies to protect vulnerable infrastructure.[139] The Fairfax County Floodplain Management Plan also identifies mitigation actions to take to avoid and/or reduce the impacts of flooding in county floodplains. These include armoring stream banks and constructing flood walls to reduce flood/erosion risk. There are several policies and actions regarding the reduction of impervious surfaces that will reduce stormwater runoff and help to reduce flood-related risk to the stormwater management system infrastructure. Implementing planning strategies usually requires longer time frames to see an impact and large capital planning requires necessary funding be available.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Inland Flooding**	**Total Vulnerability = 12** (Moderate)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have moderate total vulnerability to increasing heavy precipitation and inland flooding.

4.2.c. Severe Storms - Stormwater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**SWM Infrastructure**	**Severe Storms**	**Exposure = 2** (Moderate)

Above-ground stormwater infrastructure such as green roofs, dams, or open conveyance channels are exposed to severe storm and wind events. Below-ground stormwater infrastructure such as stormwater pipes are less exposed to storm events but may be exposed through storm-related debris blocking the system. Severe storm and wind events such as tropical storms, derechos, and severe thunderstorms are expected to increase in severity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**SWM Infrastructure**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Stormwater infrastructure has moderate sensitivity to severe storm and wind impacts. (Heavy precipitation associated with severe storms is discussed in the section above). Stormwater infrastructure is typically not damaged during severe storm and wind events. However, stormwater management *operations* may be affected through storm-related debris blocking the system. Power outages may impact electrical system components. Storm-related impacts to the transportation network could impact the ability of the county to conduct maintenance, repair, and debris removal after a storm event, further impacting the system.[140]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County is estimated to have moderate adaptive capacity to handle severe storms. DPWES regularly checks known problem areas, especially before large storm events, and proactively implements mitigation strategies to reduce chances for blockage. Further, the county has taken measures to strengthen electrical system reliability of stormwater facilities to reduce damage from climate related impacts by installing back-up generators. However, storm events are unpredictable and can create conditions that are unique, not easily anticipated and planned for, and may require substantial manpower to remove debris and return to business-as-usual conditions.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Severe Storms**	**Total Vulnerability = 8** (Moderate)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have moderate vulnerability to severe storms.

4.2.d. Extreme Cold – Stormwater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**SWM Infrastructure**	**Extreme Cold**	**Exposure = 1** (Low)

Stormwater drainage systems may be exposed to extreme cold events when they occur. However, climate projections predict a reduction in extreme cold conditions in Fairfax County, including freeze-thaw cycles, rendering overall exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**SWM Infrastructure**	**Extreme Cold**	**Sensitivity = 1** (Low)

Stormwater systems may be mildly vulnerable to damage from exposure to freeze-thaw cycles and freezing debris-blocked stormwater lines.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County has an estimated moderate adaptive capacity for extreme cold. New stormwater infrastructure has been designed to withstand freeze-thaw cycles and cold temperatures. Older stormwater infrastructure remains susceptible and requires substantial investment to replace. (For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Extreme Cold**	**Total Vulnerability = 2** (Very low)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have very low total vulnerability to extreme cold.

4.2.e. Coastal Flooding - Stormwater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**SWM Infrastructure**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. There is a small amount of stormwater infrastructure within areas exposed to projected coastal flooding. Specifically, 32 (or 0.4% of) stormwater management facilities, 15.77 line miles (0.4%) of stormwater arcs, and 979 (0.5%) of stormwater nodes, are projected to be exposed to coastal flooding. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**SWM Infrastructure**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Stormwater infrastructure is moderately sensitive to coastal flooding. Intense coastal flooding can overwhelm and damage stormwater infrastructure. Debris can accumulate in catch basins, facilitating or increasing overload of drainage systems[141]. In some Fairfax County neighborhoods such as Huntington and New Alexandria, past coastal flood events have already overwhelmed existing stormwater infrastructure and conveyance systems both within and outside of the floodplain.[142] As sea level rises, there is a projected expanse and intensity of coastal flooding, placing additional strain on stormwater infrastructure. Dangerous travel conditions can restrict or delay maintenance and repair.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County has moderate adaptive capacity for coastal flooding. The "adaptive capacity" sections under "heavy precipitation and inland flooding" and "extreme heat" describe adaptation actions that are also relevant to coastal flood mitigation. There are barriers to implementation, including funding. (For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have a low total vulnerability to coastal flooding.

4.2.f. Drought – Stormwater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**SWM Infrastructure**	**Drought**	**Exposure = 1** (Low)

Any above-ground stormwater infrastructure, such as ponds, meadows, bioswales, and green roofs are exposed to and could be impacted by drought conditions. Drought is not projected to be a significant climate hazard for Fairfax County in the coming decades, given projections for increasing precipitation. Therefore, overall exposure is estimated to be low. However, intermittent droughts may occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**SWM Infrastructure**	**Drought**	**Sensitivity = 1** (Low)

Stormwater infrastructure is minimally sensitive to drought. Drought can impact water quality of stormwater infrastructure such as wet ponds. It may also affect the health of vegetation in green roofs and meadows, reducing their capacity to serve as water storage during heavy rainfall events. Sedimentation may accumulate in stormwater pipes reducing operational capacity.[143]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**SWM Infrastructure**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Stormwater infrastructure in Fairfax County is estimated to have moderate adaptive capacity to drought. With over two-thirds of the county's SWM facilities owned and/or maintained by private property owners,[144] there may be challenges to implementing county-recommended resilience projects. Green infrastructure systems including bioretention systems and green roofs do have some natural capacity to accommodate drought conditions. DPWES selects vegetation that can handle both wet and dry conditions in the region. By monitoring drought conditions, the county is able to identify when such maintenance activities need to be increased.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

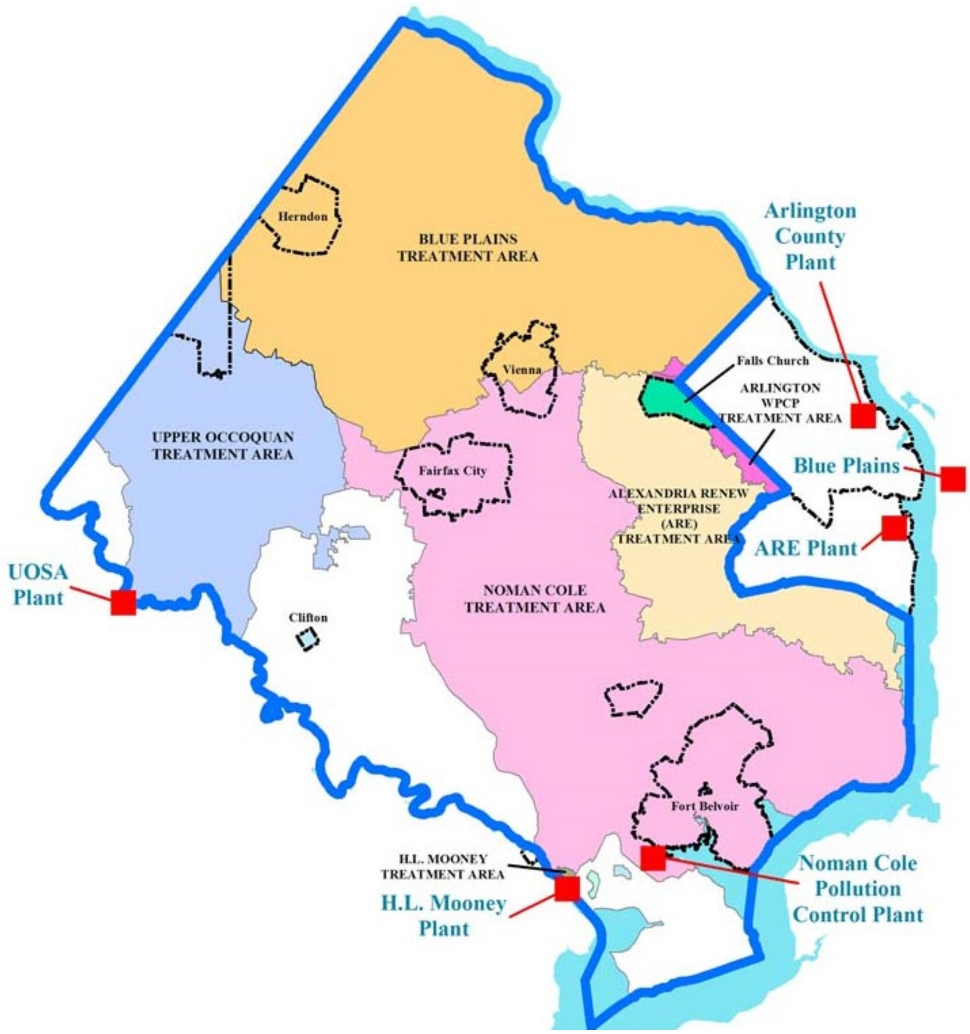
Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**SWM Infrastructure**	**Drought**	**Total Vulnerability = 2** (Very Low)

Based on the information available, stormwater infrastructure in Fairfax County is estimated to have very low total vulnerability to drought.

4.3. Wastewater Infrastructure

In Fairfax County, wastewater management infrastructure collects and treats wastewater, defined as sewage-water discharged from homes and businesses through the sanitary sewer system, for roughly 264,000 residential and commercial customers. [145] Once treated, the wastewater is then released back into the region's waterways. Through several interjurisdictional service agreements, wastewater is conveyed to one of six regional treatment facilities: Noman M. Cole Jr Pollution Control Plant in Fairfax County, Blue Plains Advanced Wastewater Treatment Plant in the District of Columbia, Arlington Water Pollution Control Plant in Arlington, VA, Upper Occoquan Service Authority in Fairfax County, Alexandria Renew Enterprise in Alexandria, VA, and H.L. Mooney Advanced Water Reclamation Facility in Prince William County, VA. (See *Figure 6* for location of treatment plants and distribution of treatment of the county's wastewater, and *Figure 7* for locations of pump stations and major trunk lines).[146]

The county owns and operates the Noman M. Cole, Jr., Pollution Control Plant, which treats approximately 40 million gallons per day of wastewater from homes and businesses.[147] In addition, some residences in Fairfax County rely on septic tanks for private onsite sewage treatment. There are over 24,000 onsite septic systems in the county.



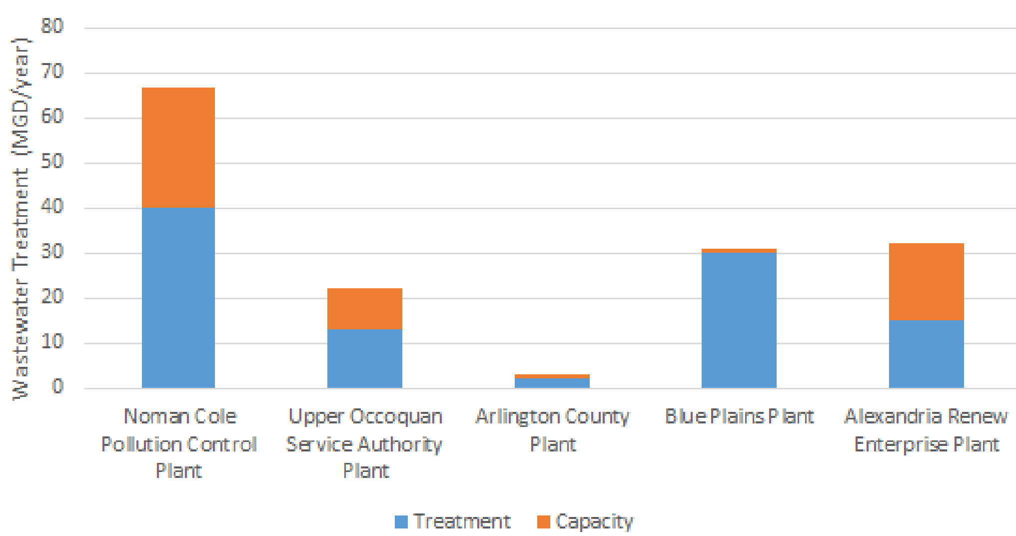


Figure 6: Locations of Wastewater Treatment Facilities
(top) and the current distribution and capacity of wastewater treatment across facilities, based on current county production of 100 million gallons per day (MGD) (bottom)
(Source: DPWES)

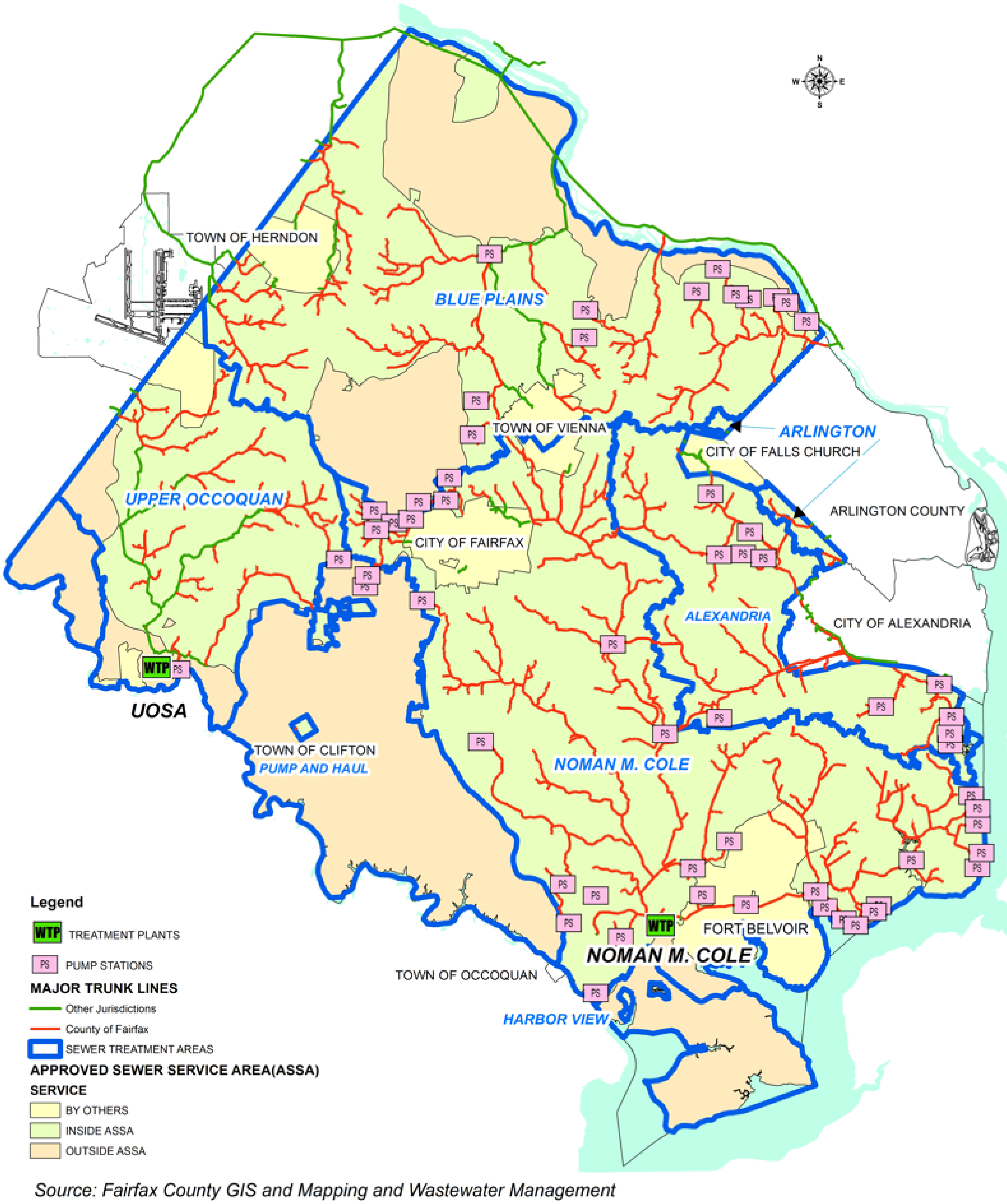


Figure 7: Sewershed Map

Table 13 summarizes the climate vulnerability scores for Fairfax County's wastewater infrastructure system. The discussion following the table provides vulnerability scores broken down by six hazard areas. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard.

Table 13: Climate Vulnerability Summary - Wastewater Infrastructure

Wastewater Infrastructure – Climate Vulnerability Water				
Climate Hazards	Exposure	Sensitivity	Adaptive Capacity	Total
Extreme Heat	2	2	2	**8**
Inland Flooding	2	3	2	**12**
Severe Storms	2	2	1	**4**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	3	2	**6**
Drought	1	1	2	**2**
Total	-	-	-	**36**

4.3.a. Extreme Heat – Wastewater Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Extreme Heat**	**Exposure = 2** (Moderate)

Wastewater infrastructure has moderate exposure to extreme heat conditions. Many wastewater infrastructure components, such as sewer lines, are buried more than four feet underground. Exposed pipes are often in encasements. Wastewater management staff working outdoors, however, may be exposed to extreme heat conditions, particularly during daytime hours. Additionally, both the Noman Cole Wastewater Treatment Plant and the Upper Occoquan Sewage Treatment Plant are located in areas with significantly higher land surface temperature due to the Urban Heat Island (UHI) effect. Further, 71% of sewer structures and 44% of wastewater pump stations are in areas with high UHI.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**WW Infrastructure**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Wastewater management infrastructure systems are moderately sensitive to extreme heat. Extreme heat events can impact wastewater treatment and conveyance, which includes sanitary sewer lines, pumping stations, and flow metering stations. Impacts can include the performance of biological systems, oxidation ponds, and sludge management.[148] *Wastewater* temperatures above 95°F can cause microorganisms beneficial to the biological wastewater treatment process to slow down and potentially cease functioning. This is unlikely by 2050, because current summertime *wastewater* temperatures are rarely above 77°F. During current heat waves, despite significant air temperature swings, wastewater temperatures rarely increase by more than 1.8°F. Increases in wastewater temperatures that are released into the region's waterways can decrease oxygen solubility and accelerate oxygen absorption. Increase in algal growth and generally diminishing water quality in receiving waters may lead to more stringent requirements for wastewater discharge, higher treatment costs, and the need for capital improvements.

Heat events may also lead to power outages, affecting wastewater management operations. (Excluded from this are all 63 pump stations which have a generator to provide secondary power should an outage occur). Frequent outages may require 24-hour management to ensure uninterrupted service and continual conveyance of wastewater to the wastewater treatment facility. Prolonged temperatures over 100°F could make it difficult for employees to complete mission-essential functions outdoors, posing problems for DPWES infrastructure.[149]

Higher temperatures and drought conditions can lead to higher strength of waste and odor issues. In addition, higher strength waste (that is, wastewater that requires higher level of treatment such as from restaurants or industrial facilities) can result in higher levels of hydrogen sulfide (H_2S) released from wastewater that could impact employee health and lead to deterioration of pipes and pumps.[150]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**WW Infrastructure**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Wastewater infrastructure in Fairfax County is estimated to have moderate adaptive capacity for extreme heat. DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES has already taken steps to build redundancy and resilience into wastewater operational and process systems. Existing resilience measures include two power feeds and a backup generator onsite for the Noman M. Cole, Jr, Pollution Control Plant to withstand power outage scenarios which may occur during extreme heat events.[151] All 63 pump stations have generators to provide secondary power should an outage occur. This flexibility provides for some resiliency. Additionally, DPWES-managed plants have aerators to increase oxygen levels.[152] However, there may be barriers to implement adaptation measures. Wastewater management staff capacities present a barrier to implementation.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**WW Infrastructure**	**Extreme Heat**	**Total Vulnerability = 8** (Moderate)

Based on the information available, wastewater infrastructure in Fairfax County is estimated to have a moderate overall vulnerability to extreme heat.

4.3.b. Heavy Precipitation and Inland Flooding – Wastewater Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Inland Flooding**	**Exposure = 2** (Moderate)

Wastewater infrastructure is moderately exposed to heavy precipitation and inland flooding. By design, numerous wastewater pump stations and encasements are in low-lying (and therefore flood-prone) areas, and a smaller portion of other water conveyance assets are exposed to flooding. DPWES has noted that the wastewater treatment plant and some of the wastewater collections infrastructure are sited in low lying flood prone areas, making them vulnerable to flood damage.[153] Specifically, the Noman M. Cole, Jr., Pollution Control Plant and Upper Occoquan Sewage Treatment Plant are both within FEMA and county floodplains. Approximately 5% of sewer structures, 8% of sewer lines, 27% of wastewater pump stations, and 21% of wastewater encasements are within FEMA floodplains. Additionally, wastewater infrastructure components may be exposed to urban flooding outside of floodplains. Heavy precipitation is projected to increase in quantity and intensity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**WW Infrastructure**	**Inland Flooding**	**Sensitivity = 3** (High)

Wastewater infrastructure is highly sensitive to inland flooding caused by heavy precipitation. Increased heavy precipitation events may lead to flooding and higher groundwater tables that impact wastewater reuse, storage, conveyance, and treatment infrastructure, including the impacts of increased inflow and infiltration.[154,] Inflow occurs when rain infiltrates the sewer system through drains, sump pumps, manhole covers and other infrastructure. Infiltration occurs when groundwater enters the sewer system through leaks in pipelines and manholes. Increased rainfall may lead to inland flooding of pumping stations and a potential increase in blockages. Severe precipitation events may lead to an increased chance of sanitary sewer overflows, exceeding the capacity of treatment plants, which can cause backups into homes and businesses and result in increased inflow and infiltration into the sanitary system.[155] Stream bank erosion caused by heavy precipitation exposes sanitary sewers adjacent to and crossing streams.

The underground pipes designed for gravity flow in the wastewater conveyance system may become pressurized and backup into homes and businesses, causing a health hazard.[156] Underground pipes may become buoyant and crack due to displacement if the water table rises either due to increased sustained precipitation. A higher groundwater table can also impact sewer sludge management dewatering – that is, the removal of water from the sludge residual that is taken out of the wastewater. Drain fields for septic tanks (also termed onsite sewage systems), where the ground is used to facilitate the percolation of wastewater into the surrounding soil, can become saturated when the water table is high, reducing the capacity of wastewater to move from the house into the septic tank. Groundwater can also inundate septic tanks. DPWES indicated that a higher groundwater table could result in higher inflow and infiltration in places like Belle Haven and New Alexandria.

A rising groundwater table may also crack underground pipes, impact sewer sludge management, saturate drainfields for septic tanks, and inundate septic tanks through leads into the tank. DPWES noted that during unusually wet winters that have occurred twice out of the past five years, the utilities' ability to land apply biosolids was affected (i.e., the application of spreading the biosolids on top of or within soils).

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**WW Infrastructure**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's wastewater systems are estimated to have moderate adaptive capacity to inland flooding. There have been actions and investments that reduce the overall impact of heavy precipitation and inland flooding to wastewater infrastructure, as well as assessments that have identified adaptation strategies that could be implemented. Overall, this hazard remains impactful to wastewater infrastructure.

DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. The DPWES Wastewater Management division initiated a program to identify, evaluate and prioritize improvements to protect exposed sanitary sewer lines in collaboration with Stormwater Management staff, who manage stream restoration projects.[157] Northern Virginia Hazard Mitigation Plan (HMP) 2017 Mitigation Action 5 stipulated to armor the stream bank and construct a flood wall to prevent stream bank erosion and flooding at the Noman M. Cole Jr Pollution Control Plant. The Plant was also equipped with an extra equalization tank, elevation of new and improved buildings beyond the 500-year stormwater surface, backup generators at all pump stations, a backflow preventer program.

Assessments have been done and are ongoing to determine appropriate infrastructure upgrades and flood mitigation strategies to protect this vulnerable infrastructure.[158] DPWES has determined that pipe lining can be added to improve adaptive capacity for inflow and infiltration, but significant amounts of inflow and infiltration occurs with connections that are privately maintained. Wastewater Management staff are also making improvements to reduce the impact of the inability to apply biosolids through backup disposal contracts and increased storage capacity.[159] However, this improvement is not directly related to system capacity to convey or treat increased flows during heavy precipitation. If facilities lose water reuse capacity (e.g., cannot supply cooling water), then DPWES needs to rely on water from Fairfax Water. This may result in reductions in available drinking water in the county.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**WW Infrastructure**	**Inland Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, wastewater infrastructure in Fairfax County is estimated to have a moderately high vulnerability to heavy precipitation and inland flooding.

4.3.c. Severe Storms – Wastewater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Severe Storms**	**Exposure = 2** (Low)

Above-ground wastewater treatment facilities and associated infrastructure, including chemical tanks, treatment tanks, and pump stations, are exposed to severe storms and wind events. Underground wastewater infrastructure is not as exposed to severe storms and wind. Severe storms are projected to increase in intensity with climate change. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**WW Infrastructure**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Wastewater infrastructure is moderately sensitive to severe storms. Storm-related power outages, road closures to/from the wastewater treatment facilities and conveyance systems, and wind damage can all affect wastewater operations and services. Storms may create large volumes of debris that require removal and may damage wastewater infrastructure.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**WW Infrastructure**	**Severe Storms**	**Adaptive Capacity = 1** (High)

Wastewater infrastructure in Fairfax County is estimated to have high adaptive capacity to severe storms. A significant effort was undertaken to armor and support operations during severe storm events. Though this does not remove all potential impacts, it demonstrates a significant stewardship in action, protecting wastewater infrastructure against severe storms.

The DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES has already taken steps to build redundancy and resilience against power outages into wastewater operational and process systems, including installing two power feeds and a backup generator onsite for the Noman M. Cole, Jr, Pollution Control Plant.[160] All 63 pump stations have generators to provide secondary power should an outage occur. After past events including Hurricane Isabel and Tropical Storm Lee, DPWES added an extra equalization tank, backup generators, and completed a flood wall to prevent stream bank erosion and flooding. (This was an action item specified by the Northern Virginia Regional Hazard Mitigation Plan). However, current DPWES funding is insufficient to support costs for addressing resiliency of the wastewater system and potential emergencies due to climate change.[161] In addition, if facilities lose water reuse capacity (e.g., cannot supply cooling water), then DPWES needs to rely on water from Fairfax Water.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**WW Infrastructure**	**Severe Storms**	**Total Vulnerability = 4** (Low)

Based on the information available, wastewater infrastructure in Fairfax County has a low overall vulnerability to severe storms, largely due to strong adaptive capacity.

4.3.d. Extreme Cold - Wastewater Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Extreme Cold**	**Exposure = 1** (Low)

Wastewater infrastructure in Fairfax County is projected to have low exposure to extreme cold. Cold events are projected to reduce in frequency under a warming climate. Additionally, most wastewater infrastructure is located underground, less exposed to temperature fluctuations. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**WW Infrastructure**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Wastewater infrastructure is mildly sensitive to extreme cold. In extreme cases, if extreme cold is combined with precipitation such as large snowfall or extreme icing wastewater infrastructure can be damaged, and the ability of DPWES employees to provide service can be impacted.[162] For example, rapid snow melt from a blizzard could impact inflow and infiltration for both collection and treatment. With respect to staffing, wastewater field staff are dual-serviced to assist with snow removal operations which can theoretically expose them further to cold injury issues.[163] A sustained snowfall event requiring their support could lead to man power impacts, such as reduced staff at the wastewater treatment facilities, and could lead to impacts to service vehicles. Wastewater Management staff note that in current conditions, wastewater infrastructure has not been affected by extreme cold, and given warming conditions, this is not expected to be an area of sensitivity.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**WW Infrastructure**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Wastewater infrastructure is estimated to have moderate adaptive capacity to extreme cold. The DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES has already taken steps to build redundancy and resilience into wastewater operational and process systems. However, current DPWES funding is insufficient to support costs for addressing resiliency of the wastewater system and potential emergencies due to climate change.[164] (For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**WW Infrastructure**	**Extreme Cold**	**Total Vulnerability = 4** (Low)

Based on the information available, wastewater infrastructure in Fairfax County is estimated to have a low overall vulnerability to extreme cold, largely due to low exposure and low sensitivity.

4.3.e. Coastal Flooding – Wastewater Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. Wastewater infrastructure in Fairfax County has low exposure to coastal flooding. Most wastewater assets are not located in areas that are projected to be inundated by sea level rise or coastal flooding, with the exception of wastewater pump stations. Approximately 8.5% of wastewater pump stations are projected to be exposed to coastal flooding. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	WW Infrastructure	Coastal Flooding	**Sensitivity = 3** (High)

If exposed, wastewater infrastructure is highly sensitive to coastal flooding. Numerous sensitivities discussed under the "heavy precipitation and inland flooding" section above are relevant sensitivities to coastal flooding, including higher inflow and infiltration in certain parts of the county, including Belle Haven and New Alexandria. Coastal flooding of the conveyance and wastewater treatment facilities may lead to sanitary sewer overflows, backups into homes and businesses, and damage to wastewater infrastructure. Coastal flooding and rising sea levels can lead to coastal erosion which could expose sanitary sewers located along the coastal banks. Drain fields of septic tanks may become saturated, making systems inoperative.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	WW Infrastructure	Coastal Flooding	**Adaptive Capacity = 2** (Moderate)

Wastewater management infrastructure in Fairfax County is estimated to have moderate adaptive capacity to coastal flooding. Though DPWES has undertaken efforts to reduce overall physical threats to the wastewater infrastructure, coastal flooding remains a potential threat to wastewater infrastructure.

DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES has implemented some actions to address climate risk in wastewater operations and facilities. DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES has already taken steps to build redundancy and resilience into wastewater operational and process systems. However, current DPWES funding is insufficient to support costs for addressing resiliency of the wastewater system and potential emergencies due to climate change.[165] There are barriers to adaptation as wastewater management infrastructure cannot be easily relocated, replaced, or fortified.

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	WW Infrastructure	Coastal Flooding	**Vulnerability Score = 6** (Moderate)

Based on the information available, wastewater infrastructure in Fairfax County is estimated to have a moderate total vulnerability to coastal flooding.

4.3.f. Drought - Wastewater Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**WW Infrastructure**	**Drought**	**Exposure = 1** (Low)

Wastewater infrastructure in Fairfax County has low exposure to drought. Drought is not projected to increase with significant frequency and intensity in Fairfax County, as increased precipitation is projected locally with climate change. However, intermittent drought events may still occur, and on those occasions, wastewater infrastructure will be exposed to these drought conditions. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**WW Infrastructure**	**Drought**	**Sensitivity = 1** (Low)

Wastewater infrastructure has low sensitivity to drought. Higher temperatures and drought conditions can lead to higher strength of waste and odor issues. In addition, higher strength waste (that is, wastewater that requires higher level of treatment such as from restaurants or industrial facilities) can result in higher levels of H_2S released from wastewater that could impact employee health (from exposure to high levels of H_2S which is a highly poisonous, corrosive, colorless gas that smells like rotten eggs) and lead to deterioration of pipes and pumps.[166] However, these conditions do not highly threaten operations.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**WW Infrastructure**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's wastewater infrastructure has an estimated moderate adaptive capacity for drought conditions. Some measures have been undertaken that would strengthen wastewater infrastructure against the impacts of drought. However there have not been targeted actions to protect against drought, likely due to lack of need. DPWES Wastewater Management staff regularly monitor all wastewater infrastructure and operating conditions in accordance with all applicable policies and procedures, minimizing risk. DPWES's Wastewater Management Program has an Environmental Management System Program through the Virginia Environmental Excellence Program that focuses on water conservation and reuse.[167]

(For more detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**WW Infrastructure**	**Drought**	**Total Vulnerability = 2** (Very Low)

Based on the information available, wastewater infrastructure in Fairfax County is estimated to have very low overall vulnerability to drought.

5. ENERGY & TELECOMMUNICATIONS INFRASTRUCTURE

Our homes, businesses, infrastructure, and services depend on reliable energy and telecommunications. It is critical to assess the climate vulnerabilities of energy and telecommunications systems, because such vulnerabilities have cascading effects on nearly all other sectors. For the purposes of this climate vulnerability assessment, the "energy sector" includes electricity and natural gas infrastructure. These are the predominant sources of energy for residential, commercial, industrial, institutional, and government buildings and associated infrastructure in Fairfax County. The "communications sector" includes telecommunication lines and facilities in Fairfax County. The assessment was limited to available data and infrastructure manager feedback. *Table* 14 summarizes the climate vulnerability scores for energy and telecommunications infrastructure by the three main infrastructure sub-sectors: electricity, natural gas, and telecommunications.

Table 14: Climate Vulnerability Summary - Energy & Telecommunications Infrastructure

Energy & Telecommunication Sector - Climate Vulnerability Summary				
Climate Hazards	**Electricity**	**Natural Gas**	**Telecommunications**	**Total**
Extreme Heat	18	2	8	**28**
Inland Flooding	18	8	8	**34**
Severe Storms	18	8	12	**38**
Extreme Cold	6	6	4	**16**
Coastal Flooding	8	4	4	**16**
Drought	4	2	2	**8**
Total	**72**	**30**	**38**	**140**

*****Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

The geographic information systems (GIS) data available for the energy and communications sectors are limited to the major utility lines (such as major transmission or supply lines) and utility-owned properties shown in *Figure 8*. Exposure of these assets to floodplains, coastal flooding, urban heat islands, and other hazard layers are provided in tabular form in Appendix 3 and in maps in Appendix 2.

More detailed electricity and communications infrastructure data (such as distribution lines to residences) are owned by energy and communications companies rather than Fairfax County and are typically not released in public reports for security reasons.

However, to supplement this limited GIS data, Fairfax County coordinated with Dominion Energy, Northern Virginia Electric Cooperative (NOVEC), Washington Gas, Columbia Gas, Cox of Northern Virginia, and Verizon for the substance of this section.

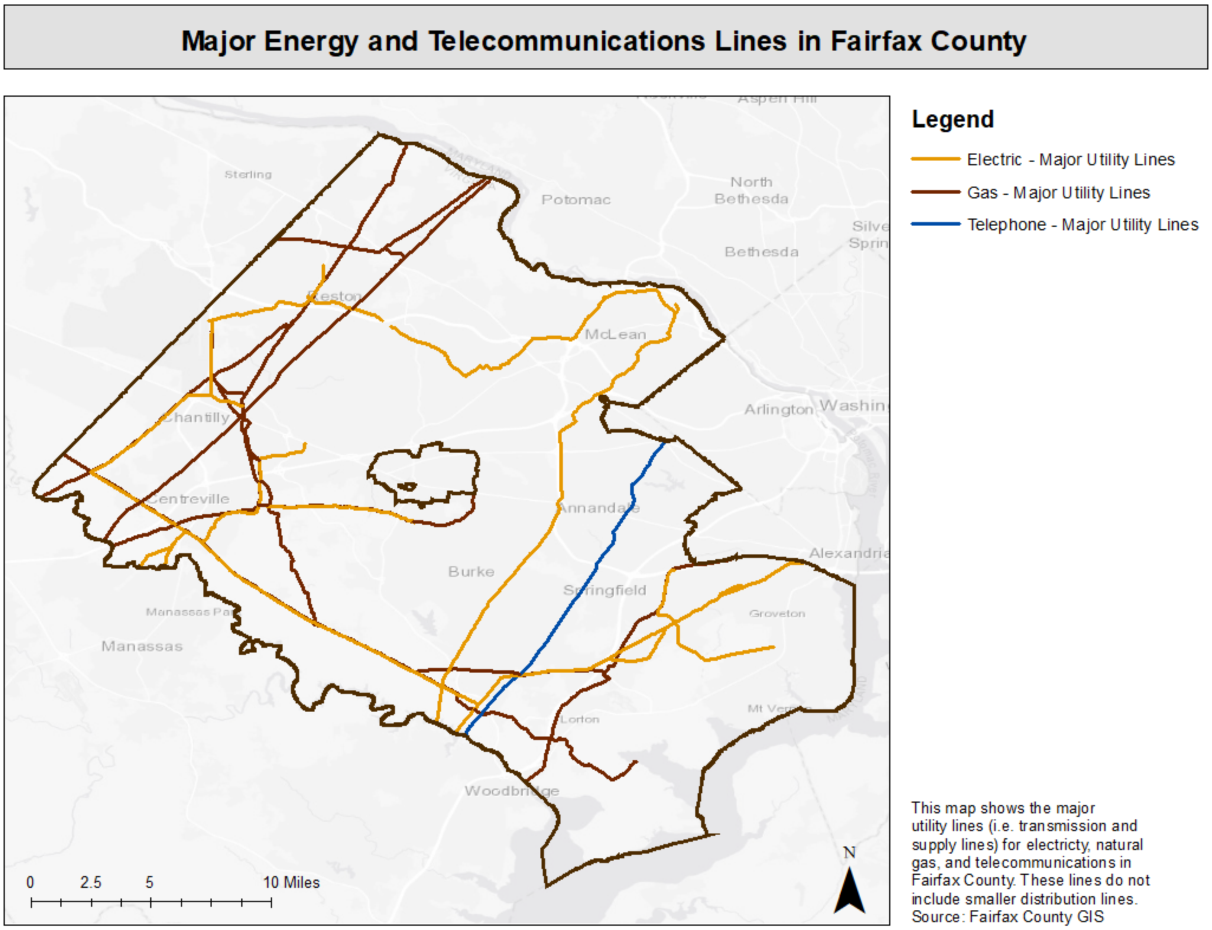


Figure 8: Major utility lines for the County
(Source: Fairfax County Geospatial Data)

The following discussion provides vulnerability scores for each of the three energy and telecommunications sub-sectors. These vulnerability scores are further broken down to include discussions for each of the six hazard areas. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard. For detailed methodology, please see Appendix 1.

5.1. Electricity Infrastructure

The "electricity grid" is made up of several components to facilitate electricity generation, transmission, and distribution (*Figure 9*). First, a power plant or other power source (e.g., wind, solar) generates electricity. Next, this electricity is transformed to a higher voltage for transmission and carried along transmission lines. Another transformer reduces the voltage so the electricity can be carried by regular distribution lines (such as in a residential neighborhood), to be used by customers.[168]

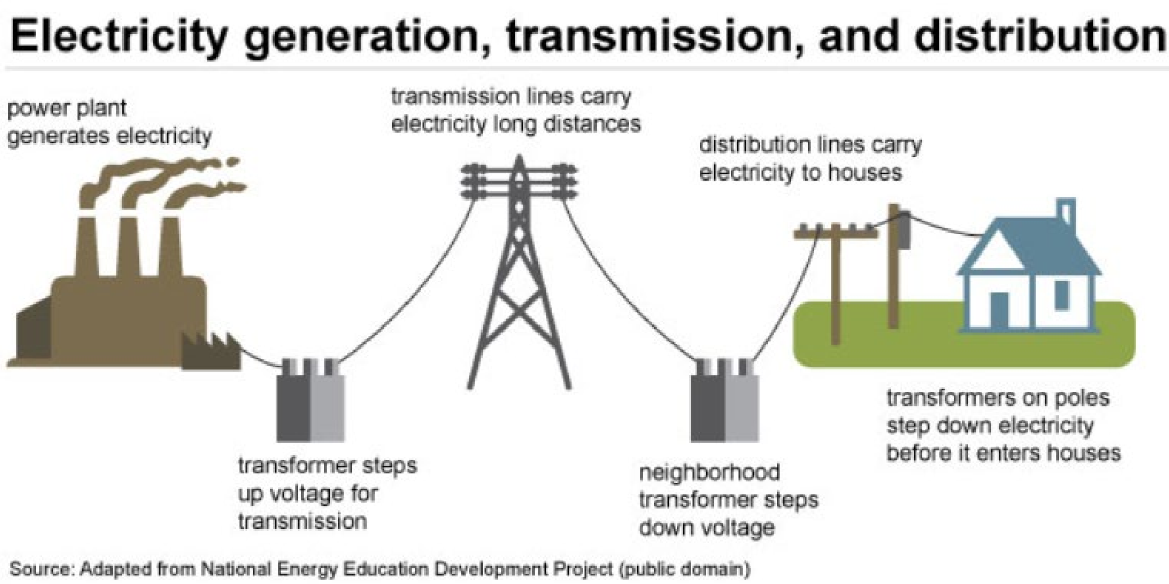


Figure 9: Generation, Transmission, Distribution Relationship

There are numerous asset types that make up the infrastructure of the electrical grid. These include the energy generation source (e.g., power plants), transformers to adjust voltage, substations that house transformers and circuit breakers to collect power, change voltage, and transfer power from one line to another, high-voltage transmission lines, and lower voltage distribution lines. Vulnerabilities to the system from climate change will vary by asset type. Additionally, there are operational vulnerabilities associated with climate change, such as blackouts due to increased demand during high heat events. The following sections summarize climate vulnerabilities to the entire system for each climate hazard.

Most residents of Fairfax County receive electricity service from Dominion Virginia Power (otherwise referred to as Dominion Energy, Dominion Energy Virginia, or Virginia Power). Dominion Energy's portfolio of energy sources includes natural gas, coal, oil, biomass, solar, wind, hydropower, and nuclear power.[169,170] Parts of Centreville, Chantilly, Herndon, Fairfax, Fairfax Station and all of Clifton are served by Northern Virginia Electric Cooperative (NOVEC) (*Figure 10*).[171]

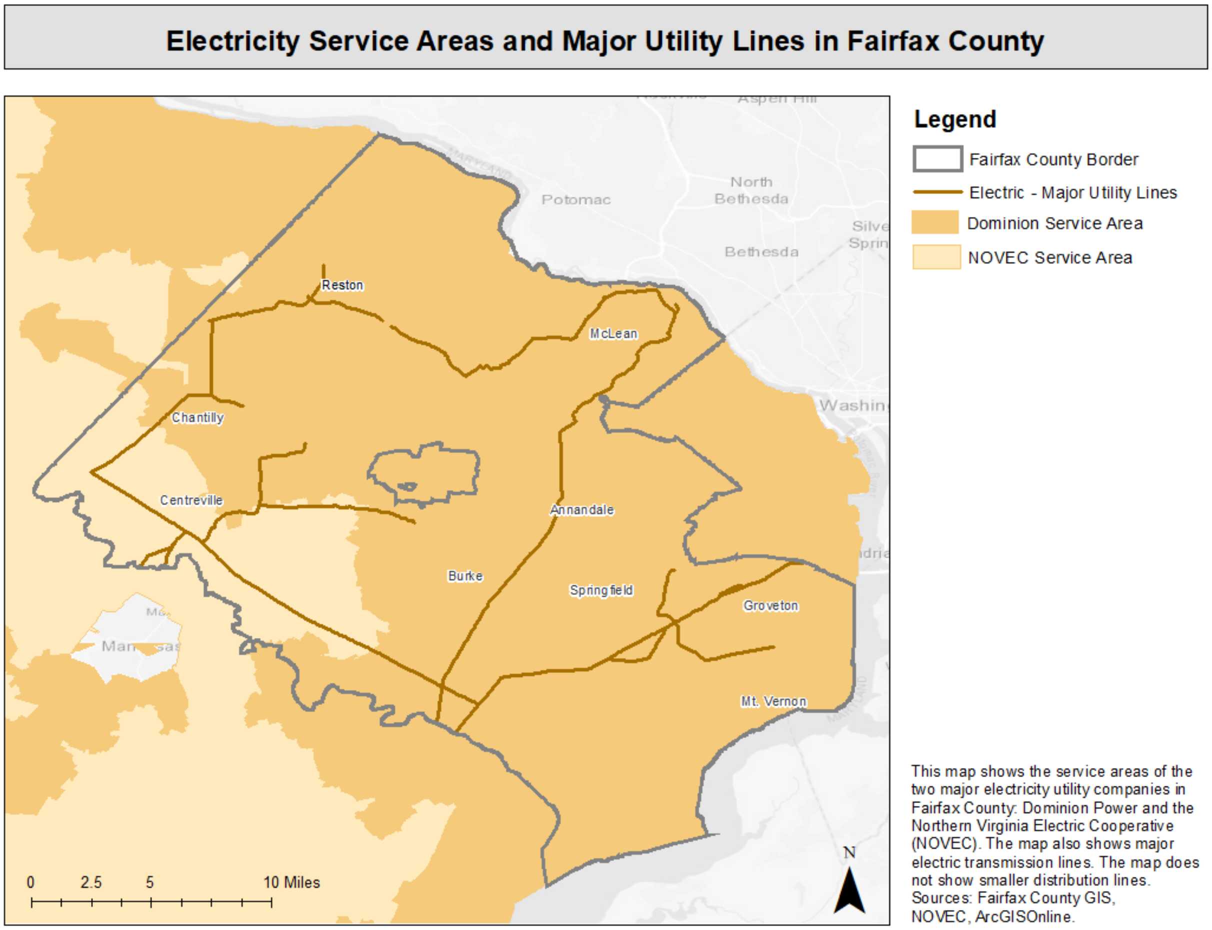


Figure 10: Electric Utility Service Areas and Lines in Fairfax County.
Dominion Energy is shown in medium orange and NOVEC is shown in lighter orange. Major electricity utility lines are shown in dark orange.

Dominion Energy Virginia's 2020 Integrated Resource Plan reflected a quadrupling of renewable energy and energy storage compared to the prior year's iteration.[172] Through 2035, the company expects to expand offshore wind, solar, and energy storage by roughly 24,000 megawatts. Through 2035, Dominion Energy anticipates capital investments in offshore wind of up to $17 billion to meet Virginia's mandate for up to 5,200 megawatts of offshore wind, in solar and/or onshore wind of up to $20 billion, and in natural gas of up to $2 billion.

Dominion Energy's existing distribution system in Virginia consists of more than 53,000 miles of overhead and underground cable, and over 400 substations. Subject to State Corporation Commission approval, Dominion Energy reports that they have proposed over $1.5 billion of improvements through a 10-year Grid Transformation Plan to update power grid technology and increase resiliency. Dominion Energy operates 13 coal and oil facilities in Virginia and 10 natural gas facilities: Bear Garden, Brunswick County, Darbytown, Elizabeth River, Gordonsville, Gravel Neck, Greensville County, Ladysmith, Remington, and Warren County.[173] Power stations fueled by these resources generate more than 40% of all power used by Dominion Energy customers. Dominion also operates biomass power facilities in Altavista, Hopewell, and Southampton. In addition, Dominion Energy Virginia states that they "committed in 2018 to add another 3,000 megawatts of in-state solar or wind resources to its slate of projects either in operation or under development by 2022."[174]

NOVEC owns and operates a 49.9-megawatt renewable energy biomass power plant in Halifax County. The plant can power about 16,000 homes. NOVEC also purchases renewable power generated at the Prince William County Landfill. The co-op has a contract to add 300 more megawatts of solar to its power portfolio by 2023. NOVEC Solutions encourages solar energy by offering photovoltaic (PV) systems through its contractor, ProspectSolar.

NOVEC spent $10 million in 2010 for a "smart grid" project to make its distribution system more robust and reliable. The new technology also reduces power loss along distribution power lines. The co-op reports that it spends millions of dollars annually to maintain and enhance its system. NOVEC reports that it has kept power on 99.99% of the time for its customers for 23 consecutive years. This record has made the cooperative the most reliable electric utility in the Washington, DC, metropolitan area for more than two decades. Comparable statistics for Dominion Energy are unknown.

Electricity infrastructure is managed by these private companies and overseen by the State Corporation Commission (SCC); electricity infrastructure is not managed by Fairfax County government.

Table 15 summarizes the climate vulnerability scores for electricity infrastructure in Fairfax County. These scores are general and qualitative in nature; they are designed to highlight high-level vulnerabilities that may need additional county attention and analysis. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. Based on the assessment, the highest vulnerabilities to electricity infrastructure in Fairfax County are believed to be severe storms and extreme heat. Each of the scores is explained in greater detail following the table.

Table 15: Climate Vulnerability Summary - Electricity Infrastructure

Electricity Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	3	2	**18**
Inland Flooding	3	3	2	**18**
Severe Storms	3	3	2	**18**
Extreme Cold	1	3	2	**6**
Coastal Flooding	2	2	2	**8**
Drought	1	2	2	**4**
Total	-	-	-	**72**

5.1.a. Extreme Heat - Electricity Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Electricity**	**Extreme Heat**	**Exposure = 3** (High)

Major electric utility lines (transmission lines) throughout the county are highly exposed to extreme heat, which is projected to increase. In addition to county-wide warming due to climate change, more than half (52%) of the electricity transmission lines are in areas of highly enhanced warming due to the Urban Heat Island (UHI) effect. Nearly 10% of the electricity transmission lines in Fairfax County are in areas with very high UHI, or existing land surface temperatures above 100° F during the summer months. This statistic does not include distribution lines that travel to individual residential homes and are prolific across the county. However, such distribution lines, especially those above-ground, are also assumed to be highly exposed. In addition to transmission lines, electricity utility owned properties, which contain substations and other infrastructure assets, are highly exposed to heat conditions. Over 80% of these assets are located in high Urban Heat Islands in Fairfax County. Extreme heat conditions are projected to increase across the entire county, resulting in high exposure for outdoor, above-ground electrical assets. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Electricity**	**Extreme Heat**	**Sensitivity = 3** (High)

Electricity infrastructure is highly sensitive to extreme heat. Extreme heat can reduce overall efficiency and availability of energy. Power plant cooling systems optimally function when the surrounding environment is significantly cooler than internal conditions.[175] With an increase in extreme heat, cooling systems may fail to perform as needed, which can cause reduced or deferred production. Similarly, electrical substations are sensitive to changes in temperature and humidity and can experience lifetime reductions under the strain of extreme heat. Electricity generators and nuclear power stations can be physically damaged above a certain temperature or may need to be shut off to avoid hazards.[176] Higher operating temperatures also affect the electrical efficiency and power output of solar PV panels.[177]

Electric grid infrastructure may become unreliable under the strain of changing temperatures.[178] Transformers and overhead transmission and distribution lines have reduced transmission capacity when external temperature increases[179] (e.g., during summertime). As Fairfax County experiences an increase in hot days along with an increased demand for energy during these periods, electrical systems are likely to be strained. One study predicts that within the next 20 to 40 years, summer transmission capacity of electrical infrastructure will be reduced by about 1.9-5.8% when compared to the 1990-2010 average.[180] Reduced capacity can cause disruptions of electricity supply and damage to electric grid infrastructure. Additionally, extreme heat can cause sagging of overhead line conductors. Excessive sag presents a safety concern and failure to comply with ground clearance requirements. Sustained periods of heat can also cause failure among power transformers which can lead to further disruption. Power outages have consequences across the community. (Please see descriptions within other sectors for those sectors' additional power outage impacts). Dominion Energy's 2021 Climate Report notes that its infrastructure could be impacted by many of the same sensitivities as outlined above.[181]

For energy demand, "heating degree days" are projected to decrease as winters warm. This reduction in heating degree days is projected to be greater than the increase in "cooling degree days," suggesting a small net reduction over the year in energy use.[182] However, it is understood energy costs in the summer may be more expensive per kilowatt-hour because of increased demand, so the annual energy costs for a building may increase even with this small net reduction in overall energy use.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Electricity**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Electrical infrastructure in Fairfax County is estimated to have a moderate adaptive capacity to handle extreme heat. Adaptive capacity is scored according to four criteria. (Please see Appendix 1 for detailed methodology). While the county and energy providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Dominion Energy states that it is hardening its system and expanding its generation supply to accommodate projected increased demand and climate change conditions. Dominion Energy is also engaged in placing vulnerable electric distribution tap lines underground. NOVEC reports that two thirds of its distribution power lines are underground, reducing vulnerability.[183] In addition to direct resilience actions, proper maintenance activities can enhance the resilience of an electricity system. Both NOVEC and Dominion Energy report that they spend millions of dollars each year to maintain and enhance their systems. In addition, Dominion Energy's Electric Transmission groups are engaging with national labs, peer utilities, and advanced data analytics and network simulations for the design and maintenance of transmission and substation infrastructure.

Diversity of energy sources (such as solar plus storage) can help enhance energy resilience in the event of power loss resulting from extreme heat or associated strain on demand. Dominion Energy and NOVEC both report that they are diversifying their generation portfolio. However, there are still legal and logistical limitations to the ability of customers to install and use solar energy that is not integrated into the grid. Expansion of solar energy (including rooftop solar) and solar-plus-storage would enable continuity of power during grid shutdowns.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Electricity**	**Extreme Heat**	**Total Vulnerability = 18** (High)

Based on the information available, electricity infrastructure in Fairfax County is estimated to have a high overall vulnerability to extreme heat, due to both high exposure and high sensitivity. Please see Appendix for maps and tables.

5.1.b. Heavy Precipitation and Inland Flooding - Electricity Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Electricity**	**Inland Flooding**	**Exposure = 3** (High)

For the purposes of this analysis, "heavy precipitation and inland flooding" includes both "riverine" flooding, which is caused by water bodies overflowing onto floodplains, and "urban flooding," caused by heavy precipitation overwhelming stormwater management infrastructure. Over 10% of Fairfax County's major electric transmission lines are located in FEMA or county floodplains. Additionally, over 13% of electricity utility-owned properties (i.e. substations) are located in FEMA floodplains and over 20% are in county floodplains. Electricity infrastructure is also exposed through urban flooding. Over 30% of electric utility lines and properties are located on flood-prone parcels with a score of two or higher. Exposure is projected to increase as precipitation quantities and intensities continue to increase due to climate change. Due to limited GIS mapping data, these statistics do not include distribution lines that travel to individual residential homes across the county, which are also potentially exposed. (Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Electricity**	**Inland Flooding**	**Sensitivity = 3** (High)

Electricity infrastructure is highly sensitive to inland flooding. Heavy precipitation and associated flooding can lead to flooded substations, transformers, switch gear, disrupted or downed powerlines, and flooding of other supporting electrical infrastructure. Electrical lines that are waterlogged can experience faulting. Flooding of substations and related infrastructure (such as transformers and switch gears) can become hazardous above 3 feet[184] and lead to blackouts[185] along with reduced reliability of substation systems. Additionally, excessive underground moisture can produce corrosion of oil tanks,[186] resulting in leakages that can cause fires and other extreme threats to safety.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Electricity**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Electrical infrastructure in Fairfax County is estimated to have a moderate adaptive capacity to handle heavy precipitation and inland flooding. While the county and energy providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Electricity infrastructure is difficult and costly to reinforce due to its widespread nature and external vulnerabilities. Easement acquisition also poses challenges as the population increases, which can cause resource constraints on potential adaptation. Both NOVEC and Dominion Energy report spending millions of dollars each year to maintain and enhance their system. On the distribution grid, standards include establishing a minimum pole class across the system, requiring deeper pole setting or select backfill in areas with poor soil, expanding the use of fiberglass cross-arms, and using upgraded insulators. Dominion Energy also reports routine improvements to facilities for drought, flood, and storm preparation, and recovery plans based on experience during drills. (Please see also the "adaptive capacity" section under "extreme heat" and "severe storms" for more discussion of applicable adaptation efforts and barriers).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Electricity**	**Inland Flooding**	**Total Vulnerability = 18** (High)

Based on the information available, electrical infrastructure in Fairfax County is estimated to have a moderately high overall vulnerability to inland flooding. Please see the Appendix for data tables and maps.

5.1.c. Severe Storms – Electricity Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Electricity**	**Severe Storms**	**Exposure = 3** (High)

Electricity grid infrastructure is highly exposed to severe storm events, and such events are projected to increase in severity and frequency.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Electricity**	**Severe Storms**	**Sensitivity = 3** (High)

The electricity grid is highly sensitive to severe storms. Transmission and distribution systems are particularly sensitive to damage from high winds, which can cause power outages and fire risks. The risk of a transmission and distribution pole failure is dependent upon its material, with hybrid steel and concrete poles performing best.[187] Finally, increased exposure to lightning presents a unique vulnerability to overhead lines and transmission and distribution poles. Damaged systems can result in increased safety concerns and maintenance or replacement costs. Lightning strikes also present a fire risk. Dominion Energy noted in its 2021 Climate Report that severe and powerful storm events could damage its infrastructure and equipment and interrupt normal business operations and transportation.[188]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Electricity**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

There is moderate adaptive capacity built into the electricity grid in the National Capital Region (NCR), which includes Fairfax County. While electricity providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Although electricity infrastructure is difficult and costly to reinforce due to its widespread nature and external vulnerabilities, Dominion Energy reports that its Electric Transmission groups take proactive measures to meet the resiliency challenges of climate change and increasingly frequent severe weather. Active engagement with national labs and peer utilities, both domestically and worldwide, along with advanced data analytics and network simulations, help to ensure alignment with industry best practices for the design and maintenance of transmission and substation infrastructure. Design standards are evolving to address severe weather challenges through improved asset management, condition-based maintenance, and the latest equipment hardening research and designs. Innovations such as mobile transmission infrastructure, gas-insulated substations, hardened bulk power transformers and accessories, physical and cyber security systems for substations, light detection and ranging (LIDAR), and Real Time Digital Simulators (RTDS) offer rapid and optimized maintenance and construction, hardened infrastructure, and service restoration.

On the distribution grid, Dominion Energy uses the National Electric Safety Code's (NESC) combined ice and wind loading criteria as the basis for design standards for typical distribution facilities. The company anticipates designing all future construction to meet the stronger of the NESC's heavy loading criteria for combined ice and wind, or the extreme-winds criteria of the American Society of Civil Engineers. These standards include larger poles and shorter spans between them. Additional standards include establishing a minimum pole class across the system, requiring deeper pole setting or select backfill in areas with poor soil, expanding the use of fiberglass cross-arms, and using upgraded insulators.

Two thirds of NOVEC's distribution power lines are underground as cables; therefore, the co-op reports that it has less vulnerability to storm damage than other utilities.[189] Dominion Energy is also undergrounding a portion of its electric distribution tap lines. Dominion reported updating construction standards in an effort to improve overhead grid resiliency, designing facilities to withstand severe weather, and continuously monitoring physical risks associated with severe weather.

There is potential for battery storage and microgrid energy projects, which can be made viable with accompanying legislative change and support. Dominion Energy's electric school buses may serve as a grid resource by creating additional energy storage technology with microgrid batteries to support the power system in the event of a power interruption or outage. NOVEC has indicated that it spent $10 million in 2010 for a "smart grid" project to make its distribution system more resilient and reliable. The new technology also reduces power loss along distribution power lines. For county facilities, the Fairfax County Facilities Management Department (FMD) provides a full range of facility management services for 245 county-owned and designated leased facilities. FMD's emergency generator systems are independent sources of electrical power that, in the event of the loss of commercial utility power, support life safety systems and other critical building systems. Although there is potential for battery storage and microgrid energy projects, there are uncertainties surrounding ownership of the power. Legislative changes are needed to address this issue and ensure that backup energy sources are viable and feasible mechanisms for enhancing energy resilience.

The Metropolitan Washington Council of Governments (MWCOG) conducts energy emergency preparation exercises and hosts workshops for the NCR stakeholders to consider strategic consequences and operational implications of long-term outage of electric grids. During the workshops, participants examine categories of plausible electric grid failure and likely response scenarios. Participants also identify potential resource needs and missing components in existing energy emergency plans. This preparedness helps to fortify the region's resilience.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Electricity**	**Severe Storms**	**Total Vulnerability = 18** (High)

Based on the information available, electrical infrastructure in Fairfax County is estimated to have a high overall vulnerability to severe storms.

5.1.d. Extreme Cold – Electricity Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Electricity**	**Extreme Cold**	**Exposure = 1** (Low)

Electricity grid infrastructure, especially above-ground elements, are exposed to extreme cold when such events occur. However, this hazard is projected on average to decrease in frequency and intensity, rendering future exposure low. Intermittent extreme cold conditions may still occur.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Electricity**	**Extreme Cold**	**Sensitivity = 3** (High)

Electricity grid infrastructure and operations are highly sensitive to extreme cold. Ice and snow can weigh down branches, increasing the likelihood of contact with power lines and causing outages. Dangerous driving conditions also increase the likelihood of automobile accidents with poles and other electrical infrastructure, causing further delays in power restoration. This was demonstrated by recent extreme weather conditions that affected Virginia and its infrastructure, including "Snowmageddon" in 2010. The "Snowmageddon" storm event dropped several feet of snow and brought extreme cold to the metropolitan Washington region and a State of Emergency was declared in Washington, DC, Virginia, and Maryland.[190] The event caused widespread power outages. Increased demand for heating during extreme cold events puts additional pressure on the system.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Electricity	Extreme Cold	**Adaptive Capacity = 2** (Moderate)

Electricity infrastructure in Fairfax County is estimated to have a moderate adaptive capacity to handle extreme cold. While electricity providers are taking various measures to reduce harm, damage and loss of service remains a concern.

On the distribution grid, Dominion Energy uses NESC's combined ice and wind loading criteria as the basis for design standards for typical distribution facilities. The company anticipates designing all future construction to meet the stronger of the NESC's heavy loading criteria for combined ice and wind, or the extreme-winds criteria of the American Society of Civil Engineers. Dominion Energy's electric distribution tap lines are being moved underground to decrease vulnerability.

Please see other "adaptive capacity" sections within this sector for additional adaptive capacity information applicable to multiple hazards including extreme cold.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Electricity	Extreme Cold	**Total Vulnerability = 6** (Moderate)

Based on the information available, electricity infrastructure in Fairfax County is estimated to have an overall moderate vulnerability to extreme cold.

5.1.e. Coastal Flooding - Electricity Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Electricity	Coastal Flooding	**Exposure = 2** (Moderate)

Electricity infrastructure in Fairfax County is moderately exposed to coastal flooding, largely due to assets located outside of the county. Coastal flooding refers to flooding of water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. The electricity grid that provides power to Fairfax County extends far beyond county borders. (To supplement limited data within county borders, secondary information was obtained from electricity provider's own analyses). Dominion Virginia Power, which services much of the Virginian coastline, evaluated vulnerabilities to its system from sea level rise and storm surge by the year 2100 (approximately 12 inches in their service territory).[191] The utility added storm surge heights associated with tropical cyclone strengths and tide heights to this sea level rise scenario to identify flood areas. This assessment identified substations in their territory that are vulnerable to temporary flooding from Category 3 and 4 storms with sea level rise.[192] Although this information is generalized for all of Dominion's service territory (rather than the county alone), Fairfax

County would experience these effects from Dominion's vulnerable areas. Transmission and distribution lines can also be exposed to sea level rise and coastal flooding.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Electricity	Coastal Flooding	**Sensitivity = 2** (Moderate)

Electricity infrastructure is moderately sensitive to coastal flooding. Coastal flooding can cause damage to and displacement of transmission and distribution poles and lines, and waterlogging of other critical electrical infrastructure. Electrical lines that are waterlogged can experience faulting. Coastal flooding can also make it difficult to access electricity infrastructure assets, hindering repair and maintenance.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Electricity	Coastal Flooding	**Adaptive Capacity = 2** (Moderate)

Based on the information available, electricity infrastructure in Fairfax County is estimated to have a moderate adaptive capacity to handle coastal flooding. While electricity providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Measures to enhance adaptive capacity in coastal areas are similar to actions taken to protect against inland flooding and severe storms. (See also the "adaptive capacity" sections under "heavy precipitation and inland flooding" and "severe storms" for more discussion of applicable adaptation efforts and barriers.)

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Electricity	Coastal	**Total Vulnerability = 8** (Moderate)

Based on the information available, electricity infrastructure in Fairfax County is estimated to have moderate overall vulnerability to coastal flooding.

5.1.f. Drought - Electricity Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Electricity**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County in the future, making overall exposure low. Precipitation quantities are projected to increase rather than decrease locally. However, intermittent drought events may still occur. Electrical infrastructure would be exposed to these drought conditions if and when they occur.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Electricity**	**Drought**	**Sensitivity = 2** (Moderate)

Electricity infrastructure has moderate sensitivity to drought. Power plants that rely on natural gas, coal, oil, or another type of fuel (e.g., nuclear, biomass) use significant amounts of water for cooling systems and steam used to turn turbines and create electricity. If water levels drop below intake valves for once-through cooling water, plants can be shut down or power production will be reduced.[193] However, as a critical service, it is unlikely that power plants would be subject to water rationing. Dominion Energy noted in its Climate Report that drought could interfere with nearby water bodies as a source for its nuclear reactors and disrupt natural gas extraction activities.[194]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Electricity**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Electricity infrastructure in Fairfax County is estimated to have moderate adaptive capacity to handle drought. While electricity providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Dominion Energy has reported that they spend millions of dollars each year to enhance their system. Drought-related strategies including: switching a facility from a municipal or surface water supply to a reservoir, switching a power station to a less water-intensive fuel, monitoring water quality and implementing operational and structural best management practices such as changing the liner of the pond from black to white to deflect incoming solar radiation, and routinely improving facility drought/flood, storm preparation, and recovery plans based on experience during drills.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Electricity**	**Drought**	**Total Vulnerability = 4** (Low)

Based on the information available, electricity infrastructure in Fairfax County is estimated to have low overall vulnerability to drought.

5.2. Natural Gas Infrastructure

The natural gas infrastructure system in the United States is a network used to move natural gas from production areas to consumers. The system is made up of a series of pipes of varying sizes and pressure tolerances to move the raw gas to processing plants, storage facilities, distribution centers, compressor stations, and then to consumers.[195] Most residents in Fairfax County are served by Washington Gas, but portions of Chantilly and Herndon are served by Columbia Gas of Virginia.[196] Dominion Energy also uses natural gas for its natural gas-powered electricity generation facilities, but that use falls within "electricity." Additionally, several natural gas pipelines cross the county, including those associated with Colonial, Columbia Gas, Cove Point, Dominion, and Transcontinental. Natural gas infrastructure is managed by these private entities; it is not managed by Fairfax County government. *Figure 11* shows the major gas supply lines in Fairfax County. The GIS data below does not include distribution or lateral connections to homes, which are prolific throughout the county.

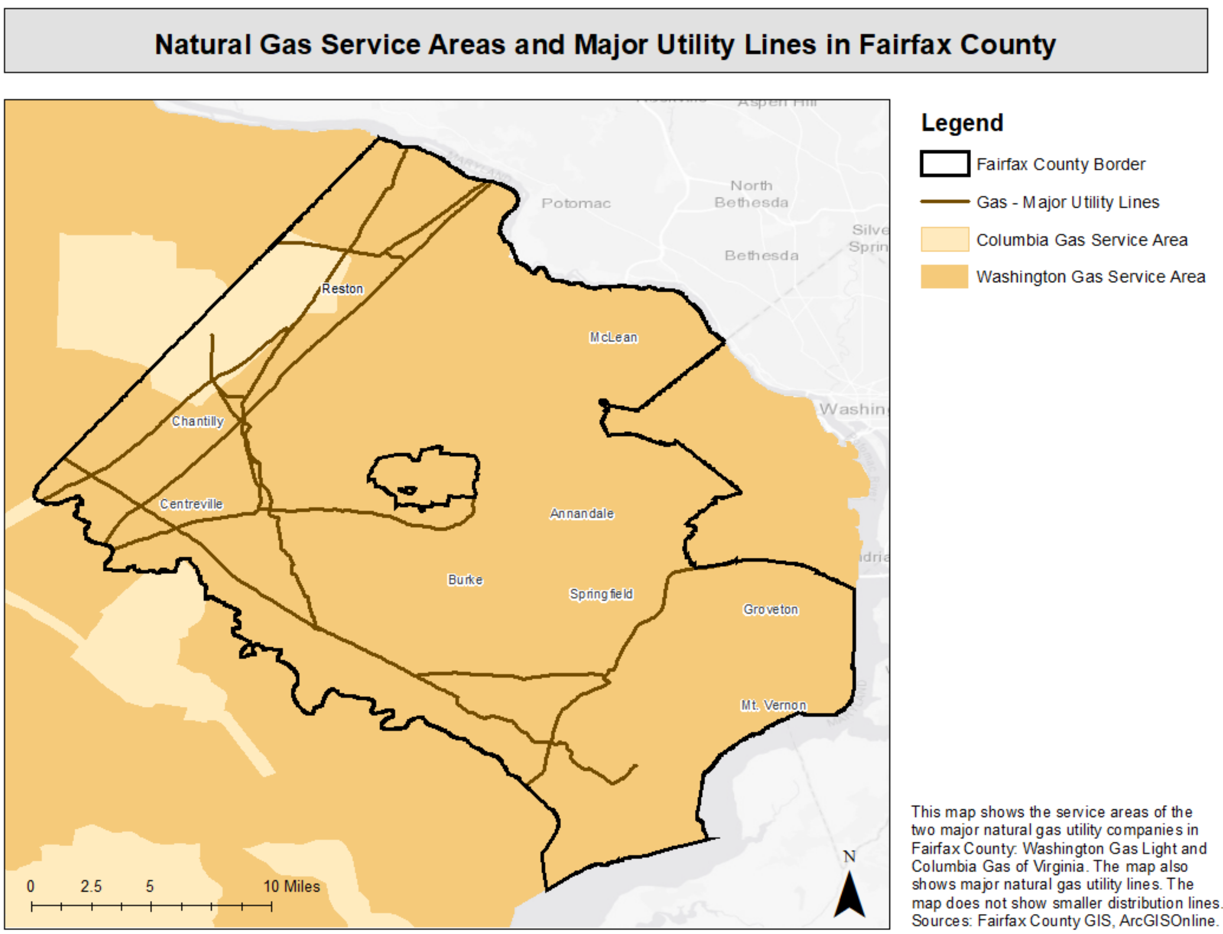


Figure 11: Major Utility Lines in Fairfax County - Major natural gas and supply lines. (This does not include natural gas distribution lines or lateral household connections) Source: Fairfax County GIS.

Table 16 summarizes the climate vulnerability scores for natural gas infrastructure in Fairfax County. These scores are general and qualitative in nature; they are designed to highlight high-level vulnerabilities that may need additional county attention and analysis. For each hazard, vulnerability was estimated through consideration of exposure, sensitivity, and adaptive capacity to that hazard. The highest vulnerabilities to natural gas infrastructure are estimated to be heavy precipitation and inland flooding and severe storms. Each of the scores is explained in greater detail following the table.

Table 16: Climate Vulnerability Summary - Natural Gas Infrastructure

Natural Gas Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	1	1	**2**
Inland Flooding	2	2	2	**8**
Severe Storms	2	2	2	**8**
Extreme Cold	1	3	2	**6**
Coastal Flooding	1	2	2	**4**
Drought	1	1	2	**2**
Total	-	-	-	**30**

5.2.a. Extreme Heat | Natural Gas Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Natural Gas**	**Extreme Heat**	**Exposure = 2** (Moderate)

Natural gas lines are largely underground and, as such, are considered to have low exposure to extreme heat. However, above-ground facilities such as compressor stations, city gates, storage facilities, and pressure regulating stations are more exposed to rising temperatures. In addition to general county-wide temperature increases due to climate change, the Urban Heat Island effect exacerbates land surface temperatures further. Approximately 78% of gas utility owned parcels are currently exposed to highly enhanced land surface temperatures due to the Urban Heat Island (UHI) effect. Approximately 26% of those parcels are currently exposed to very high UHI, or land surface temperatures above 100° F during the summer months. These UHI's are projected to increase as general temperatures increase.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Natural Gas**	**Extreme Heat**	**Sensitivity = 1** (Low)

Natural gas infrastructure is mildly sensitive to extreme heat, which means that this hazard could cause reduced operational capacity but would not cause operational failure. High ambient air and water temperatures can have a small impact on natural gas distribution and power generation. High temperatures reduce the efficiency of steam turbines in natural gas power plants, due to reduced temperature differences between the steam inlet and the condenser.[197] Efficiency losses can also stem from lower mass density of intake air in natural gas combustion turbines and combined cycle plants.[198] "One study conducted by the California Energy Commission (CEC) found that natural gas combined cycle power plant capacity decreases by 0.3-0.5 percent for each 1° C increase above a reference temperature of 15°C."[199] Additionally, higher temperatures and extreme heat events lead to increased gas demand for cooling.[200]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Natural Gas**	**Extreme Heat**	**Adaptive Capacity = 1** (High)

Natural gas infrastructure in Fairfax County is estimated to have high (good) adaptive capacity to handle extreme heat. Washington Gas notes that their above ground facilities and infrastructure have been built to withstand extreme heat. Washington Gas also conducts regular maintenance activities that effectively enhance the system's resilience to extreme heat, even if climate resilience was not the original intention. There may be barriers to adaptation because affected natural gas infrastructure such as steam turbines in power plants or combustion turbines cannot be readily adapted for changing conditions. Equivalent information from Columbia Gas is unknown.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Natural Gas**	**Extreme Heat**	**Total Vulnerability = 2** (Very Low)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to increasing extreme heat is estimated to be very low.

5.2.b. Heavy Precipitation and Inland Flooding– Natural Gas Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Natural Gas**	**Inland Flooding**	**Exposure = 2** (Moderate)

"Heavy precipitation and inland flooding" refers to both "riverine" flooding, which is caused by water bodies overflowing onto floodplains, and by "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Natural gas infrastructure in Fairfax County is moderately exposed to heavy precipitation and inland flooding, both within and outside of the floodplains. Approximately 4-7% of major natural gas utility lines intersect FEMA or County Floodplains. However, nearly 40% of these major natural gas utility lines cross over parcels that have two or more "flood-prone" factors. These statistics do not include smaller distribution lines and lateral connections to homes, which are prolific throughout the county. Natural gas lines in flood-prone areas may experience increased water pressure underground. In addition to gas lines, it is important to consider gas utility-owned properties, which contain essential stations and infrastructure. Based on parcel ownership data available, approximately 14% of these parcels intersect with FEMA floodplains, and over 47% of these parcels have two (2) or more "flood-prone" factors (out of ten (10) flood-prone factors possible). Fortunately, none of these parcels have more than three (3) "flood-prone" factors. Heavy precipitation and inland flooding are projected to increase in intensity and frequency due to climate change. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Natural Gas**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Natural gas infrastructure is moderately sensitive to inland flooding, which means that the hazard could cause temporary operational failure of certain components, but not larger or long-term shutdowns of the system. Heavy precipitation and associated flooding can lead to flooded infrastructure including pressure regulating stations, odorization equipment, tanks, controls, and infiltrated gas lines.[201] Gas lines that are waterlogged can experience faulting. Washington Gas notes that one of their main concerns with flooding is the infiltration of water into pipes in low pressure areas. Equivalent feedback from Columbia Gas is unknown.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Natural Gas**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Based on the information available from local natural gas companies, natural gas infrastructure in Fairfax County is estimated to have a moderate adaptive capacity to heavy precipitation and inland flooding. (Adaptive capacity is scored according to four criteria; please see Appendix 1 for methodology.) While natural gas utility providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Washington Gas reports that they work continuously to maintain and repair natural gas infrastructure, although maintenance needs are consistently high. Washington Gas has taken several measures to mitigate the sensitivities associated with flooding. For example, if water infiltrates the natural gas pipes, Washington Gas receives an alert and is able to quickly respond to the situation. Additionally, Washington Gas has "drips" located at the bottom of hills to capture water that has infiltrated pipes. The vast size of the natural gas infrastructure network in Fairfax County and the surrounding region (with gas connections to most homes) creates a barrier to adaptation because there are many components to maintain, and a high volume of ongoing repairs needed. Equivalent information from Columbia Gas was requested but is unknown at the time of writing.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Natural Gas**	**Inland Flooding**	**Total Vulnerability = 8** (Moderate)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to increasing inland flooding is estimated to be moderate.

5.2.c. Severe Storms – Natural Gas Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Natural Gas**	**Severe Storms**	**Exposure = 2** (Moderate)

Any above-ground natural gas infrastructure is directly exposed to severe storms. Other components may be indirectly exposed to severe storm effects. Severe storms are projected to increase in intensity.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Natural Gas**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Natural gas infrastructure has moderate sensitivity to severe storms, which means temporary operational failure of certain components could occur. Severe storms and high winds could potentially damage above ground components of compressor stations, city gates, storage facilities, and pressure regulating stations. Serious storm damage can undermine natural gas infrastructure. Additionally, loss of power can eliminate Washington Gas's ability to receive alerts from the pressure monitoring stations.[202]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Natural Gas**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Natural gas infrastructure in Fairfax County is estimated to have moderate adaptive capacity to severe storms. (Adaptive capacity is scored according to four criteria; please see Appendix 1 for methodology.) While the natural gas utility providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Washington Gas reports that they work continuously to maintain and repair their natural gas infrastructure. However, maintenance needs are consistently high. Washington Gas has a Business Continuity Plan in place for crews to respond to damage and power outages from severe weather events. Additionally, Washington Gas has a SCADA system that is off the grid and solar-powered for redundancy in case of storm-related and other power outages. Washington Gas also conducts regular emergency exercises and has a playbook ready for each scenario.[203] Comparable information from Columbia Gas is unknown.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Natural Gas	Severe Storms	**Total Vulnerability = 8** (Moderate)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to increasing severe storms is estimated to be moderate.

5.2.d. Extreme Cold – Natural Gas Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Natural Gas	Extreme Cold	**Exposure = 1** (Low)

Extreme cold events are projected to decrease in frequency and intensity as winter temperatures rise, making overall future exposure low. However, when severe cold events do occur, natural gas infrastructure, especially above-ground infrastructure, is exposed. Washington Gas notes that extreme cold for natural gas infrastructure is considered to be 5°F or below.[204]

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Natural Gas	Extreme Cold	**Sensitivity = 3** (High)

Washington Gas notes that natural gas infrastructure is highly sensitive to extreme cold . Extreme cold events may lead to freezing in natural gas infrastructure at any point in the system. Low-pressure areas are especially likely to freeze because temperatures drop 7°F for every 100 pound per square inch (psi) reduction in pressure. If there is any water vapor in the lines, this can cause freezing issues as well. Freezing can also cause shutdowns in controllers or regulators and can cause inaccuracies in natural gas measurements. In addition, cold weather leads to increased demand on the natural gas transportation network as demand for heating increases.[205]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Natural Gas	Extreme Cold	**Adaptive Capacity = 2** (Moderate)

The natural gas infrastructure systems in Fairfax County are estimated to have moderate adaptive capacity to handle extreme cold. While natural gas utility providers are taking various measures to reduce harm, damage and loss of service remains a concern.

Washington Gas reports that it works continuously to maintain and repair its natural gas infrastructure. However, maintenance needs are continuously high. Washington Gas has pressure monitoring systems that provide alerts, and it conducts regular emergency exercises and has a playbook ready for each scenario, including extreme cold. However, the vast size of the natural gas infrastructure network in Fairfax County and the surrounding region (with gas connections to most homes) creates a barrier to adaptation because there are many components to maintain. Comparable information from Columbia Gas is unknown.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Natural Gas**	**Extreme Cold**	**Total Vulnerability = 6** (Moderate)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to extreme cold is estimated to be moderate. Sensitivity is high, but extreme cold events are projected to continue decreasing in frequency.

5.2.e. Coastal Flooding – Natural Gas Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Natural Gas**	**Coastal Flooding**	**Exposure = 1** (Low)

In Fairfax County, coastal flooding refers to flooding of the Potomac River due to sea level rise, tidal flooding, or coastal storm surge. Only a small portion of the major natural gas utility lines (supply lines) in the county are exposed to potential coastal inundation. Specifically, approximately 12% of the major natural gas lines are within one mile of the shoreline, and less than 0.2% of those lines are exposed to projected locations of coastal storm surge or sea level rise inundation. For above-ground stations, there is no projected exposure of gas utility-owned parcels to sea level rise or storm surge in Fairfax County. However, smaller distribution lines and lateral natural gas connections to homes that are within the coastal flooding area may be exposed. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Natural Gas**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Natural gas infrastructure is moderately sensitive to flooding, which means that the hazard could cause temporary operational failure of certain components, but not larger shutdowns of the system. Flooding can affect infrastructure including pressure regulating stations, odorization equipment, tanks, controls, and infiltrated gas lines.[206] Gas lines that are waterlogged can experience faulting. Washington Gas notes that one of their main concerns with flooding is the infiltration of water into pipes in low pressure areas.

Coastal flooding can also cause erosion and undermining of infrastructure.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Natural Gas**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Natural gas infrastructure in Fairfax County has an estimated moderate adaptive capacity to handle coastal flooding. While natural gas utility providers are taking various measures to reduce harm, damage and loss of service remains a concern. Measures to enhance adaptive capacity in coastal areas are similar to actions taken to protect against inland flooding and heavy precipitation. (See also the “adaptive capacity” sections under “heavy precipitation and inland flooding” for more discussion of applicable adaptation efforts and barriers.)

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Natural Gas**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to coastal flooding is estimated to be low.

5.2.f. Drought – Natural Gas Infrastructure

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Natural Gas	Drought	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County; however, intermittent drought events may still occur. Natural gas infrastructure is largely composed of underground pipes that will not be exposed to these drought conditions, except through drying soils.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Natural Gas	Drought	**Sensitivity = 1** (Low)

Natural gas infrastructure has low sensitivity to drought conditions. Natural gas power plants require water in production processes; therefore, energy availability to consumers may be impacted during drought conditions. However, there are no natural gas power plants within Fairfax County borders. There are no known sensitivities to natural gas transmission or distribution lines under intermittent drought conditions.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Natural Gas	Drought	**Adaptive Capacity = 2** (Moderate)

Natural gas infrastructure in Fairfax County has an estimated moderate adaptive capacity for drought conditions. Washington Gas notes that it works continuously to maintain and repair its natural gas infrastructure. However, the vast size of the natural gas infrastructure network in Fairfax County and the surrounding region (with gas connections to most homes) presents a maintenance challenge. There are no known actions taken to adapt to drought specifically, likely due to lack of need.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Natural Gas	Drought	**Total Vulnerability = 2** (Very Low)

Based on the information available, the total vulnerability of the natural gas infrastructure system in Fairfax County to drought is estimated to be very low.

5.3. Telecommunications Infrastructure

Telecommunications infrastructure refers to infrastructure relating to telephone, cable, internet, or broadcast communication. The majority of telecommunications infrastructure in Fairfax County (and the United States more broadly) is privately owned. Cox Communications (Cox), Verizon, and Comcast are among the primary providers of broadband, cable television, telephony, and security services to residential and commercial customers in Fairfax County. Cox operates a hybrid fiber-coaxial network that encompasses 6,298 total miles of network in Fairfax, of which 35% is aerial and 65% is underground.[207] Cox leases aerial access from other pole providers including Dominion Energy, Verizon, and NOVEC.[208] Comparable statistics from Verizon and Comcast were requested but are unavailable at the time of writing. In addition to private providers, the county holds authority over public safety communications for fire, police, and other emergency response agencies. According to the Department of Emergency Management and Security (DEMS), 56 communications assets are identified in the Hazus database. With increased digitalization of Fairfax and its economy, the risk of communications losses from outages is significant.[209] The impacts of climate change can jeopardize emergency communications response in Fairfax County. *Figure 12* shows the major telephone line in Fairfax County.

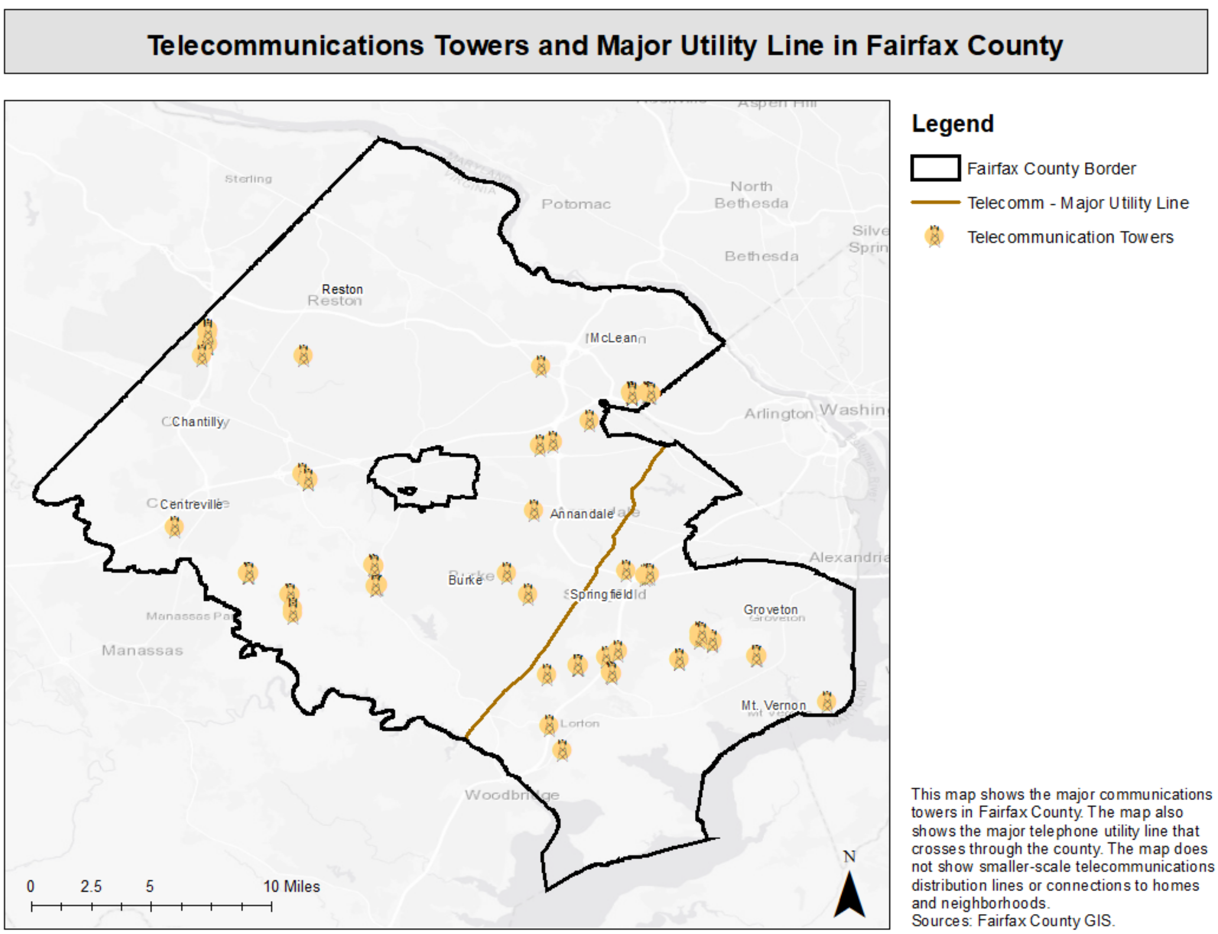


Figure 12: Major Telecommunications Towers and Telecommunications Utility Line in Fairfax County

Table 17 summarizes the climate vulnerability scores for telecommunications infrastructure. These scores are general and qualitative in nature; they are designed to highlight high-level vulnerabilities that may need deeper attention and analysis. For each hazard, vulnerability was determined through consideration of exposure, sensitivity, and adaptive capacity to that hazard. The highest vulnerability to telecommunications infrastructure is severe storms. Each score is explained in greater detail following the table.

Table 17: Climate Vulnerability Summary - Telecommunications Infrastructure

Telecommunication Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	2	2	**8**
Inland Flooding	2	2	2	**8**
Severe Storms	2	3	2	**12**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	2	2	**4**
Drought	1	1	2	**2**
Total	-	-	-	**38**

5.3.a. Extreme Heat – Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Telecommunication**	**Extreme Heat**	**Exposure = 2** (Moderate)

Across Fairfax County, telephone lines and cell towers, and additional telecommunications infrastructure are exposed to extreme heat, which is projected to increase in intensity and frequency. In addition to county-wide increasing temperatures due to climate change, the Urban Heat Island (UHI) effect creates hotter land surface temperatures. Currently in Fairfax County, over 47% of the county's major telephone utility line, 90% of communications utility-owned parcels, and 69% of communications towers are located in areas of hotter land surface temperatures to due significant UHI effect. UHI is projected to increase as temperatures increase. Underground telecommunications infrastructure assets, such as underground lines, are less exposed.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Telecommunication**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Telecommunications infrastructure is moderately sensitive to extreme heat. Extreme heat can place a strain on telecommunications infrastructure that can cause malfunctioning or decreased lifespan.[210] Additional cooling may be needed to maintain conditions for proper functioning. Heat may also cause a sag of communication lines which can lead to communication failure. An indirect consequence of heat events can be the loss of the power supply, which then impacts the communications network or critical facilities. Cox notes that their primary concern with extreme heat relates to "black out" or "brown out" activity that might impact power supply to their networks. Responses were not obtained from Verizon or Comcast.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Telecommunication**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Telecommunications infrastructure in Fairfax County is estimated to have moderate adaptive capacity for extreme heat. Cox notes that they do not expect to make any adaptive adjustments within Fairfax due to extreme heat to its network.

Cox further notes that by having multiple redundant paths, the network has more capacity to redirect its signal and minimize outages. Additionally, ongoing upgrades to its network and plant maintenance and construction efforts allows Cox to adjust its network design in advance of known risk. Comparable information from Verizon and Comcast are unknown.

Across all areas of vulnerability, cost tends to be one of the largest barriers to adaptation efforts for telecommunications infrastructure. In addition to construction and material costs, there are added costs associated with pole attachments, right-of-way, and other permitting costs. As adaptive measures are considered, relocating, replacing, and updating network and network elements can be costly. [211]

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Telecommunication**	**Extreme Heat**	**Total Vulnerability = 8** (Moderate)

Based on the information available, the overall vulnerability of telecommunications infrastructure in Fairfax County to extreme heat is estimated to be moderate.

5.3.b. Heavy Precipitation, Inland Flooding– Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Telecommunication	Inland Flooding	**Exposure = 2** (Moderate)

"Heavy precipitation and inland flooding" refers to both "riverine flooding" caused by water bodies overflowing onto floodplains, and "urban flooding" caused by heavy precipitation overwhelming stormwater management infrastructure. In Fairfax County, 8-10% of the major telephone utility line intersects with either FEMA or county floodplains. Over 15% of communications-utility owned properties intersect with county floodplains. For towers, out of the 69 known telecommunications towers within county borders, there are no intersections with FEMA or county floodplains. In addition to floodplain exposure, telecommunications infrastructure is exposed to urban flooding, which occurs throughout the county. All three telecommunications infrastructure types (lines, properties, and towers) have locations on flood-prone properties. (Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Telecommunication	Inland Flooding	**Sensitivity = 2** (Moderate)

Telecommunications infrastructure is moderately sensitive to inland flooding. Increased precipitation and flooding can place low-lying communications infrastructure at risk of damage. Humidity can also impact transmission of radio signals and wireless connection.[212] Cox Communications notes that the Cox aerial plant is considered relatively secure with the exception of locations where erosion may compromise pole stability. However, its underground network may be compromised in situations of heavy precipitation or flooding events, primarily the underground vaults that may become inundated with water. [213]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Telecommunication	Inland Flooding	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of telecommunications infrastructure in Fairfax County is estimated to be moderate for heavy precipitation and inland flooding. While telecommunications providers are taking various measures to reduce harm, damage and loss of service remains a concern. (Please see "adaptive capacity" section in "extreme heat" above for additional information).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Telecommunication**	**Inland Flooding**	**Total Vulnerability = 8** (Moderate)

Based on the information available, the overall vulnerability of telecommunications infrastructure in Fairfax County to heavy precipitation and inland flooding is estimated to be moderate.

5.3.c. Severe Storms – Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Telecommunication**	**Severe Storms**	**Exposure = 2** (Moderate)

Telephone lines, cell towers, and additional telecommunications infrastructure in Fairfax County are moderately exposed to severe storms, which are projected to intensify. Above-ground telecommunications infrastructure assets have higher direct exposure than below-ground assets.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Telecommunication**	**Severe Storms**	**Sensitivity = 3** (High)

Telephone lines, cell towers, and other telecommunications infrastructure have high sensitivity to and severe storm events. Falling trees, icing and breakage, and extreme winds can damage telecommunications infrastructure, preventing transmission.[214] Damage to telephone lines can seriously threaten human safety by delaying or preventing emergency communications. Fallen limbs on lines and loss of power generally damage the aerial network and/or can disrupt service. Cox Communications notes that it leases aerial access from other pole providers including Dominion Energy, Verizon and NOVEC. Hence, the Cox aerial network (about 2,200 miles) is vulnerable to pole disruption due to climate change (see "sensitivity" in the "electricity" section for additional details). The Cox underground network (about 4,100 miles) is generally less vulnerable to these impacts.[215] Comparable information was not provided by Verizon or Comcast.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Telecommunication**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of telecommunications infrastructure in Fairfax County to severe storms is estimated to be moderate. While telecommunications providers are taking various measures to reduce harm, damage and loss of service remains a concern. (See "adaptive capacity" section under "extreme heat" above for additional information).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Telecommunication	Severe Storms	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the total vulnerability of telecommunications infrastructure in Fairfax County to severe storms is estimated to be moderately high.

5.3.d. Extreme Cold – Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Telecommunication	Extreme Cold	**Exposure = 1** (Low)

Telephone lines, cell towers, and other telecommunications infrastructure, particularly those above ground, are exposed to extreme cold events when they occur. However, cold events are projected to decrease in frequency and intensity, making overall future exposure low.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Telecommunication	Extreme Cold	**Sensitivity = 2** (Moderate)

Telecommunications infrastructure is moderately sensitive to extreme cold. Extreme cold can impact the conductivity of telephone lines and can make infrastructure more prone to breakage. Cox reported that extreme cold combined with heavy and wet snow and ice can be particularly concerning for its network. Heavy snow and ice build-up on aerial lines adds weight and can make breakage possible. Likewise, underground vaults that become wet and freeze can be damaging. [216]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Telecommunication	Extreme Cold	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of telecommunications infrastructure in Fairfax County is estimated to be moderate for extreme cold. While telecommunications providers are taking various measures to reduce harm, damage and loss of service remains a concern (see "adaptive capacity" section in "extreme heat" above).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Telecommunication**	**Extreme Cold**	**Total Vulnerability = 4** (Low)

Based on the information available, the overall vulnerability of telecommunications infrastructure in Fairfax County to extreme cold is estimated to be low, largely due to low future exposure.

5.4.e. Coastal Flooding – Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Telecommunication**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. The major telephone utility line, communications towers, and communications utility-owned properties in Fairfax County are not directly located in areas of projected coastal flooding. However, smaller telecommunication infrastructure such as those facilitating neighborhood and residential telecommunication connections in the neighborhoods near the Potomac River may be exposed to coastal flooding. Geospatial data for smaller connections was not available for this analysis.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Telecommunication**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Similar to inland flooding, telecommunications infrastructure has moderate sensitivity to coastal flooding. Coastal flooding can cause inundation and corrosion of telecommunications infrastructure and other complications for low lying infrastructure. Cox Communications notes that its aerial plant is considered relatively secure with the exception of locations where erosion may compromise pole stability. However, Cox's underground network may be compromised in situations of flooding events; primarily, the underground vaults may become inundated with water.[217] Comparable information from Verizon and Comcast is unknown.

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Telecommunication**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of the telecommunications infrastructure in Fairfax County is estimated to be moderate for coastal flooding. While telecommunications providers are taking various measures to reduce harm, damage and loss of service remains a concern. (See "adaptive capacity" section in "extreme heat" above for additional detail on actions taken).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Telecommunication**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

The overall vulnerability of telecommunications infrastructure to coastal flooding in Fairfax County is estimated to be low.

5.4.f. Drought – Telecommunications Infrastructure Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Telecommunication**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County, making overall future exposure low. However, intermittent drought events may still occur. Telecommunications infrastructure would be exposed to any potential drought conditions.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Telecommunication**	**Drought**	**Sensitivity = 1** (Low)

There is very limited information regarding telecommunications sensitivities to drought. Some communication equipment and information technology data centers require water for cooling. If a drought creates conditions of sustained loss of water to the communication facility, then the equipment may shutdown or fail. It is important to note that the shutdown of one facility is not likely critical to the entire system providing service but could cause some disruption. [218] Cox Communications notes they do not have vulnerability concerns regarding drought for its services in Fairfax County, beyond those faced by its employees if drought impacts their communities outside of Fairfax County. [219]

Adaptive Capacity: Are we able to adapt to and address this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Telecommunication**	**Drought**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of telecommunications infrastructure in Fairfax County is estimated to be moderate for drought. While telecommunications providers are taking various measures to reduce harm, damage and loss of service remain a concern. (See “adaptive capacity” section in “extreme heat” above for more information).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Telecommunication**	**Drought**	**Total Vulnerability = 2** (Low)

The total vulnerability of telecommunications infrastructure to drought in Fairfax County is estimated to be low.

6. TRANSPORTATION

A safe, efficient, and accessible transportation system is critical to a thriving community. When climate hazards affect our transportation infrastructure, there can be cascading impacts to many other sectors and services. Climate hazards affecting transportation infrastructure can include both long-term stressors (such as increased extreme heat) that accelerate degradation of the infrastructure over time, and short-term shocks (such as more frequent severe storms) that have immediate impacts. By assessing the vulnerabilities of our transportation infrastructure to changing climatic conditions, we can make ourselves more resilient to these impacts.

For the purposes of this vulnerability and risk assessment, the transportation sector includes roadways and bridges, public transit (such as rail, bus, and airports), and bicycle and pedestrian infrastructure.

Table 18 summarizes the climate vulnerability scores of the transportation sector, including three sub-sectors and six climate hazards. Descriptions of these scores are included in the text sections below. Additional data are available in the appendices.

Table 18: Climate Vulnerability Summary - Transportation Sector

Transportation Sector – Climate Vulnerability Summary				
Climate Hazards	**Roadways**	**Public Transportation**	**Bicycle, Pedestrian**	**Total**
Extreme Heat	12	18	12	**42**
Inland Flooding	18	12	8	**38**
Severe Storms	18	12	12	**42**
Extreme Cold	4	4	4	**12**
Coastal Flooding	6	4	8	**18**
Drought	2	2	2	**6**
Total	**60**	**52**	**46**	**158**

*Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.

6.1. Roadway Transportation

For the purposes of this climate vulnerability and risk assessment, the "roadway transportation" sub-sector includes roadways, bridges and electric vehicle charging stations. The primary and secondary roadway system in Fairfax County is largely owned and maintained by the Virginia Department of Transportation (VDOT). Very few public roads are owned by the Fairfax County Department of Transportation (FCDOT).[220] The Dulles Toll Road is under the authority of the Metropolitan Washington Airports Authority. The George Washington Memorial Parkway is under the authority of the National Park Service. In addition to public roads, there are privately-owned and maintained roads throughout the county.

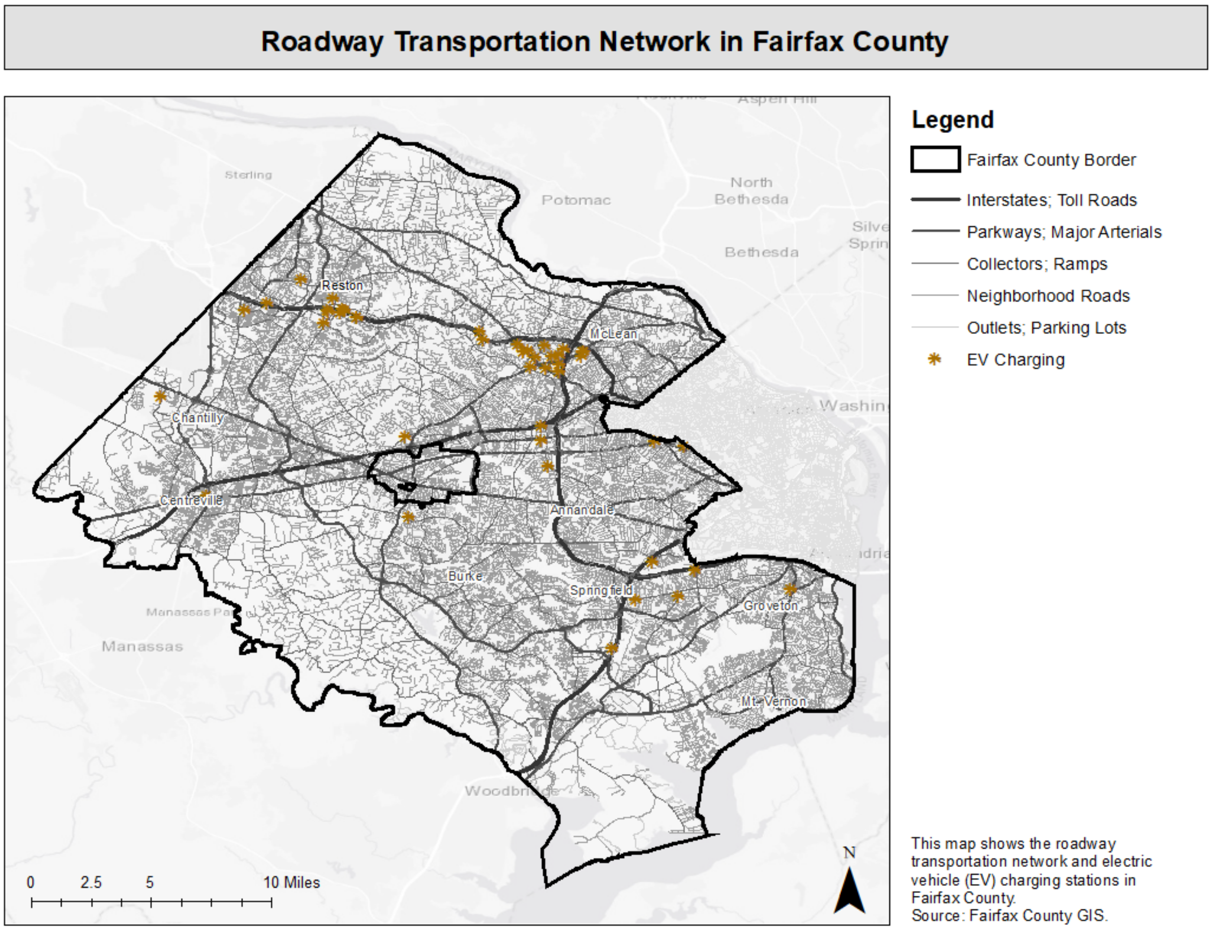


Figure 13: Roadway Transportation Network in Fairfax County

Climate change impacts can have significant implications for roadway systems, including increased maintenance needs, increase in traffic due to hazard-related maintenance and shutdowns, and blockages that restrict movement and make evacuation, emergency response, and general transportation difficult.[221]

Table 19 summarizes the climate vulnerability scores for roadway infrastructure in Fairfax County specifically. These scores are general and qualitative in nature; they are designed to highlight high-level vulnerabilities that may need deeper county attention and analysis. The following sections provide additional detail on these scores. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard. This assessment found that inland flooding and severe storms may be the highest vulnerabilities for the roadway system in Fairfax County, followed by extreme heat.

Table 19: Climate Vulnerability Summary - Roadway Infrastructure

Roadway Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	2	**12**
Inland Flooding	3	3	2	**18**
Severe Storms	3	3	2	**18**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	3	2	**6**
Drought	1	1	2	**2**
Total	-	-	-	**60**

6.1.a. Extreme Heat – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Extreme Heat**	**Exposure = 3** (High)

Roadways and bridges in Fairfax County are highly exposed to heat events, and heat events are projected to increase in frequency and intensity. In addition to general warming temperatures due to climate change, approximately 73% of road miles and 61% of bridges are located in areas of Fairfax County that experience significantly hotter land surface temperatures than the county average due to the urban heat island effect. Nearly all (98%) of electric vehicle charging stations are located in existing Urban Heat Islands. Some of these urban heat islands are especially severe, with existing measured land surface temperatures above 100° F on average during the summer months. 70% of electric vehicle charging stations, 19% of bridges, and 17% of roadway miles in Fairfax County are currently located in these areas with land surface temperatures above 100° F. As average annual temperatures and extreme heat days increase, the Urban Heat Island effect is also projected to increase. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Roadways and bridges have moderate sensitivity to extreme heat. Extreme heat events have the potential to compromise the structural quality and performance of roadways and bridges. Paving materials are sensitive to mixing temperature, ambient temperature, and ground temperature[222] for proper compaction. Excessive heat complicates the processes of mixing and laying new asphalt that complies with VDOT specifications.[223] The binder component of asphalt concrete maintains necessary properties within a specified temperature range (dependent on pavement type), beyond which roads may become sensitive to damage.[224] Additionally, hotter temperatures can cause existing roadway materials, including pavement and bridge joints,[225] to expand and break, ceasing proper functionality and causing potential safety concerns. These safety concerns are accentuated under the stress of traffic, particularly for heavily traveled roads or roads traveled by heavy trucks.[226] Overheated cars and those with premature tire deterioration from poor road conditions amplify the concern for road safety. The impact of extreme heat on high traffic roads and bridges may necessitate stricter load restrictions and speed regulations and increased maintenance in order to minimize breakage and prevent road accidents.

Extreme heat can also impact the charging and operating of electric vehicles, which optimally function within a given temperature range. One study suggests that the optimal temperature range for eight charger types to be approximately between −25°C (-13°F) and +40°C (104°F).[227] Charging electric vehicles can become dangerous with increased heat and humidity that is conducive to electrical arcs. Additionally, Battery Electric Buses (BEBs) have been found to maximally operate between about 59°F and 95°F.[228]

To supplement county data, a public survey was conducted asking residents to identify which roads (from the public perspective) were especially vulnerable to heat. The most commonly cited road was Route 1. Other commonly cited roads included Route 629, Route 236, and Route 7.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Roadways in Fairfax County have an estimated moderate adaptative capacity to extreme heat. For transportation facility design and standards, the county relies on the Public Facilities Manual (PFM) and VDOT standards. VDOT has dedicated crews who continuously repair roads and respond to blockages during hazards. Roadway infrastructure capital improvements have lengthy planning, design, and funding processes that cannot easily respond to accelerated climatic changes. A network-level vulnerability assessment has not been conducted within FCDOT for the transportation network to further assess concerns. There do not appear to be county-level recommendations for agencies to integrate future climate projections into network-level transportation planning, design, and engineering. Though there are measures to reduce damage and return service as soon as possible, extreme heat remains a threat to roads.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Extreme Heat**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the overall vulnerability of roadways and bridges in Fairfax County to extreme heat is estimated to be moderately high.

6.1.b. Heavy Precipitation and Inland Flooding – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Inland Flooding**	**Exposure = 3** (High)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," caused by water bodies overflowing onto floodplains, and "urban flooding," caused by heavy precipitation overwhelming stormwater management infrastructure. Roadways are highly exposed to the existing and projected hazards of heavy precipitation and inland flooding. In Fairfax County, much of this exposure is due to urban flooding, rather than riverine/floodplain flooding. Currently, less than 2% of roadway centerline miles are within FEMA or county floodplains. As would be expected, the statistic is higher for bridges, because some bridges cross over water bodies; approximately 20% of bridge segments in Fairfax County intersect (but are elevated above) floodplains. There are no known electric vehicle (EV) charging stations within FEMA or county floodplains. (See Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Urban flooding, however, is currently problematic for roadways throughout the county. Heavy precipitation events have resulted in high exposure of roadways to dangerous floodwater depths. Additionally, 50% of mapped EV charging stations are located on parcels estimated to be mildly flood-prone (parcels with two or more flood-prone factors), and 4% are located on parcels estimated to be moderately flood-prone (parcels with four or more flood-prone factors). As heavy precipitation events become more intense, more roads are likely to become exposed.

A public survey was conducted to supplement GIS data and gather information on roads that may be exposed to flooding from the survey respondent perspective. Some of the most frequently cited roads were Route 1, Route 29, Route 699, and Woodburn Road in Woodburn, and the northern and southern segments of the George Washington Memorial Parkway along the Potomac River.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Inland Flooding**	**Sensitivity = 3** (High)

Roadways and bridges are highly sensitive to inland flooding. Increased precipitation and flooding of roadways can cause erosion and deterioration of the quality of roads. This issue can be accelerated by roads that are already structurally compromised (for example, by excessive heat or poor condition), or roads that are already prone to flooding, such as Hickory Hollow Lane.[229] Sudden inundation of roads with water and debris can overflow drainage systems and cause overtopping of bridges, inflicting damage on surrounding environments and compromising road safety.

High-traffic bridges exposed to increased precipitation can experience bridge scour, which erodes sediments at the base of the bridge, weakening the foundation and potentially leading to bridge failure. Additionally, increases in soil moisture and lateral forces acting on the bridge can enable greater bridge movement which can compromise the structure.[230] If stream levels become too high during a precipitation event, bridge clearance may be reduced thereby affecting travel along navigable waterways. If stream levels become high enough to reach or surpass a bridge's low chord elevation, concerns of damage to the bridge may occur. If stream flow becomes significant, erosion along streambanks can impact adjacent roads. After a storm, increased maintenance may be needed to mend eroded roads and bridge structures, remove debris, improve drainage systems, and reinforce road support.

Flood-compromised roadways increase road congestion and risk of road accidents. This is an especially important point to consider given that increased flooding and road blockages may make it more difficult for emergency personnel to deliver aid.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Roadways and bridges in Fairfax County have an estimated moderate adaptative capacity to handle heavy precipitation and inland flooding. Though maintenance and planning efforts provide some levels of defense against heavy precipitation and inland flooding, the impacts on this sub-sector remain a concern for the county.

The existing roadway network in Fairfax County is largely maintained and operated by VDOT, rather than the county. Roadways are especially susceptible to inland flooding in older neighborhoods that were constructed prior to current stormwater management regulations (i.e. without sufficient stormwater conveyance systems based on today's standards). County transportation assets are generally evaluated for vulnerabilities to flooding and stormwater management as individual facilities as they are built, as opposed to at the network level. County transportation assessments largely consider past and current, (not future), climate conditions such as flooding during design.

The Fairfax County Floodplain Management Plan identifies mitigation actions to avoid and/or reduce the impacts of flooding in county floodplains. These include identifying funding opportunities to replace vulnerable or undersized culverts with larger ones or bridges.[231] It is assumed that culverts, bridges, and roads are well maintained to reduce cracks and other issues that can increase susceptibility to damage.

At the state level, VDOT has provided recommended methodology for estimating future extreme precipitation events during bridge design, providing a resource for considering climate change. VDOT's Design Manual Chapter 12 – Riverine Analysis was updated to include the 200-year design storm for certain stream crossings.

Additionally, storm sewer systems are commonly designed at 80% capacity to account for future development and changes in climate, potentially reducing flooding on roadways. This may provide a cushion of adaptive capacity. Further, the Northern Virginia Soil and Water Conservation District (NVSWCD) provides grant funding to address erosion impacts, which may mitigate stream bank and coastal erosion that undermines roadways.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Inland Flooding**	**Total Vulnerability = 18** (High)

Based on the information available, the overall vulnerability of roadway and bridges to heavy precipitation and inland flooding in Fairfax County is estimated to be high.

6.1.c. Severe Storms – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Severe Storms**	**Exposure = 3** (High)

The roadway and bridge system in Fairfax County is highly exposed and not well protected from severe storms. Storm events are projected to intensify under future climate conditions.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Severe Storms**	**Sensitivity = 3** (High)

Roadways and bridges are highly sensitive to severe storms such as tropical storms, derechos, and severe thunderstorms. Severe storms with heavy winds can disrupt travel and compromise safety by creating and distributing debris on roadway systems, eroding roadways, downing power lines, limiting access to fuel, and reducing visibility. Additionally, storm-related events can stress the foundation and stability of bridge decks and supporting structures. Higher wind speeds are correlated with faster moving water as well as stronger water force; this increased water energy can cause bridge scour and other damages. The threshold at which damage occurs is largely dependent on bridge characteristics.[232] High-speed winds blowing across bridges can flip traveling vehicles, causing safety concerns. Power outages can prevent mobile bridges from functioning, which can disrupt the flow of traffic both above and below the bridge and can cause safety concerns. Power outages may also disrupt availability of electric vehicle power, depending on grid connectivity and redundancy.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Roadways and bridges in Fairfax County have an estimated moderate adaptative capacity to handle severe storms. Roadways in Fairfax County are regularly maintained. There are systems in place for response to blockages, although these systems may need to be updated for increasing storm severity. For transportation facility design and standards, the county relies on the Public Facilities Manual and VDOT standards. Though some measures have been taken to reduce harm to roadways from severe storms, and these measures are increasing, these events continue to pose a threat to roadways.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Severe Storms**	**Total Vulnerability = 18** (High)

Based on the information available, the overall vulnerability of roadways and bridges in Fairfax County to severe storms is estimated to be high.

6.1.d. Extreme Cold – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Extreme Cold**	**Exposure = 1** (Low)

Roadways and bridges in Fairfax County are exposed to extreme cold when such events occur. However, cold events are projected to decrease in frequency and intensity, so overall future exposure is projected to be low.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Roadways and bridges are moderately sensitive to extreme cold. Freeze-thaw cycles (when temperatures fluctuate above and below freezing) can cause pavements to crack and can lead to potholes. Bridges freeze more easily than roads during extreme cold events, leading to safety concerns and requiring de-icing treatments. Drivers in cars that are unequipped to handle extreme cold may become stranded, requiring emergency services.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

The estimated adaptive capacity of roadway and bridges in Fairfax County is moderate for extreme cold. Maintenance efforts, such as salting roadways prior to cold precipitation events or fixing potholes in response to freeze-thaw exposure, reduce the impact of extreme cold on roadways. However, extreme cold continues to pose a threat to roadways. Maintenance costs and long timeframes for infrastructure upgrade processes can create barriers in the ability of transportation agencies to adapt.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Extreme Cold**	**Total Vulnerability = 4** (Low)

Based on the information available, the overall vulnerability of roadways and bridges in Fairfax County to extreme cold is low, largely due to projected low future exposure as winter temperatures rise.

6.1.e. Coastal Flooding – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Coastal Flooding**	**Exposure = 2** (Moderate)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and coastal storm surge. Coastal flooding exposure levels are based on the coastal area of the county (the area within one mile of the Potomac River shoreline), rather than the county as a whole. The George Washington Parkway, many of the roads within New Alexandria, Mount Vernon Memorial Highway, and Old Mill Road are projected to be potentially exposed to coastal flooding in the future. While this is a small portion (less than 1%) of the county's roadway miles overall, the exposure could be serious for those in the areas along the Fairfax County shoreline, and those who regularly rely on these key commuting routes. There are no known EV charging stations within areas of projected coastal flooding inundation. (See Appendix 3 for tabulation of asset exposure and Appendix 2 for maps)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Coastal Flooding**	**Sensitivity = 3** (High)

Roadways and bridges are highly sensitive to coastal flooding. Older road facilities are more sensitive because they were built to older stormwater management standards that were based on less extreme events. Additionally, coastal flooding can inundate roads, damage traffic light control and coordination systems, and worsen road congestion and safety concerns. In addition, coastal flooding can cause erosion along roadways and bridge abutments leading to significant damage. Sea level rise and increased storm surge can cause flooding and damage to bridges. Finally, electrical vehicle (EV) charging stations can be damaged by excessive moisture and flooding. This can prevent proper functioning of charging stations and electric vehicles.[233]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Coastal Flooding**	**Adaptive Capacity = 1** (Good)

The roadway and bridge system in Fairfax County is estimated to have relatively strong adaptative capacity to coastal flooding, based on the four adaptive capacity factors. (See Appendix for detailed methodology). Resources are available to design roadway infrastructure for future coastal conditions to enhance resilience; however, built coastal infrastructure remains vulnerable.

VDOT provides a resource for considering climate change and coastal storms. The methodology for transportation facility design and standards includes consideration of climate change and coastal storms for bridge design.[234] VDOT's Bridge Manual contains a chapter on "Consideration of Climate Change and Coastal Storms" and establishes practices and requirements for VDOT staff and contractors to adopt a "climate-based" approach to design. The chapter includes guidance on climate scenarios and projections and specifically identifies which NOAA sea level rise curve to consider when designing future assets. Additionally, the Commonwealth of Virginia is currently conducting a transportation climate vulnerability and risk assessments related to coastal flooding as part of the Virginia Coastal Resilience Master Plan.

The Virginia Department of Environmental Quality (VDEQ) provides Coastal Resilience grants that address sea level rise and associated coastal flooding and erosion. One aspect of the program focuses on natural resilience (e.g., wetlands, beaches, dunes) as a natural defense against sea level rise and more frequent, severe storm events. The other focuses on community resilience, or the ability of coastal areas to adapt to changing coastal conditions. These grant programs mitigate coastal erosion and flooding impacts that damage roadways through washouts, undermined roadway foundations, and flooding. Fairfax County has secured funding through the VDEQ through its 2020 Coastal Zone Management Program.[235]

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Coastal Flooding**	**Total Vulnerability = 6** (Moderate)

Based on the information available, roadways in Fairfax County are estimated to have moderate overall vulnerability to coastal flooding, or flooding of the Potomac River and associated water bodies.

6.1.f. Drought – Roadway Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Roads**	**Drought**	**Exposure = 1** (Low)

Roadways and bridges are technically exposed to drought conditions. However, drought is not projected to increase with significant frequency nor intensity in Fairfax County, so overall future exposure is low.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Roads**	**Drought**	**Sensitivity = 1** (Low)

Roadways and bridges have low sensitivity to drought. In extreme circumstances, during drought conditions, water supplies can deplete groundwater thereby causing sinkholes in roadways,[236] leading to road closure and safety concerns.

Adaptive Capacity: Are we able to adapt to and address Drought impacts?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Roads**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Information regarding how FCDOT is protecting roadways against drought was not found. Therefore, adaptive capacity was scored a two (2) (as actions and measures are unknown). However, this lack of information is likely because this is not a significant hazard for roadways to justify county time and investment.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Roads**	**Drought**	**Total Vulnerability = 2** (Very Low)

The overall vulnerability of roadways and bridges to drought is estimated to be very low.

6.2. Public Transportation (Metro, Bus, Airports) & Rail

“Public transportation” for the purposes of this climate vulnerability assessment includes Metrorail and Metrorail stations, Metrobus lines and Metrobus stops, Fairfax Connector bus stops, private railways, and Virginia Railway Express (VRE) stations. In addition to these assets within the county, the Dulles International Airport is the largest airport in Virginia and a major international airport for the Greater Washington region. The airport is physically located just outside of the Fairfax County border, in Loudoun County. Therefore, discussion of the airport is included where applicable, but hazard exposure calculations for the airport are not included because hazard data was acquired within county borders only.

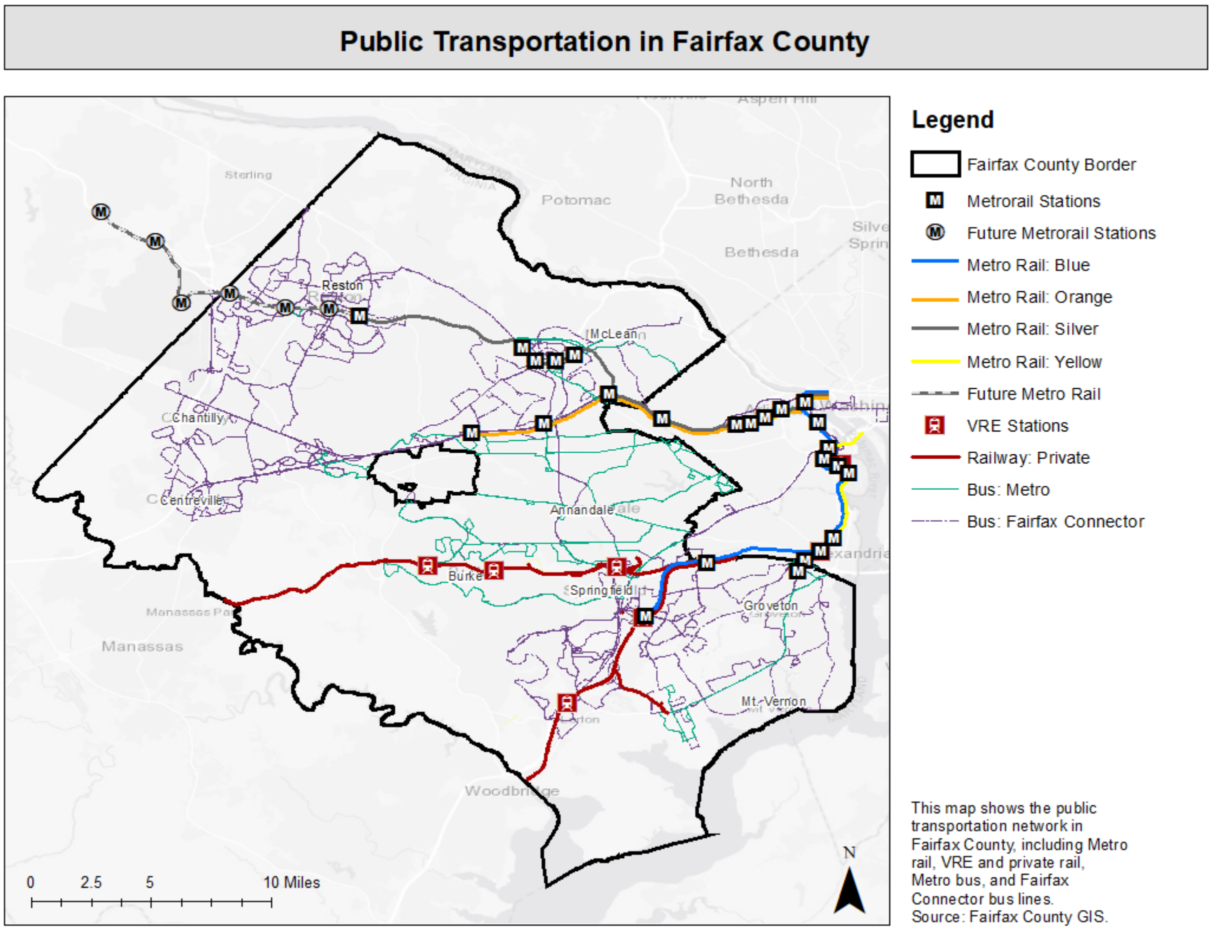


Figure 14: Public Transportation in Fairfax County

The Washington Metropolitan Area Transit Authority (WMATA)[237] is the largest transit service agency in the Greater Washington region. It operates mass transit (Metrorail) and bus service (Metrobus) in Fairfax County. Four of six of WMATA’s Metrorail lines (Blue, Orange, Silver, and Yellow) operate in Fairfax County, with a total of ten stations wholly within the county. (Van Dorn Street station on the Blue Line straddles the boundary between Fairfax County and Alexandria). The Silver Line is the newest Metrorail line; Phase II of the Silver Line is under construction and will extend service beyond the current terminus at Wiehle-Reston East through Herndon into Loudoun County. Because four lines currently terminate in the county, WMATA also has rail yards and other facilities in the county to support Metrorail operations, including the West Falls Church Rail Yard. Metrobus service operations in Fairfax County mainly operate in Northern Virginia to connect riders to Metrorail stations and other destinations not readily accessible by Metrorail, with some lines operating only during peak hour service for commuters to the Pentagon Transit Center and downtown DC. There is one Metrobus bus yard in Fairfax County, Cinder Bed, to support Metrobus operations. In addition to Metrobus, the Fairfax Connector is the main local bus system in the county, transporting about 30,000 passengers per day from over 3,000 bus stops and across 91 routes.[238]

The Virginia Railway Express (VRE) is a commuter rail service connecting numerous communities in Northern Virginia to Union Station in Washington, DC. VRE's two lines, the Manassas Line and the Fredericksburg Line, stop at five stations in Fairfax County during weekday peak commuting hours only (Backlick Road, Rolling Road, Burke Centre, Lorton, Franconia-Springfield). Morning trains predominantly travel towards Washington and afternoon trains travel in the opposite direction. Unlike WMATA, VRE does not operate on its own right-of-way, but operates on track owned by CSX and Norfolk Southern.

A summary of the county's climate vulnerabilities relating to public transportation and rail are shown in *Table 20*. Vulnerability is scored based on consideration of levels of exposure, sensitivity, and adaptive capacity. These scores are general and qualitative in nature; they are designed to highlight high-level vulnerabilities that may need additional county attention and analysis. Based on this assessment, extreme heat, inland flooding, and severe storms are estimated to pose the highest climate vulnerabilities to the local public transportation system.

Table 20: Climate Vulnerability Summary - Public Transportation Infrastructure

Public Transportation Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	3	2	**18**
Inland Flooding	2	3	2	**12**
Severe Storms	2	3	2	**12**
Extreme Cold	1	2	2	**4**
Coastal Flooding	1	2	2	**4**
Drought	1	1	2	**2**
Total	-	-	-	**52**

6.2.a. Extreme Heat – Public Transportation & Rail Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Extreme Heat**	**Exposure = 3** (High)

The public transportation system is highly exposed to extreme heat. The frequency and intensity of extreme heat is projected to increase significantly. In addition to general warming due to climate change, the vast majority of public transportation assets in Fairfax County are within areas experiencing significantly higher land surface temperatures due to the Urban Heat Island (UHI) effect. Specifically, 98% of Metrorail, 100% of Metro stations, 92% of Metro bus lines, 85% of Metro bus stop, 87% of Fairfax Connector bus stops, 66% of private railroads, and 100% of VRE stations in the county are in areas with high UHI. Within UHI areas, it may also be useful to consider locations where average land surface temperatures during summer months exceed 100° F specifically. Currently, 22% of Metrorail lines, 80% of Metrorail stations, 42% of Metro Bus lines, 30% of Metro Bus stops, 33% of Fairfax Connector Bus stops, 13% of private railways, and 0% of VRE stations are located in areas with land surface temperatures exceeding 100° F. As general temperatures increase with climate change, UHI areas are also expected to increase. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Extreme Heat**	**Sensitivity = 3** (High)

The public transportation system is moderately sensitive to extreme heat. Extreme heat events can disrupt rail transit by damaging necessary equipment and by reducing overall rail efficiency. Heat can produce buckling of railroad tracks making them unfit for use; according to U.S. DOT, rails are installed to sustain rail temperatures up to 95-100°F (this is where the stress on the rail is zero), preventing excessive buckling for rail temperatures up to 130-150°F.[239] Rail temperatures can exceed the air temperatures by 25-30°F or more, suggesting air temperatures of 100°F or more could damage rail lines.[240] Additionally, overheating of electrical equipment, such as electrified third rail and catenary wires, can cause permanent damage to rail systems.[241] Such damages necessitate reduced train speeds to ensure safety and prevent further damage to rail structures. Doing so reduces the efficiency and convenience of rail travel for individuals.

Excess heat can also interfere with voltage, producing brown or black-outs in the power grid that cause loss of service to public transit systems such as Metrorail and Metrorail stations.[242] Decreased reliability of rail stations diminishes overall practicality of rail transit.

Extreme heat can create dangerous situations for individuals utilizing bus and metro transit.[243] Extreme heat can stress the operations of air conditioning and HVAC (heating, ventilation, and air conditioning) systems used by buses, subway cars, and stations. Over-exposure to heat by transit users can cause heat cramps, exhaustion, and even stroke.[244] Groups especially at risk include children and older adults[4]. (For additional information on population vulnerabilities, please see the "populations" sector.) Heat exposure can also advance weathering of bus fleets and their communication systems, necessitating additional maintenance.

Airport operations can be impacted by extreme heat. The asphalt used for runways may soften and deteriorate under extreme heat conditions.[245] A heavier airplane requires more runway to obtain lift. As temperatures become too hot, the air becomes less dense, affecting lift for larger airplanes and requiring longer runways. For example, a Boeing 737-600 requires 2,134 meters (~7,000 feet) of runway when air temperatures reach 15°C (59°F) and 2,700 meters (~8,860 feet) of runway when air temperatures reach 33.8°C (92.8°F).[246] Regional, smaller-scale aircraft cannot fly safely when temperatures exceed 118°F. This is not anticipated to occur regularly by mid-century for Fairfax County. Occupational hazards to outdoor airport personnel as well as heat impacts on exposed travelers can occur, affecting airport staff and traveler safety.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County is estimated to have a moderate adaptive capacity for extreme heat. Many transportation assets are under the control of VDOT and WMATA, rather than Fairfax County.

WMATA has developed climate-related plans, such as the Severe Weather Plan, and is in the process of developing a more specific climate resilience implementation strategy. During periods of high heat, WMATA enhances visual inspections to identify when rail segments reach temperatures above a threshold. If the temperature threshold is exceeded, a speed restriction is imposed.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Extreme Heat**	**Total Vulnerability = 18** (High)

Based on the information available, the public transportation system in Fairfax County is estimated to have high total vulnerability to extreme heat conditions.

6.2.b. Heavy Precipitation and Inland Flooding – Public Transportation & Rail Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Inland Flooding**	**Exposure = 2** (Moderate)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," caused by water bodies overflowing onto floodplains, and "urban flooding," caused by heavy precipitation overwhelming stormwater management infrastructure. Heavy precipitation is projected to increase in intensity and frequency. The public transportation system in Fairfax County is moderately exposed to inland flooding when considering both types.

For riverine/floodplain flooding, a relatively small portion of public transit assets (less than 5% for most asset types) are exposed. There is one Metrorail Station in the county, the McLean Metro Station, that technically intersects FEMA and county floodplains, but is vertically elevated well above potential flood areas. Most metro rail stations located in Fairfax County are located above ground rather than below ground, reducing station flooding issues that are seen in other parts of the Metro system, such as the below-ground stations in Washington, DC. Private railroads potentially have more concerning exposure, with nearly 7% (5.51 miles) of track intersecting the FEMA 500-year floodplain.

Urban flooding may result in higher exposure levels. Metrobus, Fairfax Connector Bus stops, and private railroads located in areas with insufficient stormwater management systems are estimated to have higher exposure to urban flooding. These exposure levels vary by asset type and flood score level. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Inland Flooding**	**Sensitivity = 3** (High)

The public transportation system in Fairfax County is highly sensitive to inland flooding, which means that service can be disrupted by this hazard for over 24 hours. Flooding can compromise rail structures and their supporting systems. Severe flooding can introduce debris onto railways that blocks and disrupts service. Flooding that immerses wooden rail ties can weaken track support, and inundation of technology can cause shorting of electrical equipment such as switches, gates, and signals, which can ultimately threaten safety of individuals.[247]

Precipitation and flooding events can also compromise the structural integrity of rail transit by increasing ballast erosion or embankment scour. Surrounding support systems such as old or underground transit system tunnels and stations[248] can also be flooded by an increase in precipitation.[249]

For bus transit, increased precipitation can cause floods that divert or delay bus routes.[250] Insufficient drainage near bus stops can make transit inaccessible to riders and can create dangerous driving conditions and damage to vehicles. A previous flood incident at the Huntington Connector Bus Garage in

Lorton required buses to be moved to higher ground to avoid damage. Flooding may also be intermittently experienced at a WMATA garage on Huntington Avenue and a Metro Access garage.[251]

Additionally, heavy precipitation and flooding can impact the number of people who take public transportation, reducing fare revenues.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County is estimated to have moderate adaptative capacity for heavy precipitation and inland flooding. Though maintenance and planning efforts provide some levels of defense against heavy precipitation and inland flooding, the impacts on public transportation remain a concern for the county.

Many transportation assets are under the control of VDOT and WMATA, rather than FCDOT. At the time of writing, VDOT is identifying vulnerable infrastructure statewide. Recent legislation (HB 1217) requires VDOT to identify public transportation infrastructure in Planning District 8 that is at risk of deterioration due to recurrent flooding.[252] Fairfax County is in Planning District 9, but VDOT staff note that they are identifying vulnerable infrastructure statewide.

WMATA has developed climate-related plans, such as the Flood Emergency Response Plan and Severe Weather Plan and is in the process of developing a more specific climate resilience implementation strategy. WMATA notes that it has also invested in infrastructure improvements, such as upgrading pump stations and repairing interior damage within Metro tunnels.[253]

Fairfax Connector bus facilities are under FCDOT control. Fairfax Connector Bus staff have taken action to mitigate flooding issues, specifically in the Huntington Garage on Cinder Bed Road. Operations staff have moved the buses to higher ground during flooding, and stormwater improvements were completed in recent years.[254] These stormwater improvements have improved but not eradicated the issue.[255] Similar or more permanent adaptations may become necessary to preserve bus transit operations as flooding events increase in frequency and severity.

FCDOT notes that they can design stormwater management to either VDOT or FCDOT standards, the latter of which is usually more stringent. The Richmond Highway Bus Rapid Transit Project currently under development is one such example where a more stringent design was used. Retrofitting or relocating public transportation infrastructure, such as tracks and stations, are long-term, complex, and expensive investments, which makes adaptation to changing conditions more difficult.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Inland Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the public transportation system in Fairfax County is estimated to have moderately high vulnerability to increasing heavy precipitation and inland flooding events.

6.2.c. Severe Storms – Public Transportation Infrastructure Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Severe Storms**	**Exposure = 2** (Moderate)

Above-ground public transportation assets are directly exposed and not well protected from severe storms. Additionally, any portion of the public transportation system that is dependent on electricity can be indirectly exposed to extreme storm effects that cause power outages. Storm events are projected to intensify in Fairfax County under future climate conditions.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Severe Storms**	**Sensitivity = 3** (High)

Public transportation is highly sensitive to severe storms, such as hurricanes, tropical depressions, derechos, severe thunderstorms, and other storm types. High sensitivity means that this hazard can cause disruption of service for longer than 24 hours. Extreme storms and wind behavior can affect operations as well as inflict damage on WMATA, VRE, and Fairfax Connector's infrastructure and assets. Metro and rail systems are at risk of losing power for periods of time as a result of severe weather and damages to the energy grid. These types of events pose significant risk to above-ground electricity transmission distribution, which is prevalent in the northeast and mid-Atlantic region.[256] In extreme cases, storms with significant wind velocities can damage platforms and stations and make them unfit for use.[257] Rail and transit assets located in wooded areas are vulnerable to increased debris and blockages. High winds can also increase risk of rail bridge instability which presents a serious hazard.[258] Severe storms can also render it unsafe to operate Fairfax Connector bus and Metro bus services. On rare occasions, the Governor may issue a state of emergency or travel ban which can impact the level of service of public transit. Dulles airport may also find conditions are unsafe to fly at full capacity causing delays or flight cancellations, potentially stranding travelers in the terminal.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County has an estimated moderate adaptive capacity for severe storms. Adaptive capacity is scored according to four criteria (please see appendix for methodology). Many transportation assets are under the control of VDOT and WMATA, rather than FCDOT. WMATA has developed climate-related plans, such as the Flood Emergency Response plan and the Severe Weather Plan, and is in the process of developing a more specific climate resilience implementation strategy. WMATA has also invested in regular infrastructure improvements, such as repairing platforms, tracks and structures, and interior damage within Metro tunnels[259]. Fairfax

Connector is under FCDOT control. In the event of extreme weather and wind speeds, bus services may be temporarily suspended. Public transportation improvements require significantly long planning, design, and construction timelines, high levels of funding, and a complex web of approvals in the multi-jurisdictional DC metropolitan area. This makes it more difficult for these systems to readily adapt to changing climatic conditions.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Severe Storms**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the public transportation system in Fairfax County is estimated to have moderately high total vulnerability to severe storms.

6.2.d. Extreme Cold – Public Transportation & Rail Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Extreme Cold**	**Exposure = 1** (Low)

Above-ground public transportation infrastructure is especially exposed to extreme cold. However, cold events are projected to decrease in frequency and intensity, making overall future exposure low.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Extreme Cold**	**Sensitivity = 2** (moderate)

As with extreme heat, extreme cold can expose public transportation passengers to unsafe conditions along transit stops that are not heated.[260] Extreme cold and associated winter conditions can cause overhead power lines to contract and break loose, requiring repairs.[261] Ice can damage rail equipment,[262] requiring additional maintenance and safety precautions. Ice can also interfere with electrical transmission of rails which presents a safety hazard and can lead to further damage of rails and trains. Ice can jam mechanical switches, making switches unmovable and overhead wires can snap.

Aircraft are built to withstand extreme cold temperatures, because they operate at high altitudes where temperatures are lower, and denser cold air may translate to more efficient aircraft takeoff and landing. However, extreme cold conditions can lead to delayed flights if the equipment used to pump jet fuel freezes, affecting the refueling of planes.[263] Dulles airport on-time arrivals and departures may be delayed by the time needed to de-ice aircraft.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County has an estimated moderate adaptive capacity for extreme cold events. Little information was found that assesses current activities and measures to reduce impacts of extreme cold. Additionally, many transportation assets are under the control of VDOT and WMATA, rather than FCDOT. WMATA has developed climate-related plans, such as the Severe Weather Plan, and is in the process of developing a more specific climate resilience implementation strategy.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Extreme Cold**	**Total Vulnerability = 4** (Low)

Based on the information available, the public transportation system in Fairfax County is estimated to have low total vulnerability to extreme cold events, largely because extreme cold events are generally projected to decrease.

6.2.e. Coastal Flooding – Public Transportation & Rail Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. A very small portion of public transit assets in Fairfax County are projected to be exposed to sea level rise inundation and coastal flooding. Specifically, approximately 0.23 out of 22 miles (1.3%) of Metrorail, 3.4 out of 463 miles (0.74%) of Metrobus lines, 4 out of 1,509 (0.27%) Metro Bus stops, and 10 out of 3,708 (0.32%) Fairfax Connector Bus stops could be exposed to coastal storm surge. Exposure rates are lower for sea level rise alone. (Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Public transportation infrastructure is moderately sensitive to coastal flooding. Coastal flooding could introduce debris and flood waters onto rails and roads, which could block and disrupt service. Flooding that immerses wooden rail ties can weaken track support, and inundation of technology can cause shorting of electrical equipment such as switches, gates, and signals, which can ultimately threaten safety of individuals. Coastal flood events can also compromise the structural integrity of rail transit by increasing ballast erosion or embankment scour.[264] Similarly, low-lying rail yards and service buildings can become inundated with water from coastal flooding.[265] Such occurrences would decrease and potentially permanently disable rail services and could cause danger to human beings and their environments.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County has an estimated moderate adaptive capacity to handle coastal flooding. At the time of writing, the Commonwealth of Virginia is conducting transportation climate vulnerability and risk assessments related to coastal flooding as part of the Virginia Coastal Resilience Master Plan. [266] Transportation assets evaluated for coastal flooding include roadways, bridges, rail and public transit lines, and other infrastructure. Additionally, the National Capital Region Transportation Planning Board (TPB) is conducting a "Transportation Planning Board Resiliency Study"[267] as part of the Visualize 2045 long-range transportation plan. Further, recent legislation (HB 1217)[268] requires VDOT to identify public transportation infrastructure in Planning District 8 that is at risk of deterioration due to recurrent flooding. Fairfax County is in Planning District 9, but VDOT staff note that they are identifying vulnerable infrastructure statewide.

However, there are numerous barriers to adaptation for this hazard, including cost, feasibility, and the lack of local authority to implement adaptation strategies for transportation assets under control of VDOT, WMATA, federal, or private authorities.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information provided, the total vulnerability of the public transportation system in Fairfax County is estimated to be low.

6.2.f. Drought – Public Transportation & Rail Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Public Transport**	**Drought**	**Exposure = 1** (Low)

Drought is not projected to increase with significant frequency and intensity in Fairfax County. However, intermittent drought events may still occur. Public transit would be exposed to drought conditions if and when they occur.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Public Transport**	**Drought**	**Sensitivity = 1** (Low)

There appear to be minimal or no impacts of drought to public transportation infrastructure.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Public Transport**	**Drought**	**Adaptive Capacity = 2** (Moderate)

The public transportation system in Fairfax County has an estimated moderate adaptive capacity to drought. There is little information assessing how the system is being protected against drought, so this section is assigned the middle score of two (2). However, the lack of information is likely due to lack of need to prepare public transportation infrastructure for this hazard.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Public Transport**	**Drought**	**Total Vulnerability = 2** (Very low)

Based on the information available, the public transportation system in Fairfax County is estimated to have minimal vulnerability to drought conditions.

6.3. Bicycle & Pedestrian Infrastructure

According to Fairfax County geospatial data, there are currently approximately 1,580 miles of bicycle routes and close to 950 miles of bicycle trails (see tabulation in Appendix 3) in the county. Fairfax County has been a Capital Bikeshare member jurisdiction since 2016, with 54 Bikeshare stations distributed in Reston, Merrifield, Tysons, and West Falls Church. Pedestrian walkways, of which there are over 4,106 miles in the county, are managed by numerous stakeholders. Main walkway maintenance entities include the Fairfax County Department of Public Works and Environmental Services (DPWES), Fairfax County Facilities Management Department (FMD), Fairfax County Department of Transportation (FCDOT) Fairfax County Public Schools (FCPS), Northern Virginia Regional Park Authority (NVRPA), private landowners and homeowners' associations, and Virginia Department of Transportation (VDOT), among others.

At the time of writing, the county is in the process of developing the ActiveFairfax Transportation Plan, which will combine the Countywide Trails Plan and the Bicycle Master Plan and set a vision for increasing the use of bicycle and pedestrian modes in the county.[269] Additionally, there are continuous investments being made to expand the county's active transportation network. These investments can be found in the county's adopted Capital Improvement Program (CIP) documents.[270]

Table 21 summarizes the climate vulnerability scores for bicycle and pedestrian infrastructure. The following sections provide additional details on the vulnerability scores for each of the six hazard areas. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard. These scores are general and qualitative in nature; they are intended to highlight high-level vulnerabilities that may need additional county attention and analysis. Based on this assessment, extreme heat and severe storms are estimated to be the highest climate vulnerabilities for this subsector.

Table 21: Climate Vulnerability Summary – Bicycle and Pedestrian Infrastructure

Bike & Ped Infrastructure – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	2	**12**
Inland Flooding	2	2	2	**8**
Severe Storms	3	2	2	**12**
Extreme Cold	1	2	2	**4**
Coastal Flooding	2	2	2	**8**
Drought	1	1	1	**2**
Total	-	-	-	**46**

6.3.a. Extreme Heat – Bicycle & Pedestrian Infrastructure Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Extreme Heat**	**Exposure = 3** (High)

All bicycle and pedestrian assets and users are projected to be exposed to increasing severity and duration of extreme heat events, as general temperatures rise across the county due to climate change. In addition to general temperature increases, a large portion of bicycle and pedestrian routes and infrastructure are located in areas where land surface temperatures are amplified by the Urban Heat Island (UHI) effect. Specifically, over 70% of bicycle routes, 51% of bicycle trails, 83% of walkways, and 96% of Capital Bike Share Locations are in areas of the county that currently experience significantly hotter land surface temperatures than other areas of the county due to the UHI effect). (Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

The bicycle and pedestrian sub-sector is moderately sensitive to extreme heat conditions. These sensitivities relate to both the users of the infrastructure (people), and the infrastructure itself.

Many heat sensitivities for this sub-sector relate to the *users* of bicycle and pedestrian infrastructure. People who are walking or biking during extreme heat conditions face risk of heat-related illnesses. When extreme heat is caused by a heat dome, pedestrians and bicyclists also experience poorer air quality due to the trapping of pollutants close to ground level.[271] (For detail on specific heat-related health risks for populations, please see the “Populations” sector). There is an equity lens to this issue because people who do not own cars, particularly those in poverty, rely more heavily on bicycling and walking to meet daily needs.[272] Public transportation is often accessed by individuals walking or biking. From an equity perspective, lower-income individuals will have greater exposure to extreme heat than higher-income individuals for this reason. However, these heat-related sensitivities also apply more broadly to all populations. Many individuals who have access to cars still choose to walk or bike for transportation or recreation. Federal agencies like the National Highway Traffic and Safety Administration recognize that each person is a pedestrian at some point in a day,[273] meaning that an individual who drives a car will still need to walk from their car to their destination, and vice versa, and use sidewalks and other pedestrian infrastructure to do so. Therefore, all persons may at some point be sensitive to extreme heat conditions while using pedestrian or bicycle infrastructure.

Pedestrian and bicycle infrastructure itself is also is moderately sensitive to extreme heat conditions. Asphalt can deform in in extreme heat,[274] especially over long-term repeated exposure. These conditions are especially a concern for bicycle routes along roadways that are shared with heavier cars and trucks, which can deform the asphalt more easily than lighter vehicles. Such asphalt deformity can create ruts in asphalt surfaces, compromising bicyclist safety and comfort. Under certain conditions, concrete sidewalks can buckle in extreme heat.[275] Buckling occurs in response to a change in temperature, and is partially dependent on the age and quality of the concrete itself.[276] At crosswalks, vehicles can, over time, push asphalt to the roadway edge during extreme heat events and create a one-to-two-inch lip at curb cuts, limiting accessibility for wheelchair users and creating trip hazards.[277]

Crosswalk and bicycle lane markings can also get “tracked-over” during extreme heat periods, whereby vehicles driving over newly laid asphalt roads track the asphalt in the roadway onto roadway paint and make them less visible.[278] [279] While this is less of an issue in protected bike lanes, tracked-over bicycle lane markings can make it less safe for bicyclists to ride if automobile drivers cannot easily see the presence of bike infrastructure while a bicyclist is present. Similarly, tracked-over crosswalk markings can make crossings less safe for pedestrians if automobile drivers cannot easily see the presence of pedestrian infrastructure. These infrastructure-related sensitivities create both safety and maintenance concerns.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Bicycle and pedestrian infrastructure in Fairfax County have an estimated moderate adaptive capacity to extreme heat. Infrastructure managers including FCDOT and FCPA continuously conduct maintenance and improvement projects for bicycle and pedestrian assets.[280] These regular maintenance activities would include (but are not limited to) repair of assets degraded over time by extreme heat. Additionally, county agencies and partners, including DPWES Urban Forestry Management Division,[281] DPD,[282] FCPA,[283] and NVSWCD[284] promote, protect, and conduct green infrastructure installations and tree plantings, which naturally help to cool bicycle and pedestrian routes. However, barriers to adaptation exist, including limited staff capacity, funding limitations and prioritization needs, the large size and split ownership of the bicycle and pedestrian network, and technological limitations of asphalt and concrete currently used.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Extreme Heat**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the total vulnerability of pedestrian and bicycle infrastructure to extreme heat is estimated to be moderately high.

6.3.b. Heavy Precipitation and Inland Flooding– Bicycle & Pedestrian Infrastructure

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Inland Flooding**	**Exposure = 2** (Moderate)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," caused by water bodies overflowing onto floodplains, and "urban flooding," caused by heavy precipitation overwhelming stormwater management infrastructure. Heavy precipitation is projected to increase in intensity and frequency. The bicycle and pedestrian network in Fairfax County has moderate exposure to inland flooding.

In the "riverine" or floodplain category of flooding, over 16% of bicycle trails, 2% of bicycle routes, and 2% of walkways are located in county floodplains. Each of these statistics is slightly lower for FEMA floodplains. There are no existing Capital Bike Share stations within county or FEMA floodplains. The higher percentage for bicycle trails may be because some trails are located on park land, which is naturally adjacent to water bodies.

In the "urban" flooding category, exposure levels are likely to be higher than floodplain exposure for bicycle and pedestrian infrastructure. The county's roadways are currently exposed to urban flooding during heavy precipitation events; many bicycle and pedestrian assets are located on or adjacent to roadways. Severe heavy precipitation events have required swift water rescues. Such heavy precipitation is projected to increase in intensity and frequency. Roadways with insufficient stormwater management systems have higher exposure to urban flooding.

(Please see Appendix 3 for tabulation of asset exposure and Appendix 2 for maps).

To supplement geospatial data and analysis, the county surveyed residents on their experiences with flooding of pedestrian and bicycle assets. Common survey responses included Braddock Road Trail, Union Mill Trail, Washington & Old Dominion Trail, and Cook Branch Trail. (These responses are reflective of survey respondents' perspectives only).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Bicycle and pedestrian infrastructure is moderately sensitive to inland flooding. Assets exposed to flooding during heavy precipitation or inland flooding events may be rendered inaccessible. Increased precipitation and flooding of roadways can cause erosion and deterioration of the quality of bicycle and pedestrian assets. Dirt trails that are wet can become seriously eroded if disturbed by hikers and other users.[285] Heavier precipitation could lead to more trail closures. Severe inland flooding of bicycle and pedestrian infrastructure can pose safety risks to users.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Bicycle and pedestrian infrastructure in Fairfax County have an estimated moderate adaptive capacity for heavy precipitation and inland flooding. Fairfax County conducts regular maintenance and improvement activities to offset the sensitivities associated flooding. These activities include stream restorations, armoring trails, and other flood mitigation activities. There are existing workforce barriers both within and outside of county governance that hinder the implementation of flood-resilient facilities such as those composed of pervious materials. Funding, staff capacity, and size of the bicycle and pedestrian network also present barriers to adaptation. Though resilience measures are being taken, bicycle and pedestrian infrastructure remain impacted by heavy precipitation and inland flooding.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Inland Flooding**	**Total Vulnerability = 8** (Moderate)

Based on the information available, the total vulnerability of bicycle and pedestrian infrastructure in Fairfax County to inland flooding is estimated to be moderate. Additional analysis on urban flooding may be needed once feasible.

6.3.c. Severe Storms – Bicycle & Pedestrian Infrastructure Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Severe Storms**	**Exposure = 3** (High)

Bicycle and pedestrian assets and users are highly exposed to and unprotected from severe storms such as tropical storms, derechos, and severe thunderstorms, which are projected to intensify.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Bicycle and pedestrian assets and users have an estimated moderate sensitivity to severe storms. Severe storms can down trees, utility poles, and other large and tall objects, creating the presence of dangerous debris and/or inaccessibility of bicycle infrastructure and walkways. Severe storm conditions and associated debris can present physical danger to pedestrians and bicyclists.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Bicycle and pedestrian infrastructure in Fairfax County have an estimated moderate adaptive capacity for severe storm events. Fairfax County's transportation and recreational facilities are actively maintained to remove debris and other effects of severe storms, including bicycle and pedestrian trails. The county's Debris Management Plan has designated park sites for temporary storage of debris during severe storms. However, there are barriers to adaptation, including limitations to funding and staff capacity to maintain the large network of bicycle and pedestrian infrastructure. Funding limitations may be further exacerbated by climate hazards. The majority of FCPA revenue-generating activities, including trails, are located outdoors. Therefore, if more frequent and intense severe storms result in lower visitation of these sites, there may be funding limitations for FCPA while maintenance and adaptation costs are increasing.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Severe Storms**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, the total vulnerability of bicycle and pedestrian infrastructure in Fairfax County to severe storms is estimated to be moderately high.

6.3.d. Extreme Cold – Bicycle & Pedestrian Infrastructure Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Extreme Cold**	**Exposure = 1** (Low)

Bicycle and pedestrian assets and users are exposed to extreme cold when such events occur. However, cold events are projected to continue decreasing in frequency and intensity as winter temperatures increase, making overall future exposure low.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Extreme Cold**	**Sensitivity = 2** (Moderate)

Bicycle and pedestrian infrastructure and users are moderately sensitive to extreme cold conditions. Extreme cold can provide more opportunities for ice to form on sidewalks and in bike lanes. During extreme cold events, chemical deicers become less effective in removing compacted snow or ice from sidewalks and roadways, creating the need for more mechanical or manual efforts for ice or snow removal.[286] Ice, especially including black ice, can create a safety hazard for pedestrians and bicyclists.[287]

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Bicycle and pedestrian infrastructure in Fairfax County have an estimated moderate adaptive capacity to extreme cold. Information was not found that assesses current activities and measures to reduce impacts of extreme cold for bicycle and pedestrian infrastructure specifically. Therefore, in accordance with methodology, adaptive capacity was assigned a moderate score of two (2). Residents, businesses, and homeowner associations (rather than the county) are responsible for clearing ice and snow from sidewalks and trails. Fairfax County bicycle and pedestrian infrastructure managers, including FCDOT and FCPA conduct regular maintenance and improvements of bicycle and pedestrian infrastructure.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Extreme Cold**	**Total Vulnerability = 4** (Low)

Based on the information available, the overall vulnerability of bike and ped infrastructure to extreme cold is estimated to be low.

6.3.e. Coastal Flooding – Bicycle & Pedestrian Infrastructure Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Coastal Flooding**	**Exposure = 2** (Moderate)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. Though most bicycle and pedestrian assets are not projected to be exposed to coastal flooding, there are a few key exposure locations that may be important to the community. Parts of the Mount Vernon Trail, which connects to other parts of the county and region, may be exposed to inundation from a coastal storm surge near Belle Haven[288] and Fort Hunt Park[289] along the Potomac River. In sum, 8 miles of bicycle routes, 11.7 miles of bicycle trails, 32.21 miles of walkways, and zero Capital Bike Share stations are projected to be potentially exposed to coastal flooding. (Please see Appendix 3 for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Bicycle and pedestrian infrastructure is moderately sensitive to coastal flooding. Sensitivities for coastal flooding are similar to those of inland flooding. Coastal flooding of bicycle and pedestrian assets can prohibit travel and limit connectivity. Dirt trails that are wet can become seriously eroded if disturbed by hikers and other users.[290] Coastal flooding could lead to trail closures.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of bicycle and pedestrian infrastructure in Fairfax County to coastal flooding is estimated to be moderate. At the time of writing, the Virginia Department of Conservation and Recreation (DCR) is conducting the Virginia Coastal Resilience Master Plan,[291] which includes consideration of trails and bicycle and pedestrian bridges. The Fairfax County Department of Public Works and Environmental Services (DPWES) and the United States Army Corps of Engineers continue to collaborate on flood mitigation efforts along the Potomac River, such as the Dyke Marsh[292] project and assessment of potential flood risk reduction solutions.[293] Protected natural areas along the Potomac River provide some level of natural resilience to and absorption of coastal storm surge and flooding, and recent state-level legislation relating to living shorelines may strengthen this natural resilience.[294] However, barriers to adaptation exist, including property ownership and jurisdictional complexities, technical challenges for proposed solutions, cost, limited staff capacity, and variations in community support for proposed solutions.

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Coastal Flooding**	**Total Vulnerability = 8** (Moderate)

Based on the information available, the overall vulnerability of bicycle and pedestrian infrastructure to coastal flooding in Fairfax County is estimated to be moderate.

6.3.f. Drought – Bicycle & Pedestrian Vulnerabilities

Exposure: What is the level of exposure this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Bike & Ped**	**Drought**	**Exposure = 1** (Low)

Drought in Fairfax County is not projected to increase with significant frequency and intensity, however intermittent drought events may still occur. Bicycle and pedestrian infrastructure are exposed to drought conditions if and when they occur.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Bike & Ped**	**Drought**	**Sensitivity = 1** (Low)

There appear to be minimal or no impacts of drought to pedestrian and bicycle infrastructure.

Adaptive Capacity: Are we able to adapt to and address impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Bike & Ped**	**Drought**	**Adaptive Capacity = 2** (Moderate)

There is no known information relating to the adaptive capacity of bicycle and pedestrian infrastructure in Fairfax County to drought conditions, potentially due to a lack of need. Therefore, this sector is assigned the moderate score of two (2).

Total Vulnerability: How vulnerable is this infrastructure to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Bike & Ped**	**Drought**	**Total Vulnerability = 2** (Very Low)

Based on the information available, the overall vulnerability of bicycle and pedestrian infrastructure to drought conditions in Fairfax County is estimated to be very low.

7. NATURAL AND CULTURAL RESOURCES

Fairfax County is home to a range of valuable natural and cultural resources. It is essential to evaluate natural and cultural resources for climate-related vulnerabilities for two major reasons. First, these resources can be vulnerable to a range of climate hazards. Second, healthy natural resources such as wetlands and tree canopies can provide natural resilience to climate hazards, by absorbing flood water, dissipating heat, and dampening storm energy, among other benefits. It is important to understand the vulnerabilities of local natural and cultural resources to help plan for long-term resilience.

For the purposes of this climate vulnerability and risk assessment, the “natural and cultural resources” sector includes the following sub-sectors: (1) water features such as lakes, ponds, rivers, streams, and swamps; (2) wetlands and environmentally sensitive areas (3) trees and forested areas; (4) agricultural areas and farms; and (5) cultural and historical resources, including historic sites.

Table 25 summarizes the climate vulnerability scores for the natural and cultural resources sector. These scores are general and qualitative in nature; their purpose is to identify high-level vulnerabilities that may need deeper analysis or county attention.

Table 22: Climate Vulnerability Summary - Natural and Cultural Resources

Natural and Cultural Resources – Climate Vulnerability Summary						
Climate Hazards	**Water Features**	**Wetlands and ESAs**	**Trees and Forested Areas**	**Agricultural Areas and Farms**	**Cultural and Historical Resources**	**Total**
Extreme Heat	8	12	12	18	4	**54**
Inland Flooding	12	6	12	12	18	**60**
Severe Storms	8	12	18	18	12	**68**
Extreme Cold	2	2	9	6	2	**21**
Coastal Flooding	12	12	4	4	12	**44**
Drought	9	6	18	12	1	**46**
Total	**51**	**50**	**73**	**70**	**49**	**293**

**Vulnerability = Exposure x Sensitivity x Adaptive Capacity. Please see Appendix 1 Methodology section for more information.*

The following sections provide descriptions of vulnerabilities for each natural and cultural resources sub-sector, broken down by the six climate hazards. For each hazard, vulnerability was scored through consideration of exposure, sensitivity, and adaptive capacity to that hazard.

7.1. Water Features

Fairfax County is situated in the Chesapeake Bay watershed, and is home to numerous lakes, ponds, rivers, streams, and other water bodies that flow through the county. Within Fairfax County, the larger Chesapeake Bay watershed is divided into 30 smaller watersheds (see *Figure 15*), each of which has a watershed management plan.[295] Many of these water features are in need of restoration due to the impacts of development. Within Fairfax County, almost half of streams randomly sampled were categorized as being in "poor" or "very poor" condition.[296] Streams in urban and suburban areas in the county are also experiencing slight to severe erosion.[297]

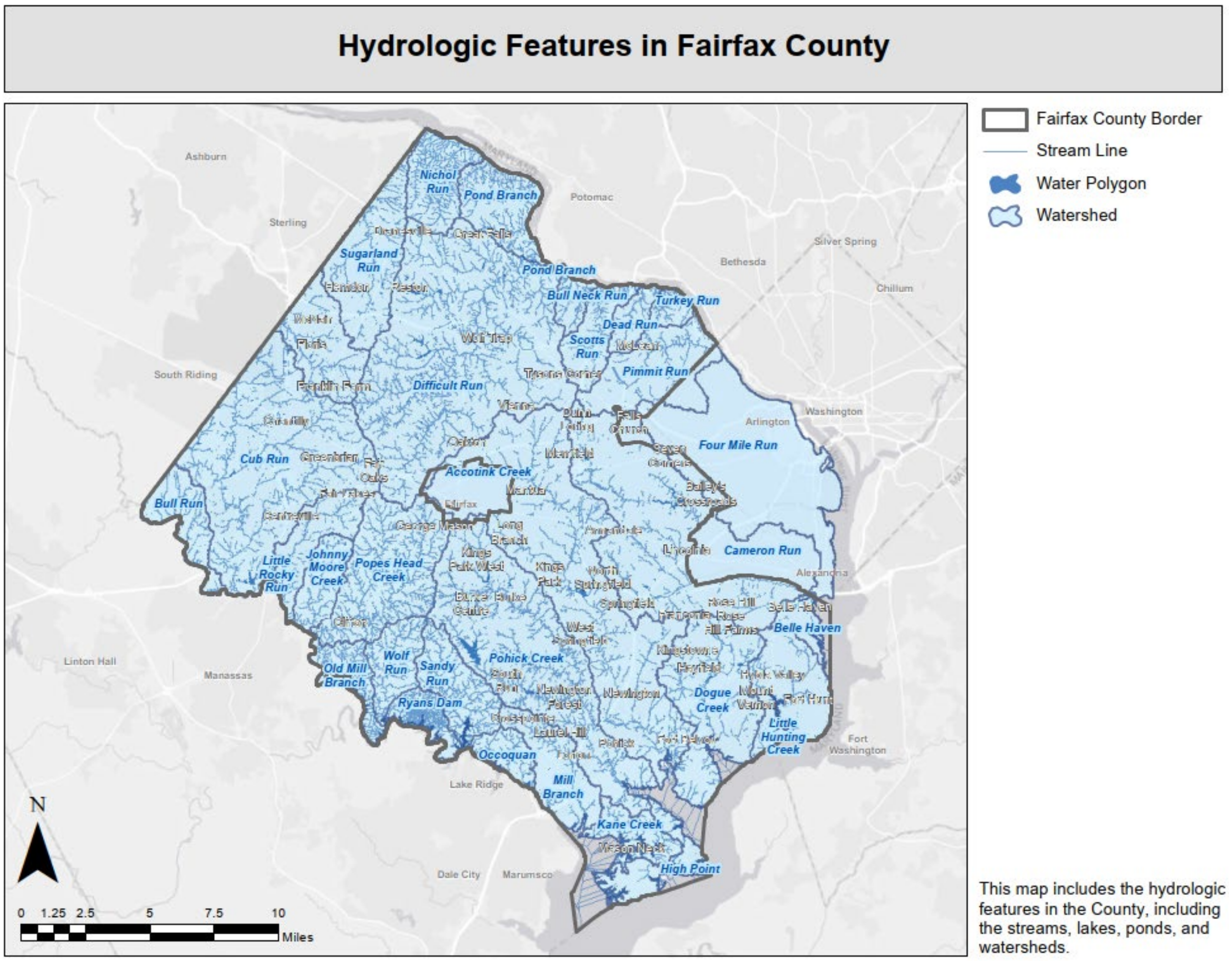


Figure 15: Hydrological features in Fairfax County
(Source: https://fairfaxcountygis.maps.arcgis.com/apps/Viewer/index.html?appid=67ca30a491084ddf92db292337bd87e1)

Fairfax County freshwater bodies are home to a variety of native vegetation and wildlife. Riparian vegetation grows along and in streams and holds soil in place and reduces erosion. Native vegetation along waterways and water bodies includes shrubs like Spicebush, Inkberry Holly, Arrowood, Buttonbush, Paw, and Witch Hazel. Understory and overstory trees are made up of native American Holly, Flowering Dogwood, Eastern Redbud, Red Maple, Willow Oak, White Oak, and others.[298] The county's aquatic ecosystems are also home to one species of newt, two species of toad, ten species of salamander, 11 species of frog,[299] and at least 60 different types of fish.[300] Streams, lakes, and ponds are also frequently visited by turtles, snakes, birds, and a variety of mammals including deer, beavers, coyotes, black bears, and more.

Beyond their intrinsic value, aquatic ecosystems provide valuable services to Fairfax County. These ecosystem services include the following: supportive serves such as soil formation; regulating services such as water quality, climate, and disease regulation; provisioning services such as drinking water and food supply; and cultural services, such as aesthetic value, recreation, and tourism.[301]

This section of the vulnerability assessment focuses on climate vulnerabilities to Fairfax County's streams, rivers, lakes, and ponds. *Table 23* summarizes the climate vulnerability scores for this sub-sector. These scores are general and qualitative in nature. For methodology, please see Appendix 1.

(For drinking water considerations, please see the "Drinking Water" section within the "Water Infrastructure" sector).

Table 23: Climate Vulnerability Summary - Water Bodies

Water Bodies – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	2	2	**8**
Inland Flooding	3	2	2	**12**
Severe Storms	2	2	2	**8**
Extreme Cold	1	1	2	**2**
Coastal Flooding	2	3	2	**12**
Drought	1	3	3	**9**
Total	-	-	-	**51**

7.1.a. Extreme Heat – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Water Features	Extreme Heat	**Exposure Score = 2** (Moderate)

Fairfax County water bodies are moderately exposed to extreme heat conditions. The county as a whole has been and will continue to be exposed to increasing average annual temperatures and extreme heat events. When extreme heat conditions occur, water bodies are exposed to those conditions. Additionally, rivers and other water features receive stormwater runoff from throughout the county; that stormwater runoff is heated on roads and other surfaces before flowing into our water bodies, ultimately raising the temperature of the water bodies. However, unlike other assets in the county, a relatively low percentage of water features (5.6%) are within significantly high Urban Heat Islands. This means that because many water features are located in areas with green space and tree canopy, those areas more effectively dissipate extreme heat and have lower measured surface temperatures than other areas. As a result, the overall exposure to extreme heat for water features in Fairfax County is deemed to be "moderate" rather than "high."

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Water Features	Extreme Heat	**Sensitivity Score = 2** (Moderate)

Water features are moderately sensitive to extreme heat conditions. Extreme heat can increase water temperatures and lead to more evaporation from water sources. Rising temperatures in streams can also intensify some algae blooms and cause disease and heat stress to sensitive fish.[302] Warmer water temperatures from extreme heat can be compounded by rainfall that falls on impervious surfaces during hot summer months and becomes superheated runoff that flows into streams, shocking aquatic life.[303] In addition, warmer water holds less dissolved oxygen, which can kill aquatic life and impact the balance between warm-water fish and shellfish species.[304] Changes in seasonal temperatures can impact the range and abundance of species, introducing invasive species, as well as the phenological cycle of existing plants and animals (the cues for blooming, reproduction, migration, and hibernation), affecting species health, biodiversity, and ecosystem services.[305] Warming temperatures will impact the balance between warm-water fish and shellfish species.[306]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Water Features	Extreme Heat	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of water features in Fairfax County for extreme heat is estimated to be moderate. Adaptive capacity is scored according to four measures. (For methodology, please see Appendix 1).

Some organisms may be able to naturally adapt to rising temperatures in water bodies. However, the shift in temperature may favor non-native species more accustomed to warmer water over native species accustomed to cooler water.[307]

Fairfax County's water protection to ordinances, policies, and plans help to maintain healthy ecosystems, which may assist with adaptive capacity. Fairfax County's policies and actions include stream monitoring, stream restorations, stream corridor protections, stormwater management ordinances to combat runoff issues, drainage plans, and enforcement of the Chesapeake Bay Preservation Ordinance, among other relevant protections. Stormwater management that minimizes contact with impermeable materials helps to reduce runoff that is heated before entering a water body.[308] Additionally, Fairfax County engages in actions such as planting trees, managing stormwater through nature-based solutions (e.g. rain gardens, green roofs, permeable materials), protecting stream channels from erosion activities, promoting groundwater infiltration to continue to feed water bodies, and managing land use near water bodies.[309]

In addition,, the Environment Element of the Comprehensive Plan Policy Plan ("Policy Plan") provides guidance for entitlement applications related to the protection of streams and RPAs. In order to minimize the impacts that new development and redevelopment projects have on county streams, the Policy Plan encourages the protection of stream channels, buffer areas along stream channels, and commitments to the restoration of degraded stream channels and riparian buffer areas.[310] Preventing the erosion of stream channels keeps them from becoming wider and shallower, thus warming more easily.[311] The Policy Plan also includes protections for the Potomac Estuary, Chesapeake Bay, Environmental Quality Corridors, Resource Protection Areas, and forestry, among other assets. Preserving forested areas shades watersheds and surface waters, keeping water temperatures cooler. Limiting land use activities which could erode streambanks (e.g., grazing land for livestock) can protect stream channels from erosion and widening.[312] Fairfax County streams are also highly protected by the Fairfax County Park Authority through their Stream Valley Parks.

However, there are barriers to adaptation for many of these actions, including cost (e.g. cost of permeable pavement over standard pavement), staff capacity, and land ownership (e.g. it is difficult to limit/affect actions of land owners neighboring water bodies).

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Extreme Heat**	**Total Vulnerability = 8** (Moderate)

Based on the information available, water bodies in Fairfax County are estimated to have moderate total vulnerability to increasing extreme heat conditions.

7.1.b. Heavy Precipitation and Inland Flooding – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Water Features**	**Inland Flooding**	**Exposure = 3** (High)

Naturally, water features are highly exposed to heavy precipitation and inland flooding. “Heavy precipitation and inland flooding” refers to both “riverine flooding,” which is caused by water bodies overflowing onto floodplains, and “urban flooding,” which is caused by heavy precipitation overwhelming stormwater management infrastructure. Stormwater in Fairfax County flows directly into our water bodies without passing through a treatment plant first. Therefore, water bodies such as rivers, streams, lakes, and ponds in Fairfax County are highly exposed to both riverine and urban flooding. As would be expected based on the definition and purpose of floodplains, 88.4% of the county’s water bodies are located in FEMA floodplains. Heavy precipitation in Fairfax County is projected to continue intensifying, leading to an increase in stream flow and flooding. Much of the year-to-year variability in streamflow is driven by precipitation (evapotranspiration plays a much smaller role).[313] Future heavy precipitation projections suggests an increase of roughly 20% for the 100-year 24-hour event. This suggests increased streamflow and increased inland flooding where today’s “100-year flood,” or an event that has a one percent chance of occurring each year, is likely to occur much more often.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Water Features**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Water features are moderately sensitive to inland flooding. Ecosystem impacts vary depending on the size of flood events, with small floods potentially having a neutral or positive effect on some aquatic ecosystem services by recharging groundwater and wetlands and rejuvenating soil fertility.

However, prior research has shown extreme flood events (greater than a 100-year recurrence interval) lead to losses in almost every ecosystem service.[314] If an intense precipitation event causes significant streamflow, streambank erosion can occur. A rising groundwater table in response to increased precipitation may also cause ground soils to become more saturated, leading to increased runoff during heavy precipitation events. In areas with significant land development with impervious surfaces such as pavement and rooftops, heavy precipitation events can lead to significant runoff to streams. This additional flow can erode stream banks and as a result, create wider and deeper stream channels. Extreme floods can also cause sanitation breakdown, microbial proliferation, and safety concerns for recreational visitors to water bodies.[315]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Water Features**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

The adaptive capacity of water bodies in Fairfax County to inland flooding is estimated to be moderate. Though the county has taken a number of actions to reduce stormwater runoff and preserve healthy water bodies, these actions along are not enough to reduce all impacts of inland flooding on water bodies.

Flood events are dynamic and the ability of water bodies to naturally adapt to or "bounce back" from flood events is largely context-dependent. Healthier water bodies with shallow, naturally vegetated slopes are better able to naturally slow, disperse, and absorb flood waters into adjacent floodplains. In contrast, water bodies with steep, eroded, degraded slopes are less able to adapt to flooding; fast-moving floodwaters tend to cause streams to erode further and deeper into the ground.[316]

There are a number of Fairfax policies and actions regarding the reduction of stormwater runoff, flooding impacts, and the preservation of healthy water bodies. These include the Stormwater Management Ordinance and program,[317] the Public Facilities Manual,[318] stream restorations and stabilizations by both DPWES[319] and the Northern Virginia Soil and Water Conservation District (NVSWCD),[320] the Chesapeake Bay Preservation Ordinance,[321] the Occoquan Reservoir Shoreline Easement Policy,[322] Comprehensive Plan protections,[323] and the Fairfax County MS4 Program,[324] among others. Additionally, the county works with NVSWCD to encourage measures to capture and infiltrate stormwater runoff on private property prior to its flow into water bodies. These activities include rain barrel workshops, conservation landscaping, technical and financial assistance, and education and outreach.[325]

However, there are barriers to adaptation, and these measures do not currently meet the level of need. The sheer size of the county and large number of streams in need of restoration presents a challenge, as staff capacity is limited and costs for such restorations are high. Limited community awareness of the issue also present a challenge. Additionally, water bodies are currently regulated and protected by several separate agencies with separate plans and initiatives. These agencies have expressed a need for a consolidated Natural Resources Management Plan to more systematically coordinate action.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Inland Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, water bodies in Fairfax County are estimated to have moderately high total vulnerability to increasing heavy precipitation and inland flooding conditions.

7.1.c. Severe Storms – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Water Features**	**Severe Storms**	**Exposure = 3** (High)

Water bodies such as lakes, ponds, and rivers are highly exposed to severe storms and wind when they occur. Severe storms are projected to increase in frequency and severity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Water Features**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Water bodies have an estimated moderate sensitivity to severe storms and wind. Storm debris can block streamflow, increasing the chance of flooding for areas upstream. Severe storm events can have a significant impact on aquatic ecosystems, with larger events causing issues for ecosystem services.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Water Features**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Water bodies in Fairfax County have an estimated moderate adaptive capacity to severe storms and wind. Severe storm events are dynamic and the ability of water bodies to recover from the event is largely context-dependent. For flood-related adaptive capacity considerations, please see the "heavy precipitation and inland flooding" section above. As detailed in prior adaptive capacity sections above, there are numerous Fairfax policies and actions that may enhance adaptive capacity to severe storm events. These actions include erosion prevention, stream restorations, debris management plans, and nature-based solutions and green infrastructure. However, there are barriers to adaptation. Please see the "heavy precipitation and inland flooding" "adaptive capacity" section above for more information. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Severe Storms**	**Total Vulnerability = 8** (Moderate)

Based on the information available, water bodies in Fairfax County are estimated to have moderate total vulnerability to increasing severe storms and wind.

7.1.d. Extreme Cold – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Water Features**	**Extreme Cold**	**Exposure = 1** (Low)

Water bodies such as lakes, ponds, streams, and rivers are exposed to extreme cold when such events occur. However, as average annual and seasonal temperatures increase, extreme cold is projected to decrease in intensity and frequency, making overall exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Water Features**	**Extreme Cold**	**Sensitivity = 1** (Low)

Water bodies have an estimated low sensitivity to extreme cold. Though unusual in Fairfax County, during periods of extreme cold, water bodies can "ice over," affecting water flow.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Water Features**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Water bodies in Fairfax County were assigned a moderate adaptive capacity score of two (2), because sufficient information was not found regarding county adaptation measures to address the reduction of extreme cold impacts on water bodies. This is likely because the overall impact experienced today is low. Some organisms may be able to adapt to cooler temperatures in water bodies. However, extreme cold is decreasing in Fairfax County, and it is more likely that cold-water species will be negatively impacted and replaced by other species adapted to warmer water. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Extreme Cold**	**Total Vulnerability = 2** (Very low)

Based on the information available, water bodies in Fairfax County are estimated to have very low total vulnerability to extreme cold conditions.

7.1.e. Coastal Flooding – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Water Features	Coastal Flooding	**Exposure = 3** (High)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. Naturally, areas where freshwater streams enter estuaries are most likely to be exposed to coastal flooding and storm surge. Approximately 72% of Fairfax County's water features (lakes, ponds, rivers, streams, and swamps) are located within one mile of the Potomac River shoreline. Over 65% of the county's water features are projected to be directly exposed to coastal storm surge and/or sea level rise. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Water Features	Coastal Flooding	**Sensitivity = 2** (Moderate)

Water features have an estimated moderate sensitivity to coastal flooding. Sea level rise and storm surge can alter the tidal range of rivers and the Chesapeake Bay.[326] Coastal flooding causes rivers to deposit more of their sediment into channels, which raises riverbeds and destabilizes rivers. In catastrophic cases (which are unlikely in Fairfax County), coastal flooding can also cause river avulsions, where rivers "jump course" or chart new paths, depending on both the rate of sea level rise and the sediment load carried by the river.[327] Coastal flooding can also lead to significant stream bank erosion.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Water Features	Coastal Flooding	**Adaptive Capacity = 2** (Moderate)

Water bodies in Fairfax County are estimated to have moderate adaptive capacity to handle coastal flooding. Adaptive capacity is scored according to four factors. (Please see Appendix 1 for methodology). In terms of natural adaptation, freshwater organisms may adapt by moving further upstream, where possible. Water bodies with healthy, non-eroded shorelines are better able to naturally withstand or absorb coastal flooding.

In terms of maintenance and risk-reduction activities, there are many policies and regulations enacted to protect Virginia's coastlines and coastal water bodies. These regulations include nature-based solutions such as living shorelines, which can enhance resilience to coastal flooding.[328]

However, there are significant barriers to adaptation. Creating resilience to coastal flooding is a major effort which requires significant stakeholder and community coordination across jurisdictions and levels of government. Waterway management responsibility and applicable regulations vary depending on the size and type of waterway.[329] Coastal adaptations, whether grey or green, can also be relatively expensive.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Coastal Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, water bodies in Fairfax County are estimated to have moderately high total vulnerability to increasing coastal flooding.

7.1.f. Drought – Water Feature Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Water Features**	**Drought**	**Exposure = 1** (Low)

Rivers, streams, lakes, and ponds are exposed to drought conditions when they occur. However, future projections do not suggest a significant increase in meteorological drought for Fairfax County compared to current conditions. Annual precipitation rates in Fairfax County are projected to increase rather than decrease through 2050 and 2085. Therefore, future drought exposure is expected to be low. However, intermittent droughts may occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Water Features**	**Drought**	**Sensitivity = 3** (High)

Water bodies are highly sensitive to drought. Short-term drought conditions can lead to reduced or altered streamflow, poor water quality, and invasion of nonnative species. Longer-term droughts can additionally lead to lost habitat availability and connectivity, continued shift towards nonnative species, and lower dissolved oxygen concentrations.[330] Drought conditions can also result in lowered groundwater levels that are critical for stream recharge and sustained streamflow. Droughts have the potential to critically impact freshwater ecosystems without management strategies in place.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Water Features**	**Drought**	**Adaptive Capacity = 3** (Poor)

Water bodies have an estimated poor adaptive capacity to drought conditions. Fish and other organisms can sometimes naturally adapt to drought conditions in refuge habitats such as deep pools. In these refuge habitats, there are limited resources and certain fish may be at a disadvantage.[331] Fish species that are accustomed to more arid regions are more able to adapt to periods of drought.[332]

Actions taken to lessen the impacts of droughts are often focused on water supply needs for humans, and are less focused on water availability within water bodies support healthy ecosystems. Multiple entities within the region track drought conditions and their impacts, including Fairfax Water, the Interstate Commission on the Potomac River Basin (ICPRB), and the Metropolitan Washington Council of Governments (MWCOG) Regional Task Force on Water Supply Issues.

(For drought implications for drinking water, please see the “Drinking Water” sub-sector within the “Water Infrastructure” sector.)

(For additional detail on the county’s policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Water Features**	**Drought**	**Total Vulnerability = 9** (Moderate)

Based on the information available, water bodies in Fairfax County are estimated to have moderate total vulnerability to drought conditions.

7.2. Wetlands and Environmentally Sensitive Areas

This sub-sector includes wetlands and environmentally sensitive areas (ESAs). These assets are grouped together to reduce duplication because in Fairfax County, many wetlands and ESAs overlap one another. *Figure 16* shows wetlands and ESAs in Fairfax County. Wetlands are areas where water covers the soil, or is present near the surface, all year or for varying periods of the year.[333] For the purposes of this vulnerability and risk assessment, wetlands mapped by the United States Fish and Wildlife Service (USFWS) were used for geospatial analysis. Both major types of wetlands exist in Virginia: (1) tidal wetlands, which are found along the coast and are tidally influenced, and (2) non-tidal wetlands, which are common in floodplains around water bodies and in low-lying areas.[334] Historically, wetlands in Virginia have been threatened by conversion to other land cover, conversion to other uses, climatological changes, hydrologic alterations, invasive species, and fragmentation.[335] Today, development and certain activities on wetlands are restricted, but wetlands remain vulnerable.[336] Wetlands provide important ecosystem services (including water filtration), flood control, carbon sequestration, habitat for native species, and recreational areas for residents. [337]

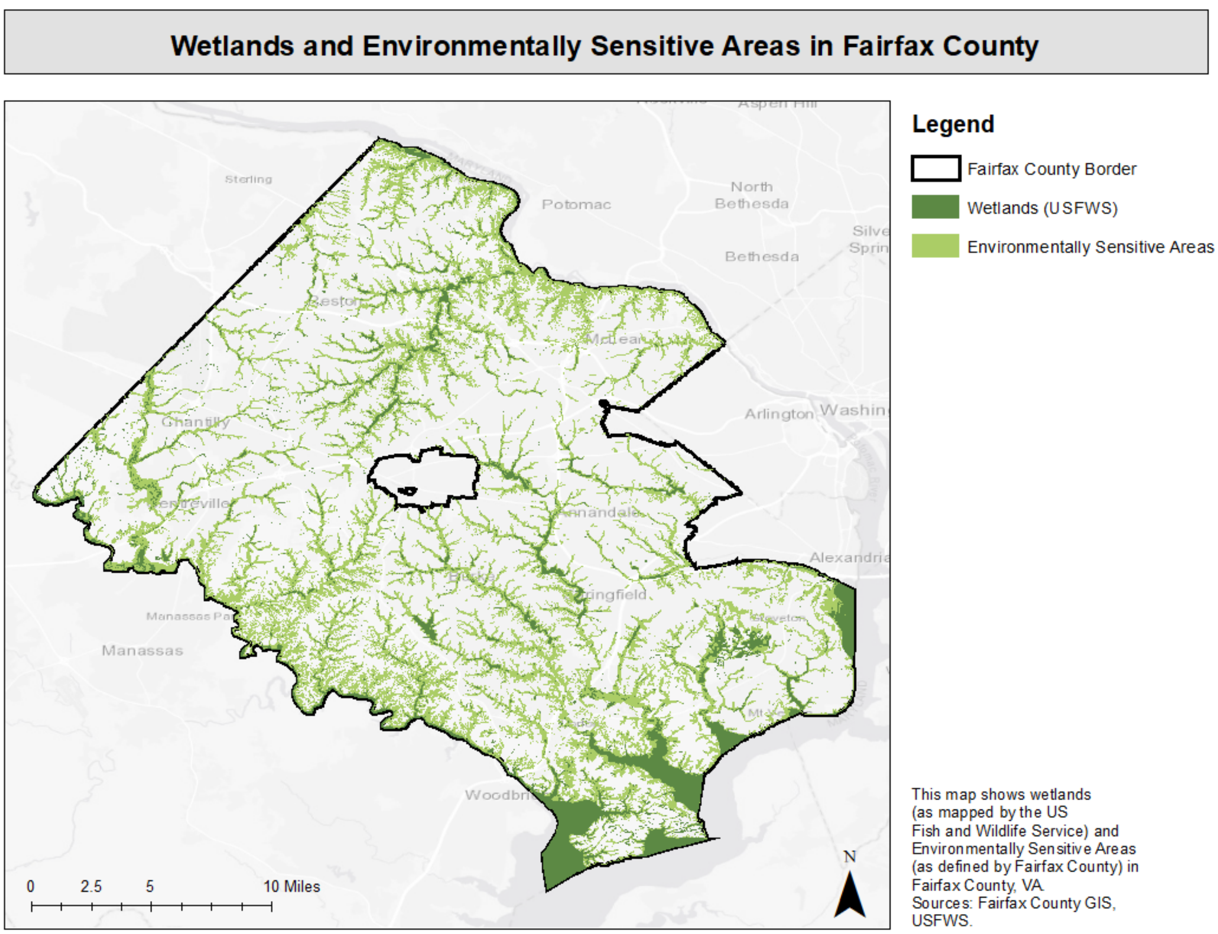


Figure 16: Wetlands and Environmentally Sensitive Areas in Fairfax County (Source: Fairfax County GIS, USFWS.)

"Environmentally sensitive areas" as defined by Fairfax County include subsets of Resource Protection Areas (RPAs), recorded floodplains, sites in proximity to fields covered under the MS4 Nutrient Management Plan (NMP) protocols, and the soil inventory. Other environmentally sensitive areas include refuges, nature preserves, and Environmental Quality Corridors (EQCs). EQCs are designated lands within the county which has a desirable or scarce habitat or hosts a species of special interest, could become part of a corridor to facilitate movement of wildlife, could become a green belt separating different land uses, provide recreational opportunities, or preservation of this land would reduce nonpoint source water pollution, provide climate control, or reduce noise.[338] Fairfax County has defined RPAs "as regulated waterbodies and associated corridors of environmentally sensitive land that lies alongside or near the shorelines of streams, rivers and other waterways which drain into the Potomac River and eventually into the Chesapeake Bay."[339] RPAs include tidal wetlands, tidal shores, water bodies with perennial flow, nontidal wetlands connected by surface flow and contiguous to a tidal wetland or water body with perennial flow, and any buffer area that includes any land within a major floodplain and any land within 100 feet of the feature beforementioned.[340] RPAs serve a purpose in protecting water quality, preventing erosion, and supporting ecosystem services. Any use of RPAs falls under the county's Chesapeake Bay Preservation Ordinance (CBPO), Chapter 118 of the Code of the County of Fairfax.

This section focuses on the vulnerabilities to ecological systems within these areas from climate change. *Table 24* summarizes the climate vulnerability scores for wetlands and environmentally sensitive areas for each climate hazard. These scores are general and qualitative in nature; they are intended to highlight high-level vulnerabilities that may require additional county attention or analysis. The text below provides additional information on these vulnerabilities.

Table 24: Climate Vulnerability Summary - Wetlands and Environmentally Sensitive Areas

Wetlands and Environmentally Sensitive Areas – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	3	2	**12**
Inland Flooding	3	2	1	**6**
Severe Storms	3	2	2	**12**
Extreme Cold	1	1	2	**2**
Coastal Flooding	3	2	2	**12**
Drought	1	3	2	**6**
Total	-	-	-	**50**

7.2.a. Extreme Heat – Wetlands and Environmentally Sensitive Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Extreme Heat**	**Exposure = 2** (Moderate)

Wetlands and environmentally sensitive areas (ESAs) in Fairfax County are moderately exposed to extreme heat. The county as a whole is projected to experience increasing annual and seasonal temperatures, and extreme heat events. In addition to general temperature increases, the Urban Heat Island (UHI) effect creates higher land surface temperatures for certain parts of the county. Wetlands and environmentally sensitive areas have comparatively lower exposure to UHI than other assets; approximately 6.2% of wetland area and 14% of environmentally sensitive areas are within the county's UHI areas. This is likely because wetlands and ESAs are located in areas with green space and flora that are able to partially dissipate heat. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Extreme Heat**	**Sensitivity = 3** (High)

Wetlands and ESAs have an estimated high sensitivity to extreme heat. Wetlands can be affected by long periods of extreme heat and increased evapotranspiration, affecting the ecological processes they support, but there is some uncertainty as to how wetlands will be affected by changing climate. Rising temperatures can change the biogeochemistry and function of wetlands so that ecosystem services they provide are turned into disservices.[341] Rising temperatures can increase rates of decomposition which produces carbon, methane, and nutrients and has a negative impact on water quality.[342] Warmer conditions can also lead to increased production of nitrous oxide from microbial activity.[343] However, if temperature rise coincides with higher levels of precipitation, the wetland may continue to act as a carbon sink as increased water entering the wetland could keep temperatures down and keep vegetation submerged.[344] Changes in seasonal temperatures can impact the range and abundance of species, introducing invasive species, as well as the phenological cycle of existing plants and animals (the cues for blooming, reproduction, migration, and hibernation), affecting species health, biodiversity, and ecosystem services.[345]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Wetlands and environmentally sensitive areas have an estimated moderate adaptive capacity for extreme heat. Adaptive capacity is scored according to four factors. (Please see Appendix 1 for methodology). There are numerous local, state, and federal protections in place for environmentally sensitive areas and wetlands. These protections help ensure the health of wetlands and ESAs, which improves their natural adaptive capacity.

However, there are barriers to adaptation. Adaptation measures for extreme heat specifically are limited for wetlands. In some cases, there may not be any further adaptation that can be done for a wetland (e.g., the wetland is already protected and shaded by trees). Some wetlands may be on private property where proposed adaptations cannot be implemented. Due to the protected nature of wetlands, adaptations that may disturb the wetland will likely need to go through environmental review and permitting processes.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Extreme Heat**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, wetlands and environmentally sensitive areas in Fairfax County are estimated to have moderately high total vulnerability to increasing extreme heat conditions.

7.2.b. Heavy Precipitation and Inland Flooding– Wetlands and Environmentally Sensitive Areas

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Inland Flooding**	**Exposure = 3** (High)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," which is caused by water bodies overflowing onto floodplains, and "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Wetlands and ESAs, by their nature, are highly exposed to flooding; over 78% of the county's wetland area and 44% of the county's ESAs are located in FEMA floodplains. Heavy precipitation and inland flooding are projected to increase over time. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Wetlands and ESAs are moderately sensitive to inland flooding. On the positive side, non-tidal wetlands can benefit from (and are dependent on) precipitation events and the groundwater table. However, changes and increases in precipitation and flooding, along with a rising groundwater table, can change the species distribution, potentially impacting their integrity and allowing opportunistic invasive species to gain a foothold.[346] Extreme inland flooding can also lead to damaged vegetation and habitat. Ecosystem impacts vary depending on the size of flood events, with small floods potentially having a neutral or positive effect on some aquatic ecosystem services by "recharging groundwater, increasing fish production, creating wildlife habitat, recharging wetlands, constructing floodplains, and rejuvenating soil fertility." However, extreme flood events can lead to losses in almost every ecosystem service.[347] A decrease in snowfall and increase in rain may be less favorable for wetlands, but this may be dependent upon location and type of wetland, among other factors.[348]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Inland Flooding**	**Adaptive Capacity = 1** (Good)

Wetlands and environmentally sensitive areas are estimated to have good adaptive capacity to heavy precipitation and inland flooding. Wetlands and ESAs naturally provide adaptation and resilience to heavy precipitation and flooding. An important ecosystem service provided by wetlands is flood control, by acting as a sink for precipitation and a buffer that reduces the speed of flood waters.[349] Maintaining and restoring wetlands is one way to adapt to flood risk and is increasingly important given historical damage to wetlands.

There are multiple policies and regulations related to the protection of wetlands, streams, EQCs, and RPAs, which are typically coincident with a floodplain. Additionally, at the time of writing, based on recent legislation adopted by the General Assembly, the county is in the process of amending portions of the Comprehensive Plan and the Chesapeake Bay Preservation Ordinance to account for climate change considerations for these natural areas. Additionally, the MS4 program's stormwater management projects include wetland construction and bioretention.

Some wetlands may be on private property, limiting county abilities. Due to the protected nature of wetlands, adaptations that may disturb the wetland will likely need to go through environmental review and permitting.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Inland Flooding**	**Total Vulnerability = 6** (Moderate)

Based on the information available, wetlands in Fairfax County are estimated to have moderate total vulnerability to increasing heavy precipitation conditions.

7.2.c. Severe Storms – Wetlands and Environmentally Sensitive Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Severe Storms**	**Exposure = 3** (High)

Wetlands and ESAs are highly exposed to (unprotected from) severe storms and wind such as tropical storms, severe thunderstorms, and derechos when they occur. Severe storms and wind are projected to increase in intensity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Severe Storms**	**Sensitivity = 2** (Moderate)

Wetlands and ESAs are estimated to be moderately sensitive to severe storms and wind. Severe storms and wind can create structural changes in wetlands and lead to accelerated erosion. Such events have the potential to compromise the integrity of the wetland area, allowing opportunistic invasive species to gain a foothold.[350] Storm debris such as fallen trees from wind, lightning and tornadoes can block streamflow, increasing the chance of flooding for areas upstream. Severity of flood events can have a significant impact on aquatic ecosystems, with larger events causing issues for ecosystem services. However, as noted above in the "heavy precipitation and inland flooding" section, if heavy precipitation and flooding are associated with storms, such precipitation can recharge non-tidal wetlands and balance some of the negative impacts.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Wetlands and ESAs in Fairfax County are estimated to have moderate adaptive capacity for severe storms and wind. Information on the ability of wetlands and ESAs to adapt to severe storms and wind specifically (independent from heavy precipitation or coastal flooding) is uncertain and context dependent. For more information, please see the "heavy precipitation" and "coastal flooding" sections. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Severe Storms**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, wetlands in Fairfax County are estimated to have moderately high total vulnerability to increasing severe storms.

7.2.d. Extreme Cold – Wetlands and Environmentally Sensitive Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Extreme Cold**	**Exposure = 1** (Low)

Wetlands and environmentally sensitive areas (ESAs) are exposed to extreme cold events when they occur. However, extreme cold events are projected to decrease, making overall future exposure to this hazard low. Intermittent extreme cold may still occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Extreme Cold**	**Sensitivity = 1** (Low)

Wetlands have an estimated low sensitivity to extreme cold. Extreme cold (and associated snow and ice) can in fact be beneficial to wetlands, by providing greater inundation and reducing evaporation.[351] The sensitivity of environmentally sensitive areas other than wetlands to extreme cold varies by type.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Wetlands and ESAs have an estimated moderate adaptive capacity to extreme cold. The effects of extreme on wetlands and environmentally sensitive areas, and their ability to adapt, is uncertain and context dependent. As noted above, snowfall and surface ice may actually benefit wetlands ecosystems. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Extreme Cold**	**Total Vulnerability = 2** (Low)

Based on the information available, wetlands in Fairfax County are estimated to have low total vulnerability to increasing extreme cold conditions.

7.2.e. Coastal Flooding – Wetlands and Environmentally Sensitive Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Coastal Flooding**	**Exposure = 3** (High)

Coastal flooding in Fairfax County refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. Tidal wetlands in Fairfax County are exposed to coastal inundation from sea level rise and storm surge. Inland wetlands are less exposed. More specifically, 42.4% of wetland area and 21% of ESAs within Fairfax County are projected to be exposed to the projected Category 1 and 2 storm surge areas mapped by NOAA. For sea level rise alone, 39% and 41% of wetland areas in the county are projected to be exposed to sea level rise of 1 foot and 3 feet, respectively. For ESAs, sea level rise exposure is lower, with 7.7% and 8.6% of ESAs projected to be exposed to sea level rise of 1 foot and 3 feet, respectively. Dyke Marsh, near the George Washington Memorial Parkway, provides one example of a freshwater, tidal wetland. Dyke Marsh is currently exposed to storm surge and erosion, which is projected to become more problematic as sea levels rise. The marsh is also sinking due to past dredging activity.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Wetlands and other environmentally sensitive areas have an estimated moderate sensitivity to coastal flooding. Due to their location, tidal wetlands are especially sensitive to this hazard. Changes in tides and larger storms can increase erosion at the shoreline edge, resulting in the loss of shoreline area and property. Tidal wetlands provide critical habitat for plants and aquatic species that play a major role in the health of the Chesapeake Bay. Wetlands are home to species that are unable to survive in other habitats. Significant sea level rise and coastal storm surge can submerge wetlands along the coastline or can cause wetland areas to migrate inland. Coastal storm surge, such as surges associated with tropical storms, can cause erosion and damage. In severe and repeated cases, coastal flooding effects can destroy coastal habitats that host high biological diversity, including coastal wetlands and estuaries, and can erode dune systems.[352] On a broad scale (beyond the size and scope of the county specifically), this may lead to biodiversity loss and species extinction. Dyke Marsh, near the George Washington Memorial Parkway, provides one example of a freshwater, tidal wetland. Dyke Marsh is habitat for hundreds of species of birds and plants, and thousands of species of insects and arthropods.[353]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Wetlands and environmentally sensitive areas have moderate adaptive capacity to coastal flooding. Adaptive capacity is scored according to four factors. (Please see Appendix 1 for detailed methodology).

One factor in adaptive capacity is the natural ability to adapt. On the positive side, wetlands and environmentally sensitive areas naturally provide notable resilience benefits. Wetlands and living shorelines outperform “grey” constructed infrastructure such as bulkheads during a storm. These natural areas are better able to absorb coastal floodwaters and storm surge energy.[354] According to NOAA, 15 feet of marsh area can absorb 50% of wave energy.[355] Marshes trap sediments from tidal waters, creating a natural increase in elevation to accommodate sea level rise. This natural ability provides protection to the communities along the shoreline.

The species within these habitats can also provide natural positive resilience benefits. For example, dams built by beavers have been shown to provide natural ecological and flood-resilience benefits.[356] Some organisms may adapt to coastal flooding by moving further inland and upstream, where possible. However, on the negative side, some of these organisms are less able to adapt, or may have no opportunity to migrate inland due to presence of developed areas. When species move away from our environmentally sensitive areas, conditions can deteriorate further. Fairfax County witnessed this effect first-hand when beavers moved away from Huntley Meadows.[357]

Maintenance and upkeep activities are another factor in adaptive capacity. Some property owners in Fairfax County have installed shoreline structures, like bulkheads or riprap to attempt to reduce property loss. While these structures may provide stability along shoreline areas with longer fetch, or shorelines that experience longer distances of open water and wind gusts, hardened solutions to shoreline stabilization can cause negative impacts to the surrounding ecosystem. The construction of structures like these requires the removal of most vegetation and once installed, acts as a barrier between aquatic life and the shoreline. In Fairfax County, tidal wetlands are directly adjacent to other protected areas, including RPAs and some areas of non-tidal wetlands. According to Virginia Code, property owners must use a “living shorelines” approach (rather than other structural materials) unless “the best available science shows that such approaches are not suitable.”[358]

A third factor in adaptive capacity is action taken to specifically address the vulnerability at hand. There are both physical and policy-oriented actions being taken to address this vulnerability in Fairfax County. For example, the U.S. Army Corps of Engineers (USACE) is constructing an 1,800-foot breakwater and a stone sill to prevent further erosion in Dyke Marsh.[359] Fairfax County Park Authority conducted an extensive restoration of the Huntley Meadows Park central wetland area, [360] and acts as a caretaker for many of our environmentally sensitive lands. The National Park Service (NPS) oversees protection of wetlands on federal land, including Dyke Marsh. Community organizations such as Friends of Dyke Marsh work to preserve, restore and enhance Dyke Marsh.[361] There are also legal protections, policies, and guidelines of relevance. There are requirements to protect wetlands and associated wildlife and natural systems at the federal, state, and local levels.[362],[363] In Fairfax County, the Wetlands Board oversees the wetlands that fall between mean-low and mean-high tide lines. The Virginia Marine Resources Commission provides guidelines on shoreline protections. Shoreline erosion inventories and plans have been created at the county and state levels.

A fourth factor in adaptive capacity is the presence of barriers to adaptation. Protecting wetlands and environmentally sensitive areas from the effects of coastal flooding and storm surge requires significant technical, political, financial, and physical effort. Fragmentation of property ownership and jurisdiction over such areas presents a challenge. Depending on location, projects in our tidal wetland areas can require approval, coordination, and buy-in from federal, state, and local agencies, in addition to local communities, property owners, and environmental groups. Lack of consensus can stall or lead to failure of proposed protection projects. Cost and staff capacity also present a major challenge. Further, the presence of existing development presents adds complexity; for example, the feasibility of enabling inland migration of wetlands is reduced when such actions would result in displacement of existing residents.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Coastal Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, wetlands in Fairfax County are estimated to have moderately high total vulnerability to increasing coastal flooding.

7.2.f. Drought – Wetlands Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Wetlands & ESAs**	**Drought**	**Exposure = 1** (Low)

Wetlands and environmentally sensitive areas are exposed to changing drought conditions when they occur. However, future projections do not suggest a significant increase in meteorological drought compared to today. Therefore, drought exposure overall is expected to be low.

(Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Wetlands & ESAs**	**Drought**	**Sensitivity = 3** (High)

Wetlands and environmentally sensitive areas are highly sensitive to drought. For wetlands, drought conditions can result in severe cracking and compaction, acidification, loss of organic matter, and enhanced greenhouse gas (e.g., methane) emissions. Long-term drought can lead to irreversible soil changes and water quality impacts once the soil rehydrates.[364] Droughts may have an impact on the viability of tidal wetland vegetation, such that extended drought may starve native wetland grasses which could result in an increased risk of erosion. Long-standing droughts may affect the formation of non-tidal wetlands. In other environmentally sensitive areas, short-term drought conditions can lead to reduced/altered streamflow, poor water quality, and invasion of nonnative species. Longer-term droughts can additionally lead to lost habitat availability and connectivity, continued shift towards nonnative species, and lower dissolved oxygen concentrations.[365]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Wetlands & ESAs**	**Drought**	**Adaptive Capacity = 2** (Moderate)

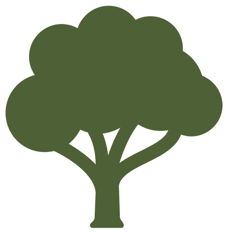
Wetlands and environmentally sensitive areas have and estimated moderate adaptive capacity for drought. Actions taken to lessen the impacts of droughts tend to be focused on water supply needs for humans, and may be less focused on water availability in wetlands and environmentally sensitive areas to support healthy ecosystems. It is difficult to generalize the ability of organisms to adapt. Drought conditions can lead to increased water temperatures. Some organisms may be able to adapt to rising temperatures. In other cases, native species can be pushed out by non-native species. For example, cold water fish species may be replaced by other species more adapted to warmer water.[366] Decreased flows during a drought can cause wetlands to dry up and reduce available habitats; fish and other organisms can sometimes survive in refuge habitats such as deep pools. In these refuge habitats, there are limited resources and certain fish may be at a disadvantage.[367] For more information, please see the "water features," and "trees and forested areas" sections. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Wetlands & ESAs**	**Drought**	**Total Vulnerability = 6** (Moderate)

Based on the information available, wetlands in Fairfax County are estimated to have moderate total vulnerability to drought conditions. Precipitation is projected to increase rather than decrease in Fairfax County.

7.3. Trees and Forested Areas



Trees and forested areas are relevant to climate resilience in two major ways. First, the trees themselves are vulnerable to a range of climate hazards. Second, trees provide natural resilience to certain climate hazards such as extreme heat and flooding.

Fairfax County is home to 22 million trees. Over half (57%) of the county's land area is covered by tree canopy. Of this tree canopy coverage, 80% is naturally occurring forest, and 20% is urban tree canopy. The three most common tree species in the county are American Beech, Red Maple, and Tulip Poplar. Other common tree species in the county include Black Tupelo, White Oak, Eastern Red Cedar, Green Ash, American Hornbeam, Sweetgum, and American Holly.[368] *Figure 17* illustrates areas where trees are denser within the county.

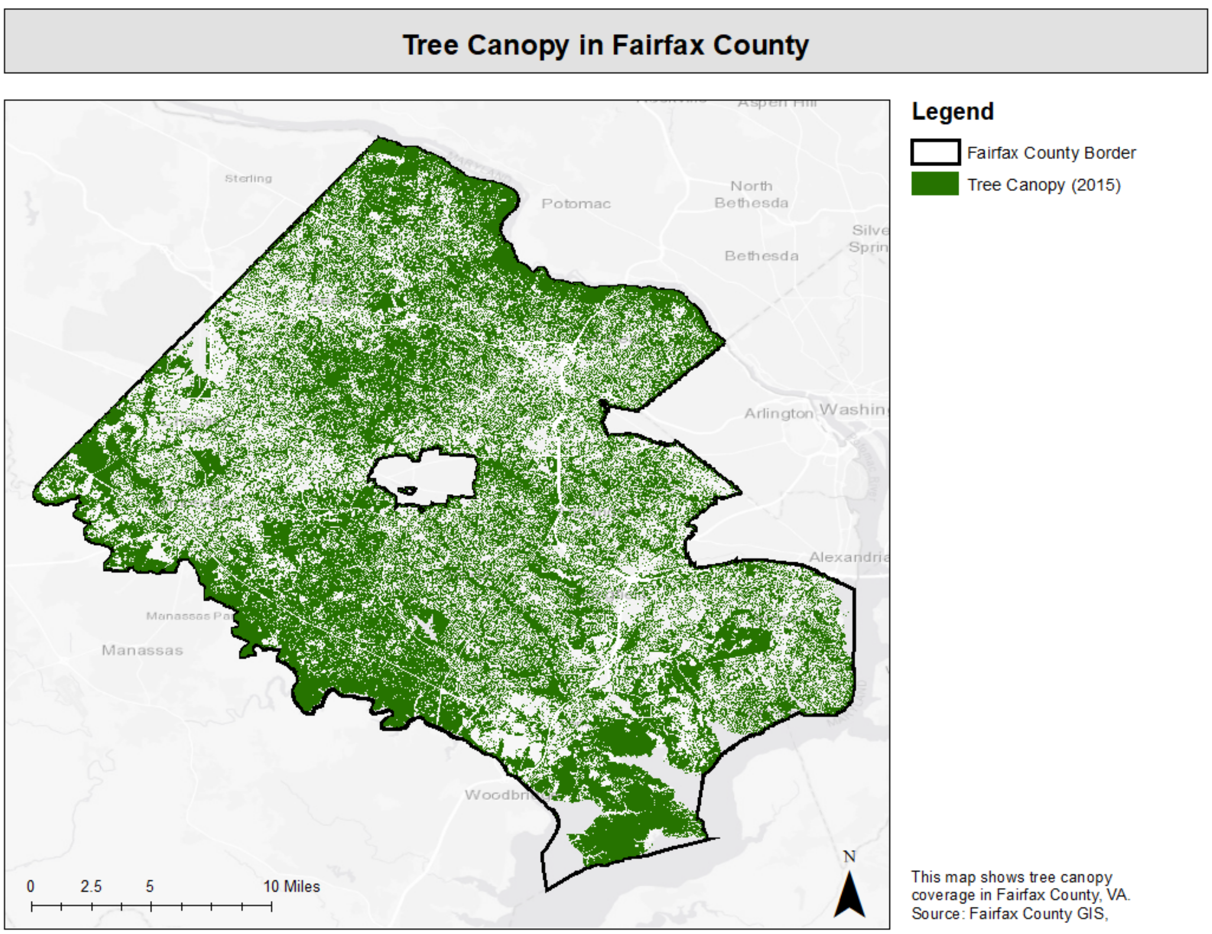


Figure 17: Tree canopy in Fairfax County.
Source: Fairfax County GIS (2015).

Fairfax County protects, preserves, and expands trees and urban forestry through regulatory enforcement, development review, tree health monitoring, and outreach and education.[369] The Urban Forest Management Division (UFMD) of the Department of Public Works and Environmental Services (DPWES) is responsible for monitoring pests that threaten forest health, answering public questions related to tree health, conserving and monitoring the urban forest, and ensuring compliance with the

Tree Conservation Ordinance.[370] The county also has a 15-person Tree Commission, which is responsible for updating and implement the county's Tree Action Plan goals, maintaining a map of Fairfax County Big Trees, nominating "Friends of Trees" and "Tree Preservation and Planting" awards winners, and providing community educational opportunities.[371] Other county tree organizations and partners include: the Fairfax County Park Authority, Land Development Services, Northern Virginia Soil and Water Conservation District, the Health Department, Neighborhood and Community Services, and several nonprofits including Earth Sangha and Fairfax ReLeaf.[372] (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Table 25 summarizes the climate vulnerability scores for trees and forested areas. These scores are general and qualitative in nature. This assessment is intended to highlight high-level vulnerabilities that may need additional county attention and analysis. Vulnerability was scored based on consideration of levels of exposure, sensitivity, and adaptive capacity. (Please see Appendix 1 for detailed methodology).

Table 25: Climate Vulnerability Summary - Trees and Forested Areas

Trees and Forested Areas – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	2	**12**
Inland Flooding	3	2	2	**12**
Severe Storms	3	3	2	**18**
Extreme Cold	1	3	3	**9**
Coastal Flooding	1	2	2	**4**
Drought	2	3	3	**18**
Total	-	-	-	**73**

7.3.a. Extreme Heat – Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Extreme Heat**	**Exposure = 3** (High)

Fairfax County trees are highly exposed to (and unprotected from) projected increases in the intensity and duration of extreme heat and rising seasonal temperatures. In addition to general countywide warming, certain areas are exposed to higher land surface temperatures due to the Urban Heat Island (UHI) effect. Fairfax County's urban trees, or those located in developed areas, are more exposed to the UHI effect than trees located in forested areas. Approximately 28% of Fairfax County's total tree cover is located in areas with significantly high UHI. Trees themselves help to mitigate extreme heat conditions by providing evapotranspiration and shade. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Extreme Heat**	**Sensitivity = 2** (Moderate)

Trees in Fairfax County are moderately sensitive to extreme heat. Long-term changes in temperature can affect water availability, soil moisture, survival of species, and influence tree migration. For example, American Beech, Red Maple, and Tulip Poplar are projected to experience decreased growth potential in a high warming future.[373] Oak trees prefer average annual temperatures between 40°F to 60°F. [374] Warmer annual temperatures and higher precipitation may compromise the health of these trees. As temperatures warm, a shift of forest species to more southern varieties is expected.[375] For forestry and the urban canopy, trees can suffer heat stress during periods of extreme heat, and trees can die if not properly taken care of after experiencing stress. This vulnerability particularly applies for younger trees[376]. Drought compounds these issues. Trees experiencing heat stress are also more susceptible to pests and other infestations.[377] Increasing winter temperatures can increase nonnative pests such as the emerald ash borer (a small green beetle) that kills ash trees across the Midwest and Eastern United States.[378]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Trees and forested areas in Fairfax County have an estimated moderate capacity to adapt to extreme heat conditions. Trees can sustain a range of future changes in temperature and precipitation. Additionally, trees themselves provide natural adaptation for extreme heat, by mitigating UHI through evapotranspiration and shade. However, certain tree species may be unable to adapt to changes in extreme heat and rising seasonal temperatures.

Maintaining the health of trees can assist with their adaptive capacity. Fairfax County's Urban Forest Management Division continuously implements numerous county policies and standards that serve to maintain and protect trees in Fairfax County. These include (but are not limited to) the conservation of trees during land development (Code of Virginia 15.2-961.1),[379] the Tree Conservation Ordinance (Fairfax County Code Chapter 12),[380] the Tree Conservation section of the Public Facilities Manual,[381] rules for Heritage, Specimen, Memorial, and Street Trees (Fairfax County Code Chapter 120),[382] Landscaping and Screening Regulations (Fairfax County Zoning Ordinance),[383] The Chesapeake Bay Preservation Ordinance (Fairfax County Code Chapter 118),[384] the Stormwater Management Ordinance (Fairfax County Code Chapter 124),[385] and the Storm Drainage regulations (Fairfax County Public Facilities Manual Chapter 6).[386]

The Urban Forest Management Division participated in a Climate Change Adaptation workshop in 2019 to create an unofficial plan that focuses on trees, forests, and related natural resources. The results evaluate how to make better tree planting and preservation recommendations and decisions, and identifies climate change impacts, vulnerabilities, and adaptation tactics. At the regional level, the MWCOG Tree Conservation Cookbook provides guidance on tree canopy preservation and enhancement. The county is taking climate change projections on individual tree species into account, using research funded by the USDA Forest Service.[387]

There are barriers to adaptation, including staff capacity and funding limitations, natural limitations to species' ability to adapt, limited county ability to prevent poor tree health on private properties, and development procedures that may not prioritize trees over other factors, among other barriers. County staff have expressed the need for a consolidated natural resources management plan that enables systematic, countywide planning of resources such as trees.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Extreme Heat**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, trees and forested areas in Fairfax County are estimated to have moderately high total vulnerability to increasing extreme heat conditions.

7.3.b. Heavy Precipitation and Inland Flooding – Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Inland Flooding**	**Exposure = 3** (High)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," which is caused by water bodies overflowing onto floodplains, and "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Trees are highly exposed to heavy precipitation and inland flooding. Over 10% of Fairfax County's trees are within FEMA or county floodplains. Additionally, approximately 49% of Fairfax County's trees are within parcels that have two or more flood-prone factors, and nearly 9% are within parcels that have four or more flood-prone factors. Heavy precipitation and inland flooding is projected to increase. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Trees are moderately sensitive to heavy precipitation and inland flooding. Trees located in flood zones can become damaged due to overhydrated soils, reduced oxygen availability for roots, and anaerobic bacteria that do not decompose organic matter in a manner that is beneficial for trees.[388] Flood water can also fell and uproot trees. Trees along stream banks may be damaged or felled if increased water velocity is particularly strong, leading to stream bank erosion. Climate change may impact the vulnerability of different clay-rich soils to heaving in the future. Flooding can also introduce other stressors that may weaken trees and make them susceptible to insects and diseases. For example, white oak trees prefer moist but well-drained soils. Future precipitation is projected to be heavier during each event, but with longer spans of time between events. Soils may become too soggy during episodic heavy precipitation events and too dry during interims between events. Depending on tree species, floods during the tree growing season, particularly later spring and during warmer weather, are more likely to damage trees than during winter months. On the other hand, increased rainfall can reduce number of pests such as the gypsy moth, because rainfall limits the spread of larvae.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Trees and forested areas in Fairfax County are estimated to have moderate adaptive capacity for inland flooding and heavy precipitation. Owners of private property maintain a significant portion of tree coverage and are not under the control of the county once developed.

Trees provide some level of natural resilience to inland flooding effects by absorbing stormwater. Trees can also help to naturally reduce erosion caused by heavy precipitation and inland flooding. Certain tree species are more adaptive than others. More specifically, trees classified as Obligate Wetland Plants or Facultative Wetland Plants (FACW) are more able to survive in areas with “wet feet” or continued water inundation. Trees that are able to survive both wetland and upland conditions are more adaptive to variable precipitation conditions.

Please see the “adaptive capacity” section under “extreme heat” above for listing of the county’s relevant policies and standards for reducing harm from these impacts. (For additional detail on the county’s policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Inland Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information provided, trees and forested areas in Fairfax County are estimated to have moderately high total vulnerability to inland flooding.

7.3.c. Severe Storms– Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Severe Storms**	**Exposure = 3** (High)

Trees and forested areas are highly exposed to and unprotected from severe storm and wind events such as tropical storms, derechos, and severe thunderstorms. Severe storm and wind events are projected to increase in intensity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Severe Storms**	**Sensitivity = 3** (High)

Trees are highly sensitive to severe storm and wind effects. High winds can cause severe defoliation and can directly injure and kill trees through such as uprooting, breakage and loss of minor and major branches, and stem breakage.[389] Trees can be permanently damaged by the bending caused by wind from severe storms, and compression injuries may be present even in seemingly undamaged trees. Older trees are more likely to uproot or break compared to younger trees, which can bend more easily.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Trees and forested areas in Fairfax County are estimated to have moderate adaptive capacity to extreme storms. Owners of private property maintain a significant portion of tree coverage and are not under the control of the county.

Some tree species may be able to cope with severe storms and winds better than others, based on such factors as root system and tree characteristics. For example, River Birch, Black Tupelo, Weeping Willow, Baldcypress, Red Maple, Hackberry, American Sweetgum, and Overcup Oak are nine tree species noted for being more resilient to storms.[390]

Please see the “adaptive capacity” section under “extreme heat” above for listing of the county’s relevant policies and standards for reducing harm from these impacts. (For additional detail on the county’s policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Severe Storms**	**Total Vulnerability = 18** (High)

Based on the information available, Fairfax County's trees and forested areas are estimated to have - high total vulnerability for severe storm and wind events.

7.3.d. Extreme Cold - Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Extreme Cold**	**Exposure = 1** (Low)

Trees are exposed to intermittent extreme cold conditions in the county. However, the frequency of extreme cold events on average is projected to decline in the coming decades, making overall exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Extreme Cold**	**Sensitivity = 3** (High)

Trees are highly sensitive to extreme cold events, particularly when those events happen during unseasonable timeframes. Fairfax County's Urban Forestry Management Division notes that their top concern for tree sensitivity is late frosts, or extreme cold that occurs during the spring when trees are no longer naturally able to withstand such conditions. Trees are at their maximum cold-hardiness levels in mid-winter, around mid to late January.[391] Frosts and other cold snaps can have detrimental impacts on trees and vegetation, particularly outside of this window.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Extreme Cold**	**Adaptive Capacity = 3** (Low)

Fairfax County's trees and forested areas are estimated to have low adaptive capacity to extreme cold events. The Fairfax County Urban Forestry Management Division conducts thorough and regular maintenance and protection of Fairfax County's trees and forested areas. However, these maintenance activities may do little in terms of resilience to extreme cold conditions. Owners of private property maintain a significant portion of tree coverage and are not under the control of the county. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Extreme Cold**	**Total Vulnerability = 9** (Moderate)

Based on the information available, Fairfax County's trees and forested areas are estimated to have moderate total vulnerability to extreme cold conditions.

7.3.e. Coastal Flooding – Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Coastal Flooding**	**Exposure = 1** (Low)

"Coastal flooding" refers to flooding of the Potomac River or connected water bodies due to sea level rise, tidal flooding, and/or coastal storm surge. In Fairfax County, the majority of tree canopy and forested areas are located away from the areas of projected future coastal flooding. Specifically, 1.83% of the tree canopy is projected to be exposed to Category 1 and 2 coastal storm surge, 0.27% is projected to be exposed to sea level rise of 1 foot, and 0.50% is projected to be exposed to sea level rise of 3 feet. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

Trees have moderate sensitivity to coastal flooding. Trees located along the Potomac River may become inundated.[392] Tree sensitivities relating to coastal flooding are similar to those relating to inland flooding. Trees located in flood zones can become damaged due to overhydrated soils, reduced oxygen availability for roots, and anaerobic bacteria that do not decompose organic matter in a manner that is beneficial for trees.[393] Flood water can also fell and uproot trees. Trees along shorelines may be damaged or felled if increased water velocity is particularly strong.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Fairfax County's trees and forested areas are estimated to have moderate adaptive capacity for coastal flooding events. Trees provide a level of natural resilience to flooding events and can reduce erosion associated with such flooding.

Fairfax County has many tree-related policies, programs, and protections that help to enhance the adaptive capacity of trees. Please see "adaptive capacity" section under "extreme heat" above for a listing of the additional adaptive capacity considerations.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information available, Fairfax County's trees and forested areas are estimated to have low total vulnerability to coastal flooding, largely due to low exposure.

7.3.f. Drought – Trees and Forested Areas Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Trees & Forests**	**Drought**	**Exposure = 2** (Moderate)

During periods of drought, trees across Fairfax County are highly exposed to drought conditions. However, future projections for Fairfax County do not suggest a significant increase in meteorological drought compared to today, as precipitation rates are projected to increase rather than decrease. Therefore, drought exposure for trees overall is expected to be moderate, because trees may be exposed to intermittent drought over their life cycle. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Trees & Forests**	**Drought**	**Sensitivity = 3** (High)

Trees have high sensitivity to drought conditions. During drought periods, trees slow and arrest their growth, and have increased susceptibility to pests and disease.[394]Droughts and enhanced evaporation can lead to soil stress by killing vital living soil ecosystems. Prolonged droughts can lead to tree death.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Trees & Forests**	**Drought**	**Adaptive Capacity = 3** (Low)

Fairfax County's trees and forested areas are estimated to have low capacity to adapt to drought conditions. Older trees that have well-developed root systems are generally better able to adapt than younger saplings or seedlings.[395] Certain species of trees are not accustomed to drought conditions and/or may not have a well-developed root system to survive periods of drought. The county's Urban Forest Management Division works to maintain the health of Fairfax County's trees, which can enhance adaptive capacity. County agencies and the Northern Virginia Soil and Water Conservation District encourage the planting of native trees, which may require less water.[396] However, there are barriers to adaptation, including staff capacity and funding limitations, natural limitations to species' ability to adapt, limited county ability to prevent poor tree health on private properties, and development procedures that may not prioritize trees over other factors, among other barriers.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Trees & Forests**	**Drought**	**Total Vulnerability = 18** (High)

Based on the information available, trees and urban forested areas in Fairfax County are estimated to have high total vulnerability to drought conditions.

7.4. Agricultural Districts and Farms

Fairfax County was historically an agricultural community. In recent decades, the presence of agricultural uses and farms have significantly declined in the county. However, such uses do still exist in a variety of types, sizes, and locations. Based on 2017 data from the US Department of Agriculture there are 117 farms (or 5,937 acres) in Fairfax County. The total number of farms reported in 2017 is a 21% reduction from 2012. The average farm size in the county is 51 acres. Most farms are small in size; approximately 43% are between one and nine acres. Approximately 60 acres are irrigated, which amounts to 1% of farmland, or 17 farms. The total market value of products sold was $1.2 million dollars. On average the market value of products sold by an individual farm in the county is $10,622 per year. Crops account for 81% of sale shares, while livestock, poultry, and products account for 19% of sale shares. The land use is estimated to be 13% cropland, 31% pastureland, 41% woodland, and 15% other.[397]

In accordance with the Fairfax County Zoning Ordinance, general agricultural operations are permitted on lots seven acres or larger in size when located in the R-A (Rural Agricultural), R-E (Residential Estate), R-C (Residential Conservation), and R-1 (Residential, One Dwelling Unit Per Acre) zoning districts.[398] In the map below, these "potential parcels" where agricultural uses would be permitted are shown in light green.

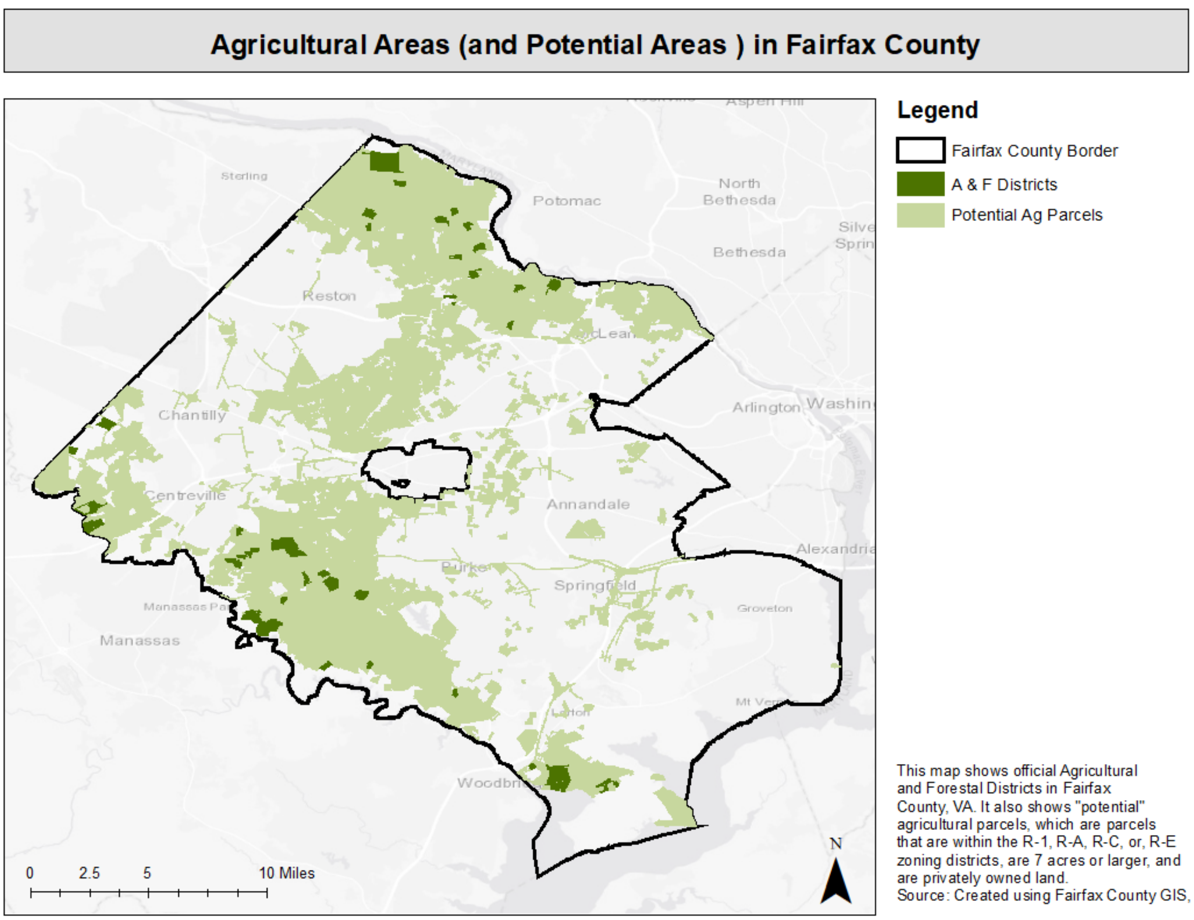


Figure 18: Agricultural Areas and Potential Agricultural Parcels in Fairfax County

Areas classified as official "agricultural and forestal districts" by zoning definition involve specific agreements, and do not represent all agricultural uses in the county. Such districts are areas where the landowner committed to a voluntary rural conservation zone for a term of four to 10 years for agricultural and timber production, as well as the maintenance of open space as an important economic and environmental resource.[399] These districts are required to be at least 20 acres in size and are a way to reduce taxes by volunteering to meet the limitations of the district.

Urban agriculture is also present in Fairfax County. Based on the Fairfax County Food Gardens dataset, which is managed by the Fairfax Food Council, there are community gardens dispersed throughout the county at public schools, faith-based organizations, residential properties, farms, and county-managed properties.[400] Additionally, the Fairfax County Park Authority operates ten farmers markets for producers within a 125-mile radius of the county to sell their food to the public.[401]

For the purposes of this vulnerability and risk assessment, climate hazard exposure calculations were based on Geographic Information Systems (GIS) data for official "agricultural and forestal districts" and also "potential agricultural use parcels." The latter shows all parcels that could *potentially* be used for agricultural purposes currently or in the future based on applicable county requirements.

Table 26 summarizes the climate vulnerability scores for agricultural districts and farmland. These scores are general and qualitative in nature; they are intended to identify high-level vulnerabilities that may need further county analysis or attention. The vulnerability scores are described in the sections below. For methodology, please see Appendix 1.

Table 26: Climate Vulnerability Summary - Agricultural Districts and Farmland

Agricultural Districts and Farmland – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	3	2	3	**18**
Inland Flooding	3	2	2	**12**
Severe Storms	3	3	2	**18**
Extreme Cold	1	3	2	**6**
Coastal Flooding	1	2	2	**4**
Drought	2	3	2	**12**
Total	-	-	-	**70**

7.4.a. Extreme Heat – Agricultural Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Agriculture	Extreme Heat	**Exposure = 3** (High)

Agricultural lands are highly exposed to and unprotected from projected increases in the intensity and duration of extreme heat and rising seasonal temperatures. In addition to countywide warming due to climate change, certain areas of the county are exposed to higher land surface temperatures due to the Urban Heat Island (UHI) effect. Approximately 6% of the county's agricultural and forestal districts and 19% of potential agricultural use parcels are located within areas with significantly high UHI. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Agriculture	Extreme Heat	**Sensitivity = 2** (Moderate)

Agriculture has a moderate sensitivity to extreme heat conditions. Warming temperatures can shift harvesting and planting dates for crops and can affect soil moisture and crop viability. Crops have optimum temperatures and precipitation for health and growth. Warming temperatures may translate to a longer growing season, which could be favorable in some circumstances. However, warming temperatures can also translate to false early starts to the growing season, followed by late freezes that affect crop yields. Rising minimum temperatures and reductions in the length of dormancy may increase the survivability and number of pests and weeds. The earlier onset of spring (and warmer winters) can allow some pathogens and parasites to survive the winters; these can be detrimental to crops. [402]

For livestock, dairy cows are very sensitive to heat and milk production can be affected. An increase in annual temperatures of 1.4 to 2.4 degrees Fahrenheit was estimated to reduce milk production by 0.6% to 1.4%. (Milk production from cows represents less than 1% of the county's market value of agricultural products sold).[403] Over time, heat stress can increase the disease vulnerability of exposed animals, and can reduce fertility.[404] In general, poultry and swine tend to be managed in housed, temperature controlled systems so they are less sensitive to outdoor temperatures.[405]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Agriculture	Extreme Heat	**Adaptive Capacity = 3** (Low)

Agricultural areas and farms in Fairfax County are estimated to have low capacity to adapt to extreme heat conditions. The Northern Virginia Soil and Water Conservation District (NVSWCD) is a close partner of the county and member of the Resilient Fairfax Planning Team. The NVSWCD promotes soil and water conservation and sustainable farming practices in Fairfax County. Their regional climate resiliency work may help increase adaptative capacity. However, crops that are conventionally grown in this region may have limited ability to naturally adapt to increasing extreme heat conditions. In addition, there are barriers to adaptation, including cost, logistics, and operational hurdles if a farm is historically reliant on a crop that cannot withstand periods of extreme heat.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Agriculture**	**Extreme Heat**	**Total Vulnerability = 18** (High)

Based on the information available, agricultural areas and farms in Fairfax County are estimated to have high overall vulnerability to extreme heat.

7.4.b. Heavy Precipitation and Inland Flooding – Agricultural Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Agriculture**	**Inland Flooding**	**Exposure = 3** (High)

"Heavy precipitation and inland flooding" refers to both "riverine flooding," which is caused by water bodies overflowing onto floodplains, and "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Agricultural lands are highly exposed to (and unprotected from) heavy precipitation and inland flooding. Approximately 7-8% of agricultural and forestal districts and 5-6% of potential agricultural use parcels are located within FEMA or county floodplains. In addition to floodplains, over 41% of agricultural and forestal districts and 48% of potential agricultural use parcels have two or more flood-prone factors. Heavy precipitation and inland flooding are projected to increase in quantity and intensity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Agriculture**	**Inland Flooding**	**Sensitivity = 2** (Moderate)

Agricultural areas and farms have an estimated moderate sensitivity to heavy precipitation and inland flooding. Moderate sensitivity means this hazard would cause temporary or limited failure, but not complete failure of the asset. Flood events can damage non-cover crops and make working in the fields challenging. Increasing intensity of severe downpours will lead to runoff and erosion, stripping healthy soils of key nutrients as well as exposing farmland to pollutants in ponding areas.[406] However, increased rainfall can reduce pests such as the gypsy moth, because rainfall limits the spread of larvae.

Based on the US Department of Agriculture's Natural Resources Conservation Service Web Soil Survey, the soil in Fairfax County (excluding urban areas) is largely comprised of Group C soils (~40%).[407] Soils are categorized by hydrologic soil group, and Group C soils have a slow water infiltration rate when wet and slow water transmission rate. After Group C soils, the most common hydrological soil types in the county are Group B (~20%), Group B/D (~6%), Group A (~4%), Group C/D (~4%), and Group D (~3%). Group B soils have a moderate rate of water infiltration. The fact that Fairfax County's soils are majority soil groups with lower infiltration rates means that heavy precipitation and flooding events could be exacerbated.

Livestock such as cows can be affected if fields that are used to forage are flooded.[408]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Agriculture**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Agricultural and farm areas in Fairfax County are estimated to have moderate capacity to adapt to heavy precipitation and inland flooding. Preserving these open areas may be an important measure against inland flooding, as these open areas serve as vehicles for infiltration of stormwater.

Certain crops are better able to adapt to heavy precipitation events and flooding. Established crops are better able to handle heavy precipitation and runoff whereas newly planted seeds may not have enough time to germinate before being washed away in a storm.[409] Rice (which is not grown in the county[410]) is the only major food crop that can consistently survive flooding, but research is finding that other plants such as tomatoes and *Solanum lycoperscium* (a plant similar to alfalfa) have similar genes to rice, which activate in response to flooding. This research may mean that through activation of these genes, other species of crops can become flood-resistant in the future.[411]

Given the unexpected nature of when heavy precipitation and inland flooding may occur, its challenging for farmers to be proactive and plan for heavy rain events during the crop cycle. Farmers may not have the time to quickly transition crops or allow for stabilizing grasses to grow before the next storm event, leading to the potential loss of topsoil.[412] Crop losses may be a significant cost burden to farmers, leading to less financial capacity to implement adaptation measures.

The Northern Virginia Soil and Water Conservation District has numerous programs that may enhance the adaptive capacity of these areas.

(For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Agriculture**	**Inland Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, agricultural areas and farms in Fairfax County are estimated to have moderately high total vulnerability to heavy precipitation and inland flooding.

7.4.c. Severe Storms– Agricultural Districts and Farms Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Agriculture**	**Severe Storms**	**Exposure = 3** (High)

Agricultural lands and farms are highly exposed to severe storm and wind events such as tropical storms, derechos, and severe thunderstorms, largely without protection. Severe storm and wind events are projected to increase in intensity. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Agriculture**	**Severe Storms**	**Sensitivity = 3** (High)

Severe storms such as tropical storms, hurricanes, derechos, and severe thunderstorms with hail can heavily damage and kill crops, especially when early in the growing season. The Fourth National Climate Assessment indicates that if conservation practices are not implemented, increases in extreme events will increase soil erosion.[413] Soil erosion left unchecked may result in loss of productivity and reduced crop yields, which have food availability and financial implications for the region.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Agriculture**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Agricultural and farm areas in Fairfax County are estimated to have moderate capacity to adapt to severe storms. As with flooding, the timing and severity of severe storms are unknown prior to the onset of the growing season. Farmers may not have the time to quickly transition crops or allow for stabilizing grasses to grow before the next storm event, leading to potential erosion and losses.[414] Crop losses may be a significant cost burden to farmers, leading to less financial capacity to implement adaptation measures. The Northern Virginia Soil and Water Conservation District has numerous programs that may enhance the adaptive capacity of these areas. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Agriculture	Severe Storms	**Total Vulnerability = 18** (High)

Based on the information available, agricultural and farm areas in Fairfax County have high total vulnerability to severe storms.

7.4.d. Extreme Cold – Agricultural Districts and Farms Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Agriculture	Extreme Cold	**Exposure = 1** (Low)

Agricultural lands are exposed to extreme cold conditions when they occur. However, the frequency of extreme cold events on average is projected to decline in the coming decades, making overall exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Agriculture	Extreme Cold	**Sensitivity = 3** (High)

Agricultural lands and farms have high sensitivity to extreme cold. Extreme cold is especially damaging if it occurs through a late frost or cold snap, which can damage young crops early in the growing season.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Agriculture	Extreme Cold	**Adaptive Capacity = 2** (Moderate)

Agricultural and farm areas in Fairfax County are estimated to have moderate capacity to adapt to extreme cold. Some cold-weather crops are hardy enough to survive light frosts and temperatures below 28 degrees Fahrenheit, such as broccoli, cabbage, and carrots.[415] For most crops sensitive to extreme cold occurring during the growing season, it may be difficult for farmers to cover or protect their fields before each extreme cold event and this may present additional costs to farmers. Farmers may be dependent upon certain crops and cannot transition to hardy, frost-tolerant varieties (some which may not be successful in warmer temperatures). Information was not found relating to activities or measures currently occurring within the county to reduce the harm of extreme cold conditions on agriculture; this may be due to lack of need, because extreme cold is decreasing on average rather than increasing. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Agriculture**	**Extreme Cold**	**Total Vulnerability = 6** (Moderate)

Based on the information available, Fairfax County agricultural and farm areas are estimated to have moderate total vulnerability to extreme cold events.

7.4.e. Coastal Flooding – Agricultural Districts and Farms Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Agriculture**	**Coastal Flooding**	**Exposure = 1** (Low)

Coastal flooding refers to flooding of the Potomac River and associated water bodies due to sea level rise, tidal flooding and/or coastal storm surge. Approximately 0.14 square miles (3%) of agricultural and forestal districts, and 0.55 square miles (0.4%) of potential agricultural use parcels are projected to be inundated with coastal storm surge. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Agriculture**	**Coastal Flooding**	**Sensitivity = 2** (Moderate)

If agricultural lands are inundated with coastal flooding, those areas can be moderately sensitive. Such flooding could lead to runoff and erosion and make working conditions difficult. Flooding may also cause erosion of topsoil and damage fields. Livestock such as cows can be affected if fields that are used to forage are flooded. [416]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Agriculture**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Agricultural and farm areas in Fairfax County have an estimated moderate capacity to adapt to coastal flooding. Certain crops are better able to adapt to flooding. Established crops are better able to handle floods whereas newly planted seeds may not have enough time to germinate before being washed away.[417] Farmers may not be able to move to fields unaffected by coastal flooding, or may not be able to transition to crops adapted to wetland areas. Crop losses may be a significant cost burden to farmers. The Northern Virginia Soil and Water Conservation District has numerous programs that may enhance the adaptive capacity of these areas. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Agriculture**	**Coastal Flooding**	**Total Vulnerability = 4** (Low)

Based on the information available, agricultural areas and farms in Fairfax County have an estimated low total vulnerability to coastal flooding.

7.4.f. Drought – Agricultural Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Agriculture**	**Drought**	**Exposure = 2** (Moderate)

Agricultural lands are highly exposed to drought conditions when droughts occur. However, future projections for Fairfax County do not suggest a significant increase in meteorological drought compared to today; precipitation is projected to increase rather than decrease. Therefore, drought exposure overall is expected to be low. A moderate score of two (2) was assigned as agricultural areas may be exposed to intermittent drought over their life cycle which increases their susceptibility to harm. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Agriculture**	**Drought**	**Sensitivity = 3** (High)

Agricultural areas are highly sensitive to drought conditions. Droughts and greater evaporation can lead to soil stress by killing vital living soil ecosystems. Droughts can also stress crops and lead to losses. One study found that "each additional week of drought in non-irrigated [US] counties is associated with crop yield reductions in the range of 0.1 to 1.2%, on average."[418] Uneven water availability and high temperatures can even affect taste and quality of final produce. Almost all crops are especially sensitive to drought during two periods: two to three weeks before harvest and at harvest time.[419] Livestock that rely on crop production of grain may be impacted during droughts.[420]

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Agriculture**	**Drought**	**Adaptive Capacity = 2** (Moderate)

Agricultural and farm areas in Fairfax County are estimated to have moderate capacity to adapt to drought. Unlike extreme heat, there are measures that can be taken to adapt to drought conditions, such as drip irrigation and other more efficient watering practices. The Northern Virginia Soil and Water Conservation District (NVSWCD) is a close partner of the county and member of the Resilient Fairfax Planning Team. The NVSWCD promotes soil and water conservation and sustainable farming practices in Fairfax County, which may aid the adaptive capacity of farmers. Additionally, the county, Fairfax Water, and regional entities such as MWCOG and the ICPRB have extensive plans in place in case of drought. However, there are barriers to adaptation, including cost, logistics, and operational hurdles if a farm is historically reliant on a crop that cannot withstand periods of drought. The cost of transitioning to drip irrigation or lower water use irrigation methods may be cost prohibitive to farmers. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Agriculture**	**Drought**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, Fairfax County agricultural and farm areas are estimated to have moderately high vulnerability to drought conditions.

7.5 Cultural and Historic Resources

Fairfax County is home to a wealth of historic sites and resources that may be vulnerable to a changing climate. Fairfax County Park Authority landholdings contain archaeological sites of Native American hunters from 8,000 to 15,000 years ago, Native American hunter gatherer societies between 3,200 and 8,000 years ago, and Native American agricultural societies between 3,200 and 400 years ago.[421] Additional historic sites include the tidewater plantations of George Washington and George Mason, Civil and Spanish-American War camps and trading grounds, and the towns of Reston and Dunn Loring.[422]

Historic Sites, Overlay Districts, and Buildings in Fairfax County

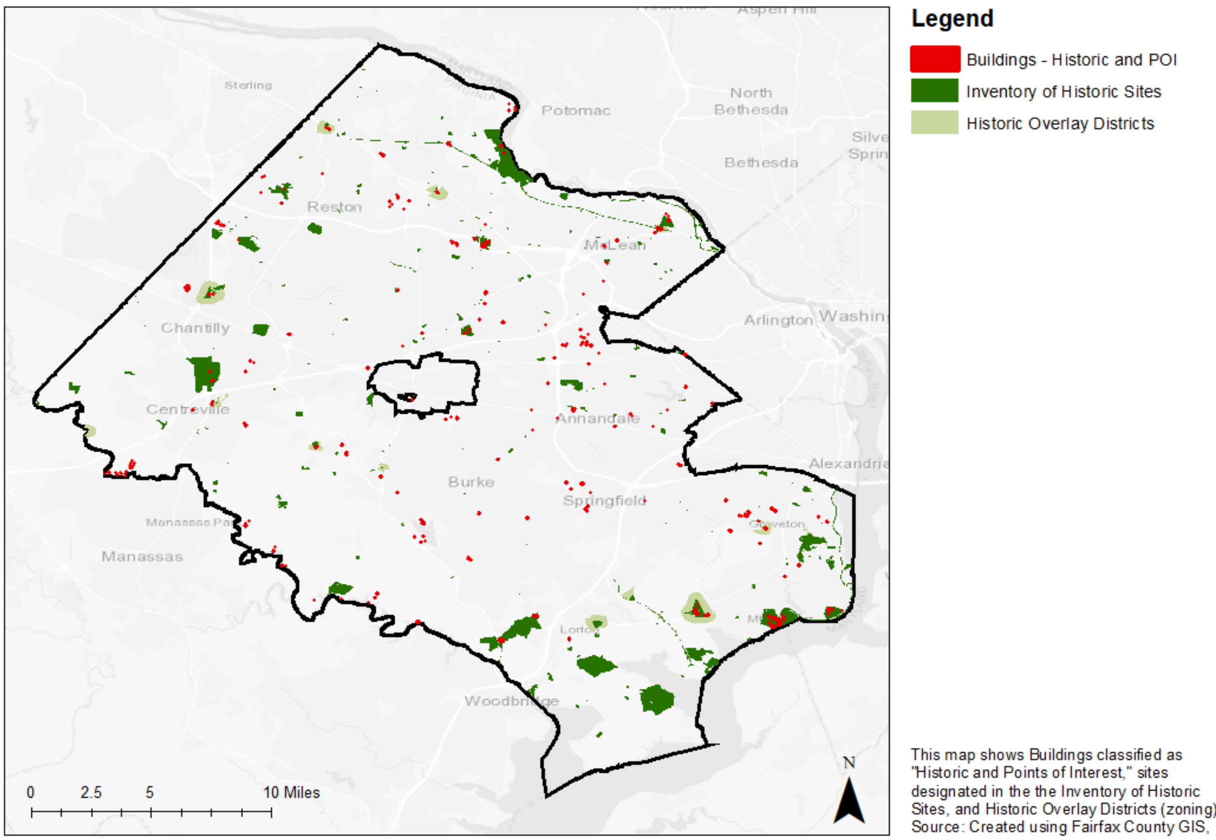


Figure 19: Historic Sites, Historic Overlay Districts, and Buildings - Historic and Points of Interest in Fairfax County

There are 13 county Historic Overlay Districts which are areas with unique architectural, historic, and/or archaeological value which should be preserved.[423] The Architectural Review Board (ARB) is authorized to oversee and administer Fairfax County regulations concerning certain physical changes and uses within Historic Overlay Districts in Fairfax County as designated by the Board of Supervisors, and to assist the Board of Supervisors in its efforts to preserve and protect historic places and areas in the county. Current Historic Overlay Districts include Bull Run Stone Bridge, Centreville, Colvin Run Mill, Dranesville Tavern, Huntley, Lake Anne Village Center, Langley Fork, Mount Air, Pohick Church, Robey's Mill, Saint Mary's Church, Sully, Wellington at River Farm, and Woodland Plantation and Pope-Leighey House. There are other potential districts under review. Section 3101 of the Zoning Ordinance pertains to the preservation of these districts. Department of Planning and Development staff provide support to the ARB through meeting organization and feedback on submitted applications.

For the purposes of this climate vulnerability and risk assessment, climate hazard exposure overlays were based on the following Geospatial Information Systems (GIS) map data layers: Inventory of Historic Sites, and Public Buildings: Historic Site/ Points of Interest.

Table 27 summarizes the climate vulnerability scores for cultural and historical resources. These scores are qualitative and general in nature; they are intended to identify high-level vulnerabilities that may need further county attention or analysis. These scores are described in the sections below. For methodology, please see Appendix 1.

Table 27: Climate Vulnerability Summary - Cultural and Historical Resources

Cultural and Historical Resources – Climate Vulnerability Summary				
Climate Hazards	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Total**
Extreme Heat	2	1	2	**4**
Inland Flooding	2	3	2	**18**
Severe Storms	2	3	2	**12**
Extreme Cold	1	1	2	**2**
Coastal Flooding	2	3	2	**12**
Drought	1	1	1	**1**
Total	-	-	-	**49**

7.5.a. Extreme Heat – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Historic**	**Extreme Heat**	**Exposure = 2** (Moderate)

Cultural and historic resources are moderately exposed to extreme heat which is projected to increase in intensity and severity. In addition to general county-wide warming due to climate change, certain areas are exposed to higher land surface temperatures due to the Urban Heat Island (UHI) effect. Over 36% of historic sites (132 sites) and 37% of historic buildings (159 buildings) in Fairfax County are located in areas with significantly high UHI. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Historic**	**Extreme Heat**	**Sensitivity = 1** (Low)

Historic sites have an estimated low sensitivity to extreme heat conditions. There may be fewer visitors to historic sites on hot days, especially if historic buildings lack air conditioning. Outdoor workers providing maintenance of buildings and grounds may be at risk to heat exposure.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Historic**	**Extreme Heat**	**Adaptive Capacity = 2** (Moderate)

Historic and cultural resources in Fairfax County are estimated to have moderate capacity to adapt to extreme heat conditions. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. This upkeep may effectively enhance facilities' structural resilience to climate effects, even if not the original intent. Retrofitting of historic buildings with cooling mechanisms, air conditioning, enhanced shade through tree planting, and building energy efficiency enhancement reduces the risk faced from extreme heat. However, historic preservation requirements may limit the ability of historic or cultural buildings to make adaptation upgrades to handle extreme heat, such as building energy efficiency improvements, cool roofs, or structural fortifications. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Historic**	**Extreme Heat**	**Total Vulnerability = 4** (Low)

Based on the information available, Fairfax County's historic and cultural resources are estimated to have low total vulnerability to extreme heat.

7.5.b. Heavy Precipitation and Inland Flooding – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Historic**	**Inland Flooding**	**Exposure = 3** (High)

Historic sites in Fairfax County are highly exposed to inland flooding. "Heavy precipitation and inland flooding" refers to both "riverine flooding," which is caused by water bodies overflowing onto floodplains, and "urban flooding," which is caused by heavy precipitation overwhelming stormwater management infrastructure. Nearly 20% of historic sites and 14% of historic buildings are located in FEMA floodplains. Similarly, 23% of historic sites and 12% of historic buildings are located in county recorded floodplains. Further, 71% of historic sites and 47% of historic buildings are located on parcels with two or more flood-prone factors, and 22% of historic sites and 25% of historic buildings are located on parcels with four or more flood-prone factors. These flood exposure rates are notably higher than other assets. Heavy precipitation and inland flooding is projected to increase in intensity and frequency. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Historic**	**Inland Flooding**	**Sensitivity = 3** (High)

Historic sites are highly sensitive to historic flooding. This threat may lead to structural damage of sites that are irreplaceable. Flooding can cause physical damage to buildings and their contents. During severe flooding, many contents within flooded structures that are inundated with water are contaminated and unsalvageable. Structurally, severe flooding of buildings often requires removal of all contents and dry wall, treatment of the studs, and rebuilding. Excessive moisture produces an increased risk of mold which thrives in wet and warm conditions.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Historic**	**Inland Flooding**	**Adaptive Capacity = 2** (Moderate)

Historic and cultural resources in Fairfax County are estimated to have moderate capacity to adapt to increasing heavy precipitation and inland flooding. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. The Cultural Resource Management Plan (2018) requires park staff to promote upkeep and rehabilitation of older structures and encourage appropriate land use planning and development.[424] This careful upkeep may effectively enhance facilities' structural resilience to climate effects, even if not the original intent. The Cultural Resource Management Plan (2018) requires Park Authority staff to identify potential threats and assess severity to known resources as well as locations with moderate-to-high archaeological potential. The Park Authority staff are to work in coordination and consultation with the Natural Resource Branch, amongst others such as DPWES, to try to mitigate or eliminate natural threats whenever possible.[425] However, historic preservation requirements may limit the ability of historic or cultural buildings to make adaptation upgrades to handle flooding, such as modern floodproofing measures or flood walls. Additionally, flooding impacts may be beyond the ability of staff to mitigate. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Historic**	**Inland Flooding**	**Total Vulnerability = 18** (High)

Based on the information available, historic and cultural resources in Fairfax County are estimated to have high total vulnerability to inland flooding.

7.5.c. Severe Storms – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Historic**	**Severe Storms**	**Exposure = 2** (Moderate)

Cultural and historic resources, including historic buildings, are moderately exposed to severe storm and wind events. Artifacts housed within buildings have some level of protection. Severe storm and wind events are projected to intensity. (Please see the Resilient Fairfax [Climate Projections Report] for detailed climate projections.

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Historic**	**Severe Storms**	**Sensitivity = 3** (High)

Historic sites and buildings have high sensitivity to severe storm and wind events. Intensified severe storms such as hurricanes, tropical storms, and derechos, may damage archaeological and historic sites, which may be irreplaceable. In addition, debris on historic sites may prohibit visitors and be expensive to remove.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Historic**	**Severe Storms**	**Adaptive Capacity = 2** (Moderate)

Historic and cultural resources in Fairfax County are estimated to have moderate adaptive capacity to increasing severe storm and wind events such as tropical storms, severe thunderstorms, and derechos. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. The Cultural Resource Management Plan (2018) requires park staff to promote upkeep and rehabilitation of older structures and encourage appropriate land use planning and development.[426]This upkeep may effectively enhance facilities' structural resilience to climate effects, even if not the original intent. The Cultural Resource Management Plan (2018) requires Park Authority staff to identify potential threats and assess severity to known resources as well as locations with moderate-to-high archaeological potential. The Park Authority staff work in coordination and consultation with the Natural Resource Branch, amongst others such as DPWES, to try to mitigate or eliminate natural threats whenever possible.[427] However, historic preservation requirements may limit the ability of historic or cultural buildings to make adaptation upgrades to handle severe storms, such as improved wind ratings. Additionally, the impacts of severe storm and wind events may be beyond the ability of staff to mitigate. There are additional barriers to adaptation, including cost and staff capacity. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax [Audit of Existing Policies, Plans, and Programs]).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Historic**	**Severe Storms**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, historic and cultural resources in Fairfax County are estimated to have moderately high total vulnerability to increasingly severe storms and wind events.

7.5.d. Extreme Cold – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Historic**	**Extreme Cold**	**Exposure = 1** (Low)

Though periodic extreme cold conditions may occur, overall, extreme cold is projected to decline in duration and magnitude, making overall future exposure low. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Historic**	**Extreme Cold**	**Sensitivity = 1** (Low)

Historic sites are estimated to have low sensitivity to extreme cold. Historic sites are not typically physically sensitive to extreme cold conditions. Visitors may be less likely to visit historic sites on extremely cold days. Pipes within facilities may be prone to freezing and bursting.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Historic**	**Extreme Cold**	**Adaptive Capacity = 2** (Moderate)

Historic and cultural resources in Fairfax County are estimated to have moderate capacity to adapt to extreme cold events. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. The Cultural Resource Management Plan (2018) requires park staff to promote upkeep and rehabilitation of older structures and encourage appropriate land use planning and development.[428] This upkeep may effectively enhance facilities' structural resilience to climate effects, even if not the original intent. The Cultural Resource Management Plan (2018) requires Park Authority staff to identify potential threats and assess severity to known resources as well as locations with moderate-to-high archaeological potential. The Park Authority staff work in coordination and consultation with the Natural Resource Branch, amongst others such as DPWES, to try to mitigate or eliminate natural threats whenever possible.[429] Historic preservation requirements may limit the ability of historic or cultural buildings to make adaptation upgrades to handle extreme cold, such as energy efficiency improvements. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Historic**	**Extreme Cold**	**Total Vulnerability = 2** (Very Low)

Based on the information available, Fairfax County's historic and cultural resources are estimated to have very low total vulnerability to extreme cold.

7.5.e. Coastal Flooding – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	**Historic**	**Coastal Flooding**	**Exposure = 2** (Moderate)

Coastal flooding in Fairfax County refers to flooding of the Potomac River or associated water bodies due to sea level rise, tidal flooding, or coastal storm surge. Out of 365 historic sites, 21 (6%) are projected to be exposed to coastal storm surge, 18 (5%) are projected to be exposed to sea level rise of one foot and 19 (5%) are projected to be exposed to sea level rise of three feet. For buildings, out of 428 buildings, 9 (2%) are projected to be exposed to coastal storm surge, 0 are projected to be exposed to sea level rise of one foot, and one (0.2%) is projected to be exposed to sea level rise of three feet. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections. Please see Appendix 3 of this Vulnerability and Risk Assessment for tabulations of asset exposure and Appendix 2 for maps).

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	**Historic**	**Coastal Flooding**	**Sensitivity = 3** (High)

Historic sites and buildings are highly sensitive to coastal flooding. Coastal flooding that is the result of sea level rise can permanently inundate historic sites. This threat may lead to structural damage of sites that are irreplaceable. Flooding can cause physical damage to buildings and their contents. During severe flooding, many contents within flooded structures that are inundated with water are contaminated and unsalvageable. Structurally, severe flooding of buildings often requires removal of all contents and dry wall, treatment of the studs, and rebuilding. Excessive moisture produces an increased risk of mold which thrives in wet and warm conditions. Coastal storm surge, flooding, and erosion can lead to damage and instabilities in building foundations.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	**Historic**	**Coastal Flooding**	**Adaptive Capacity = 2** (Moderate)

Historic and cultural resources in Fairfax County are estimated to have moderate adaptive capacity to coastal flooding events. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. The Cultural Resource Management Plan (2018) requires park staff to promote upkeep and rehabilitation of older structures and encourage appropriate land use planning and development.[430]This upkeep may effectively enhance facilities' structural resilience to climate effects, even if not the original intent. The Cultural Resource Management Plan (2018) requires Park Authority staff to identify potential threats and assess severity to known resources as well as locations with moderate-to-high archaeological potential. The Park Authority staff work in coordination and consultation with the Natural Resource Branch, amongst others such as DPWES, to try to mitigate or eliminate natural threats whenever possible.[431] However, historic preservation requirements may limit the ability of historic or cultural buildings to make adaptation upgrades to reduce coastal flooding impacts. Additionally, coastal flooding may be beyond the ability of staff to mitigate or prevent. There are additional barriers to adaptation, including cost and staff capacity. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	**Historic**	**Coastal Flooding**	**Total Vulnerability = 12** (Moderately High)

Based on the information available, historic and cultural resources in Fairfax County are estimated to have moderately high vulnerability to coastal (Potomac) flooding.

7.5.f. Drought – Cultural and Historic Resources Vulnerabilities

Exposure: What is the level of exposure to this hazard?

Consideration	Sector	Hazard	Score
Exposure	Historic	Drought	**Exposure = 1** (Low)

Historic sites and buildings are exposed to drought conditions if and when they occur. However, future projections do not suggest a significant increase in meteorological drought compared to today. Therefore, drought exposure overall is expected to be low. Intermittent droughts may still occur. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.)

Sensitivity: What are the effects of this hazard?

Consideration	Sector	Hazard	Score
Sensitivity	Historic	Drought	**Sensitivity = 1** (Low)

Historic sites and buildings are estimated to have low sensitivity to drought conditions.

Adaptive Capacity: Are we able to adapt to and address the impacts of this hazard?

Consideration	Sector	Hazard	Score
Adaptive Capacity	Historic	Drought	**Adaptive Capacity = 1** (Good)

Historic sites and buildings (and associated staff) in Fairfax County are estimated to have strong capacity to adapt to drought conditions. Fairfax County conducts meticulous maintenance and preservation of historic and cultural sites. However, there are no known maintenance needs or protection actions needed to protect historic sites from drought. (For additional detail on the county's policies, plans, and programs as they relate to climate resilience, please see the Resilient Fairfax Audit of Existing Policies, Plans, and Programs).

Total Vulnerability: How vulnerable is this asset to this hazard overall?

Consideration	Sector	Hazard	Score
TOTAL VULNERABILITY	Historic	Drought	**Total Vulnerability = 1** (Very Low)

Based on the information available, Fairfax County's historic and cultural resources are estimated to have very low vulnerability to drought conditions.

RISK ASSESSMENT

In the preceding sections (the Vulnerability Assessment), Fairfax County's top climate hazard-related vulnerabilities were qualitatively identified, based on exposure, sensitivity, and adaptive capacity. These sector-based top vulnerabilities were then categorized, to enable grouping of overlapping vulnerabilities.

The top vulnerability categories identified through the Vulnerability Assessment are as follows:

I. **Heavy Precipitation Causing Inland Flooding of Communities**
II. **Combined Stress on Natural Systems**
III. **Storms and Wind Vulnerabilities due to Debris, Damage, and Unsafe Storm Conditions**
IV. **Storms and Winds Vulnerabilities due to Power Outages**
V. **Extreme Heat Causing Health-Related Impacts**

The Risk Assessment evaluates those top vulnerability categories to determine the following:

- Likelihood
- Severity of Consequence

The table below illustrates how qualitative risk scores were determined for each vulnerability category based on likelihood of occurrence and severity of consequence. Please see Appendix 1 for detailed methodology.

Qualitative Risk Score (Likelihood x Consequence)

Table 28: Qualitative Risk Score

		Severity of Consequences		
		Low	**Moderate**	**High**
Likelihood of Occurrence	High	Moderate	Moderate/High	High
	Moderate	Low/Moderate	Moderate	Moderate/High
	Low	Low	Low/Moderate	Moderate

I. HEAVY PRECIPITATION AND INLAND FLOODING OF COMMUNITIES

High Risk Sub-Sectors for this category
- Vulnerable Populations
- General Population
- Cultural and Historic Resources
- Electricity Infrastructure
- Stormwater infrastructure
- Wastewater infrastructure
- Water Bodies

Fairfax County has historically and recently faced heavy precipitation events and flash flooding. Heavy precipitation events are projected to increase in quantity and intensity in Fairfax County. (Please see the Resilient Fairfax Climate Projections Report for detailed climate projections.) These events can be hazardous to the public, who may be trapped in their homes or cars, or be injured or killed in flood waters. Beyond impacts to public health, flooding directly impacts homes and other property. Furthermore, flooding presents a risk to Fairfax County's infrastructure, services, systems, and natural resources.

Resilient Fairfax analyses, including this risk assessment, are conducted in coordination with related plans and programs. The Virginia 2018 Hazard Mitigation Plan suggests Fairfax County's overall risk to flooding is medium-high, including high risk for populations, medium-high risk for property damage, medium-low risk for injuries and fatalities, and low risk for crop damage.[432] The Northern Virginia Hazard Mitigation Plan 2017 suggests Fairfax County is at high risk to flooding. The increasing intensity and frequency of such events will have a significant impact on the people of Fairfax County if necessary flood mitigation steps are not taken.

Subsectors Evaluated – Inland Flooding of Communities

The following sectors/subsectors showed moderate or high vulnerability to inland flooding (a score of 12 or higher) and are therefore included in this risk analysis:

- Vulnerable Populations (27)
- General Population (18)
- Buildings (18)
- Cultural and Historic Resources (18)
- Roadways (18)
- Agricultural Districts and Farms (12)
- Electricity Infrastructure (12)
- Emergency Services (12)
- Health and Community Services (12)
- Parks and Recreation (12)
- Public Transit (12)
- Stormwater Infrastructure (12)
- Trees and Forests (12)
- Wastewater Infrastructure (12)
- Water Bodies (12)

In this Risk Assessment, these sub-sectors were further qualitatively evaluated for likelihood of occurrence and severity of consequence if the event were to occur.

Likelihood of Occurrence – Inland Flooding of Communities

For this section, (inland flooding of communities), the likelihood of occurrence considered both the likelihood that the event itself (heavy precipitation) would take place, and the likelihood that the sub-sector would be affected. The likelihood that the climate hazard will occur was derived from projections detailed in the Climate Projections Report. The likelihood that a sub-sector will be affected utilizes the same methodology as the "exposure" section of the Vulnerability Assessment.

Likelihood that the Hazard Will Occur – Inland Flooding of Communities

There is a high likelihood that this hazard will occur any given year. As detailed in the Resilient Fairfax Climate Projections Report, from 1990 to 2021, Fairfax County experienced 21 damaging heavy rain events (66% chance of occurring in any given year), 37 damaging flash flood events (greater than 100% chance of occurring in any given year), and 18 damaging flood events (56% chance of occurring in any given year).[433] Over the last 50 years, the Southeast United States has experienced an 18% increase in the heaviest 1% of precipitation events.[434] This suggests there is a high probability for the occurrence of heavy precipitation events and flooding. Recent examples include:

- In July 2019, an intense localized rain from thunderstorm activity led to urban flooding due to exceeded capacity of stormwater infrastructure. Prosperity Avenue was significantly damaged, shutting down travel.[435] There were at least 55 water rescues in the county.[436]
- In the August 2021 flooding events that hit parts of Fairfax County, there were reports of multiple trees and downed power lines in roadways and non-functioning traffic lights. As an example of how quickly flood waters can rise, in one "flash flooding" event, water levels rose six feet in less than 30 minutes in Alexandria near Landmark.[437]

Fairfax County is expected to experience increased precipitation depth and intensity over the coming century. Warmer air can contain more water vapor than cooler air, allowing for heavier precipitation events. Precipitation depths are projected to increase for the 2-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year return periods. The existing flood vulnerability in the county compounded with projections for heavier and more intense precipitation under both future scenarios result in a high likelihood of heavy precipitation and inland flooding in the future.

Likelihood of Sub-Sectors Being Affected

The likelihood that the sub-sectors will be affected is moderate to high. For the purposes of this Risk Assessment, the likelihood that individual sub-sectors will be affected by inland flooding was determined based on exposure to riverine and/or urban flooding. Riverine flooding was based upon FEMA 100-year and 500-year floodplains. Urban flooding exposure was based upon parcel-by-parcel analysis of properties for 10 flood-prone factors. These exposure scores are consistent with those shown in the "exposure" sections of the Vulnerability Assessment. It should be noted that FEMA maps do not assess how riverine flooding may change in the future with more intensified precipitation events. However, it can be generally assumed that as precipitation events are projected to increase in precipitation amounts, the spatial extent and magnitude of flooding will likely increase.

- **High likelihood**:
  - At least 10% of the asset, population, or system is exposed to the 100-year FEMA flood map (high probability flood event), or
  - At least 10% of the asset, population, or system is exposed to a Flood Score of four (4) or above (high probability of flooding).

- **Moderate likelihood:**
  - At least 10% of the asset, population, or system is exposed to the 500-year FEMA flood map (moderate probability flood event) and/or
  - 1-10% of the asset, population, or system is exposed to the 100-year FEMA flood map (high probability flood event), and/or
  - 1-10% of the asset, population, or system is exposed to a Flood Score of four (4) or above
- **Low likelihood**: Lower rates than above.

Table 29: Likelihood of asset exposure to inland flooding

Subsectors	Description	Likelihood of Occurrence
Vulnerable Populations (by HH)	20,165 located in the 100-year floodplain (6%) 22,521 located in the 500-year floodplain (7%) 34,819 located on parcels with a Flood Score of 4+ (11%)	High
General Populations (by HH)	57,937 located in the 100-year floodplain (5%) 64,287 located in the 500-year floodplain (6%) 163,284 located on parcels with a Flood Score of 4+ (14%)	High
Buildings	2,063 located in the 100-year floodplain (1%) 2,781 located in the 500-year floodplain (1%) 17,141 located on parcels with a Flood Score of 4+ (7%)	Moderate
Cultural and Historic Resources	67 located in the 100-year floodplain (18%) 70 located in the 500-year floodplain (19%) 80 located on parcels with a Flood Score of 4+ (22%)	High
Roadways	71 miles located in the 100-year floodplain (1%) 89 miles located in the 500-year floodplain (2%)	Moderate
Agricultural Districts and Farms	0.3 square miles located in the 100-year floodplain (7%) 0.4 square miles located in the 500-year floodplain (8%) 0.1 square miles located on parcels with a Flood Sore of 4+ (1%)	Moderate
Electricity Infrastructure	10.4 miles of line located in the 100-year floodplain (10%) 10 assets located in the 100-year floodplain (13%) 11.5 miles of line located in the 500-year floodplain (11%) 10 assets located in the 500-year floodplain (13%)	High
Emergency Services	1 fire station located in the 500-year floodplain (2.3%) 4 fire stations located on parcels with a Flood Score of 4+ (9%) 1 police station located on parcels with a Flood Score of 4+ (5%)	Moderate
Health and Community Services	1 community center located in the 100-year floodplain (2%) 0 hospitals/urgent cares located in the 100-year floodplain (0%) 0 libraries located in the 100-year floodplain (0%) 1 HHS facility located in the 100-year floodplain (2%) 1 community center located in the 500-year floodplain (2%) 0 hospitals/urgent cares located in the 500-year floodplain (0%) 0 libraries located in the 500-year floodplain (0%) 1 HHS facility located in the 500-year floodplain (2%) 5 community centers located on parcels with a Flood Score of 4+ (10%) 2 hospitals/urgent cares located on Flood Score of 4+ (4%) 1 library located on a parcel with a Flood Score of 4+ (4%) 1 HHS facility located on a parcel with a Flood Score of 4+ (2%)	Moderate

Subsectors	Description	Likelihood of Occurrence
Parks and Recreation	91.5 miles of county trails in the 100-year floodplain (27%) 29.9 miles of non-county trails in the 100-year floodplain (10%) 10.1 square miles of county parks in the 100-year floodplain (27%) 5.5 square miles of non-county parks in the 100-year floodplain (18%) 103.7 miles of county trails in the 500-year floodplain (31%) 33.2 miles of non-county trails in the 500-year floodplain (11%) 10.9 square miles of county parks in the 500-year floodplain (29%) 5.8 square miles of non-county parks in the 500-year floodplain (19%)	High
Public Transit	0.3 miles of Metrorail line in the 100-year floodplain (1%) 1 Metrorail station in the 100-year floodplain (10%) 7.7 miles of MetroBus line in the 100-year floodplain (2%) 12 MetroBus stops in the 100-year floodplain (1%) 27 Fairfax Connector Bus Stops in the 100-year floodplain (1%) 0.67 miles of private rail in the 100-year floodplain (1%) 0 VRE stations in the 100-year floodplain (0%) 0.3 miles of Metrorail line in the 500-year floodplain (1%) 1 Metrorail station in the 500-year floodplain (10%) 11.1 miles of MetroBus line in the 500-year floodplain (2%) 17 MetroBus stops in the 100-year floodplain (1%) 34 Fairfax Connector Bus Stops in the 500-year floodplain (1%) 5.5 miles of private rail in the 500-year floodplain (7%) 0 VRE Stations in the 500-year floodplain (0%)	Moderate
Stormwater Infrastructure	238 stormwater management facilities in the 100-year floodplain (3%) 129 miles of stormwater arcs in the 100-year floodplain (4%) 7803 stormwater nodes in the 100-year floodplain (4%) 296 stormwater management facilities in the 500-year floodplain (3%) 162 miles of stormwater arcs in the 500-year floodplain (5%) 9,158 stormwater nodes in the 500-year floodplain (5%)	Moderate
Tree Canopy	21.61 square miles of tree canopy in the 100-year floodplain (10%) 23.56 square miles of tree canopy in the 500-year floodplain (11%)	High
Wastewater Infrastructure	2 wastewater treatment plants in the 100-year floodplain (100%) 4,664 sewer structures in the 100-year floodplain (4%) 257.2 miles of sewer line in the 100-year floodplain (8%) 13 wastewater pump stations in the 100-year floodplain (22%) 9.64 miles of wastewater encasements in the 100-year floodplain (20%) 2 wastewater treatment plants in the 500-year floodplain (100%) 5,394 sewer structures in the 500-year floodplain (5%) 286.8 miles of sewer lines in the 500-year floodplain (8%) 16 wastewater pump stations in the 500-year floodplain (27%) 10.4 miles of wastewater encasements in the 500-year floodplain (21%)	High
Water Bodies	15.1 square miles of water bodies in the 100-year floodplain (88%) 15.1 square miles of water bodies in the 500-year floodplain (88%)	High

Severity of Consequences - Inland Flooding of Communities

Potential direct and indirect consequences were assessed for each vulnerable subsector. Consequences consider impacts beyond the loss of the asset, including impacts to the economy, environment, and community. For each subsector, each consequence category was ranked low, moderate, or high for four categories:

- Economic Impact and Service Loss
- Costs to Repair
- Public Health and Safety
- Environmental Impact

The highest scoring consequence category for each subsector was used as the top score to determine the severity of consequence of inland flooding. The table below summarizes these qualitative scores.

Table 30: Severity of Consequences – Inland Flooding of Communities

Sector/Subsectors	Severity of Consequence – Inland Flooding of Communities				
	Economic Impact & Service Loss	Cost to Repair	Public Health & Safety	Environmental Impact	Top Score
Vulnerable Populations	High	High	High	N/A	High
General Population	High	High	High	N/A	High
Buildings	High	High	High	N/A	High
Cultural and Historic Resources	Moderate	High	N/A	N/A	High
Roadways	Moderate	Moderate	High	N/A	High
Agricultural Districts and Farms	Low	Low	N/A	Moderate	Moderate
Electricity Infrastructure	High	High	High	N/A	High
Emergency Response and Management Services	N/A	Low	High	N/A	High
Health and Community Services	High	Moderate	High	N/A	High
Parks and Recreation	Moderate	Low	Low	Moderate	Moderate
Public Transit	Moderate	Moderate	Moderate	N/A	Moderate
Stormwater Infrastructure	High	High	N/A	Moderate	High
Trees and Forests	N/A	Low	N/A	Moderate	Moderate
Wastewater Infrastructure	High	High	Moderate	Moderate	High
Water Bodies	N/A	N/A	N/A	High	High

Vulnerable Population – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [High]:** Businesses, attractions, and local services may be shut down or inaccessible for more than three days during cleanup, resulting in service loss to populations. During and post flood events, hourly workers unable to reach employment locations may suffer loss wages affecting income. Neighborhoods with higher portion of disadvantaged populations may experience longer delays to back-to-normal business conditions which affect the ability to purchase goods and support livelihoods. Income may be impacted if displaced and unable to reach employment location. FEMA's value of statistical life (VSL) estimates that each fatality or ten injuries is equivalent to $7.6 million of economic loss.[438]

- **Cost to Repair [High]:** Damage to residences may deplete financial savings during recovery. Vulnerable communities may have greater challenges responding to and recovering from inland flooding due to the cost of loss of production, cost of repairs, land in submitting insurance claims. (See "Buildings" sector below for potential costs)
- **Public Health and Safety [High]:** Major flash flooding events can lead to drowning. High flood waters lead to the risk of injury requiring medical care or death.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

General Population – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [High]:** Businesses, attractions, and local services may be shut down or inaccessible for more than three days during cleanup, resulting in service loss to populations. Damage to residences may deplete financial savings during recovery. FEMA's value of statistical life (VSL) estimates that each fatality or ten injuries is equivalent to $7.6 million of economic loss.[439] See "Buildings" sector below for potential costs.
- **Cost to Repair [High]:** Damage to residences may deplete financial savings during recovery. See "Buildings" sector below for potential costs.
- **Public Health and Safety [High]:** Major flash flooding events can lead to drowning. High flood waters lead to the risk of injury requiring medical care or death. A 100-year flood may displace 3,065 people in Fairfax County and prompt 2,016 people to need short-term sheltering (this number combines inland and coastal flooding).[440]
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Buildings – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [High]:** Building damages may delay or disrupt economic activity. Commercial, mixed use, and industrial buildings can experience shutdown, delaying and/or disruption production.
- **Cost to Repair [High]:** Standing flood waters in Fairfax neighborhoods can cause water damage to homes, contents within the homes, and vehicles. Increased water absorption and retention in clay-rich soils, damaging buildings and infrastructure.[441] According to the Virginia Department of Emergency management, annualized losses due to flooding amount to $14,104,000 property damage for Fairfax County.[442] A 500-year flood event could cause $1,794,989,000 in damage to buildings (flood events include coastal).[443] FEMA's National Risk Analysis suggests a total building value of $3,121,517,240 is exposed to riverine flooding today, and estimate an expected annual loss of $877,887. [444] The average property damage per flood event from 1950 to 2015 was $72,705 (flood events include coastal).[445]
- **Public Health and Safety [High]:** Physical damage to health and community service buildings and contents, hindering the county's ability to provide services
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Cultural and Historic – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [Moderate]:** Closure of sites can lead to reduced revenue and visitors. This may in turn affect revenue of shops and retail in proximity to historic and cultural sites.
- **Cost to Repair [High]:** Flooding and erosion damage archaeological and historic sites that may be costly to repair or irreplaceable.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For detailed sensitivities, please see the Vulnerability Assessment).

Roadways – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [Moderate]:** The loss of transportation mobility can impact business services and the supply chain. During flood events, bridge clearance may be reduced, impacting waterway travel.
- **Cost to Repair [Moderate]:** Erosion along streambanks and deterioration of the quality of road pavement can lead to increases in repair and maintenance costs. Flooding can cause bridge scour and/or overtopping of bridge decks.
- **Public Health and Safety [High]:** Motorists in hazardous situations could become stranded, injured or be at risk of drowning.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For detailed sensitivities, please see the Vulnerability Assessment).

Agriculture – Severity of Consequence – Inland Flooding of Communities [Top Score = Moderate]

- **Economic and Service Loss [Moderate]:** Flooding conditions can damage crops, inhibit working in the fields, and strip healthy soils of key nutrients for agriculture. This may impact agricultural production.
- **Cost to Repair [Low]:** Currently, annualized crop damage losses due to flooding have averaged $26,000 for Fairfax County.[446] FEMA's National Risk Analysis suggests agricultural value of $105,443 is exposed to riverine flooding today and an expected annual loss of $3,244. [447]
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [Moderate]:** Flooding can expose farmland to pollutants in ponding areas. Flooding in agricultural fields can lead to contaminated runoff that reduces water quality.[448]

(For detailed sensitivities, please see the Vulnerability Assessment).

Emergency Services – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [N/A]**: Not applicable or insufficient information.
- **Cost to Repair [Moderate]:** Emergency services buildings and assets can be costly to repair and are often taxpayer funded.
- **Public Health and Safety [High]:** Flash flooding of roads and properties results in a significant increase in call volume for swift water rescues and evacuations by FCFRD, Fairfax County Police Department, and VDOT. Emergency response vehicles may be impacted by flooded roads when from traveling to individuals in need. Increased flooding, especially of roads and essential infrastructure, may require emergency planning for road redundancies and alternate routes.
- **Environmental Impact [N/A]**: Not applicable or insufficient information.

(For detailed sensitivities, please see the Vulnerability Assessment).

Parks– Severity of Consequence – Inland Flooding of Communities [Top Score = Moderate]

- **Economic and Service Loss [Moderate]:** Parks, trails, and recreational centers may be unavailable. Reduced park usage may reduce revenue generated from the facilities. If parks are closed due to flooding, revenue of nearby shops and retail may be affected.
- **Cost to Repair Severity [Moderate]:** Severe erosion of stream channels can occur, affecting trails, trees, and streambanks. Increased maintenance may be required, increasing agency operation costs.[449]
- **Public Health and Safety Severity [Low]:** Visitors who are traveling along trails that become flooded may be impacted.
- **Environmental Impact Severity [Moderate]:** Significant flooding can lead to loss of vegetation and habitat.

(For detailed sensitivities, please see the Vulnerability Assessment).

Public Transit – Severity of Consequence – Inland Flooding of Communities [Top Score = Moderate]

- **Economic and Service Loss Severity [Moderate]:** Flooding can introduce debris onto railways that blocks and disrupts service. Inundation of technology can cause shorting of electrical equipment such as switches, gates, and signals. Old or underground transit system tunnels and stations[450] can also be flooded by an increase in precipitation.[451] Loss of public transit can lead to loss of economic productivity for workers who rely on this service. Loss of public transit can also lead to increased regional vehicular congestion, which can have economic impacts.
- **Cost to Repair Severity [Moderate]:** Immersed wooden rail ties can weaken track support and increase ballast or embankment scour. Public transit assets have significant costs to repair.
- **Public Health and Safety Severity [Moderate]:** Flooding of public transit routes and stops can impact public safety.
- **Environmental Impact Severity [N/A]:** Not applicable or insufficient information.

(For detailed sensitivities, please see the Vulnerability Assessment).

Stormwater Infrastructure – Severity of Consequence – Inland Flooding [Top Score = High]

- **Economic and Service Loss [High]:** Overwhelmed stormwater infrastructure can lead to significant flooding of nearby roads, buildings, and land, affecting businesses, travel, and residences. This may impact mobility and business operations.
- **Cost to Repair [High]:** Debris may damage stormwater infrastructure. Undersized stormwater drainage systems require substantial investment to upgrade.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [Moderate]:** Backed up drainage can lead to pollutants or other contaminants entering waterways, leading to water quality concerns.

(For detailed sensitivities, please see the Vulnerability Assessment).

Trees and Forests– Severity of Consequence – Inland Flooding of Communities [Top Score = Moderate]

- **Economic and Service Loss [N/A]:** Not applicable or insufficient information.
- **Cost to Repair [Low]:** Damage to trees from flood events may require tree removal and/or increased tree maintenance.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [Moderate]:** Tree damage and loss can occur. Decomposition of leaves and other organic matter may be slowed.[452] Flooding can also introduce other stressors that may weaken trees and make them susceptible to insects and diseases.

(For detailed sensitivities, please see the Vulnerability Assessment).

Wastewater Infrastructure – Severity of Consequence – Inland Flooding [Top Score = High]

- **Economic and Service Loss [High]:** Flooding to the wastewater treatment plant facility area could cause wastewater service interruption; wastewater service is a critical service and its loss could disrupt economic productivity of areas affected.
- **Cost to Repair [High]:** Significant repairs costs may be required due to damage caused by flooding, including flooding of pumping stations and increased blockages, erosion of stream bank exposing sanitary sewers adjacent to and crossing streams, cracking of underground pipes, and cleanup costs.
- **Public Health and Safety [Moderate]:** Underground pipes designed for gravity flow in the wastewater conveyance system may become pressurized and backup into homes and businesses. Reduce capacity for wastewater may result if drain fields for septic tanks are saturated.
- **Environmental Impact [Moderate]:** Sanitary sewer overflows can contaminate water and other environmental resources.

(For detailed sensitivities, please see the Vulnerability Assessment).

Water Bodies – Severity of Consequence – Inland Flooding of Communities [Top Score = High]

- **Economic and Service Loss [N/A]:** Not applicable or insufficient information.
- **Cost to Repair [N/A]:** Not applicable or insufficient information.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact Severity [High]:** Inland flooding can cause streambank erosion, leading to wider and deeper stream channels. Rising groundwater table can lead to saturated soils, increasing runoff to water bodies. Extreme flood events (greater than a 100-year recurrence interval) lead to losses in almost every ecosystem service.[453]

(For detailed sensitivities, please see the Vulnerability Assessment).

Total Risk – Inland Flooding of Communities

The total risk score is a combination of the "likelihood" and "severity of consequence" scores described above. This qualitative screening scored the following sub-sectors as having "high risk" for inland flooding: vulnerable populations, general population, cultural and historic resources, electricity infrastructure, wastewater infrastructure, and water bodies. The following sub-sectors were scored as having "moderate/high risk" for inland flooding: buildings, roadways, emergency services, health and community services, parks and recreation, stormwater infrastructure, and trees and forests. Agricultural districts and farms and public transit were scored as having "moderate risk" for inland flooding.

Table 31: Total Risk – Inland Flooding of Communities

Sub-sector	Likelihood	Severity of Consequence	Qualitative Risk Score (*Likelihood x Consequence)*
Vulnerable Populations	High	High	High
General Population	High	High	High
Buildings	Moderate	High	Moderate/High
Cultural and Historic Resources	High	High	High
Roadways	Moderate	High	Moderate/High
Agricultural Districts and Farms	Moderate	Moderate	Moderate
Electricity Infrastructure	High	High	High
Emergency Services	Moderate	High	Moderate/High
Health and Community Services	Moderate	High	Moderate/High
Parks and Recreation	High	Moderate	Moderate/High
Public Transit	Moderate	Moderate	Moderate
Stormwater Infrastructure	Moderate	High	Moderate/High
Trees and Forests	High	Moderate	Moderate/High
Wastewater Infrastructure	High	High	High
Water Bodies	High	High	High

In addition to evaluating individual sub-sectors, it is important to consider impacts that are amplified because they impact multiple sectors. The results of this qualitative analysis suggest that for inland flooding, there are important combined concerns including but not limited to the following:

- Public health and safety concerns, including health risks to general and vulnerable populations, and potential flooding-related threats to safe transportation, housing, utilities, and access to services,
- Economic impacts and service loss from businesses and services being closed for more than a few days,
- Costs to repair flood damage to buildings and infrastructure,
- Environmental concerns in terms of water quality and changes to stream geomorphology.

The combination of densely populated areas with undersized stormwater infrastructure and exposed wastewater infrastructure may be of significant concern. Communities along Barrett Road, Cub Run, Herndon, Hybla Valley region, Little Pimmit Run area, and Valley Avenue area have been identified as especially high-risk areas for inland flooding.

II. COMBINED CLIMATE HAZARDS IMPACTING NATURAL SYSTEMS

High Risk Sub-Sectors for this Category
- Water Bodies
- Wetlands and Environmentally Sensitive Areas (ESAs)
- Agricultural Districts and Farms

Natural systems are exposed to multiple threats from climate-related hazards, including extreme heat, inland flooding, coastal flooding, severe storms, and drought. These climate hazards can occur simultaneously and/or sequentially, multiplying realized impacts. For example, when periods of drought are followed by heavy precipitation, severe erosion and environmental damage can occur. This section explores the risk that combined climate hazards pose to natural systems. Extreme heat, heavy precipitation, severe storms, coastal flooding, and drought were considered.

Subsectors Evaluated – Combined Climate Hazards on Natural Systems

In the Vulnerability Assessment, the following subsectors showed high to moderately-high vulnerability to climate hazards, and are therefore included in this risk analysis:

- Water Bodies
- Wetlands and Environmentally Sensitive Areas (ESAs)
- Trees and Forests
- Agricultural Districts and Farms
- Parks and Recreation

Likelihood of Occurrence - Combined Climate Hazards on Natural Systems

There is a high likelihood that a combination of climate hazards will occur, and impact natural systems. This section considered multiple climate-related hazards: extreme heat, heavy precipitation and inland flooding, severe storms, coastal flooding, and drought. Research outside the scope of this project is required to understand and ideally quantify the likelihood of combined climate-related hazards occurring simultaneously or in tandem. For this assessment, it was assumed that multiple climate hazard combinations are plausible and could occur within the next 30 years. Because a likelihood scoring was not feasible for this section, the risk score is based on the consequence scores.

Severity of Consequences – Combined Climate Hazards on Natural Systems

Potential direct and indirect consequences were assessed for each vulnerable subsector. Consequences consider impacts beyond the loss of the asset, including impacts to the economy, environment, and community. For each subsector, each consequence category was ranked low, moderate, or high for four categories:

- Economic Impact and Service Loss
- Costs to Repair
- Public Health and Safety
- Environmental Impact

The highest scoring consequence category for each subsector was used as the top score to determine the severity of consequence of inland flooding. The table below summarizes these qualitative scores.

Table 32: Severity of Consequences - Combined Climate Hazards on Natural Systems

Subsectors	Severity of Consequence – Combined Climate Hazards on Natural Systems				
	Economic Impact & Service Loss	Cost to Repair	Public Health & Safety	Environmental Impact	Top Score
Water Bodies	N/A	N/A	Low	High	High
Wetlands and ESAs	N/A	N/A	Moderate	High	High
Trees and Forests	N/A	N/A	Moderate	Moderate	Moderate
Agricultural Districts and Farms	High	Moderate	N/A	Moderate	High
Parks and Recreation	Moderate	Low	Moderate	Moderate	Moderate

Water Bodies – Severity of Consequence - Extreme Heat and Heavy Precipitation; Heavy Precipitation and Coastal Flooding: [Top Score: High; High]

- **Economic Impact and Service Loss [N/A]:** Not applicable or insufficient information.
- **Costs to Repair:** Not applicable or insufficient information.
- **Public Health and Safety [Low]:** Members of the public using water bodies for recreation could be exposed to poor water quality conditions.
- **Environmental Impact [High]:**
  - [Extreme Heat/Heavy Precipitation]: Warmer water temperatures from extreme heat can be compounded by rainfall that falls on impervious surfaces during hot summer months and becomes superheated runoff that flows into streams, shocking aquatic life.[454]
  - [Heavy Precipitation/Coastal Flooding]: Heavy precipitation along with coastal flooding could lead to rising groundwater tables, saturating soils and increasing runoff. Precipitation and coastal flooding can also compound stress on stream channels and streambanks, causing increased erosion.

(*For detailed, sector-specific sensitivities, please see the Vulnerability Assessment).*

Wetlands and Environmentally Sensitive Areas (ESAs): Extreme Heat and Heavy Precipitation; Heavy Precipitation and Coastal Flooding: [Top Score: High; High]

- **Economic Impact and Service Loss [N/A]:** Not applicable or insufficient information.
- **Costs to Repair [N/A]:** Not applicable or insufficient information.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [High]:**
  - [Extreme Heat/Heavy Precipitation]: Warmer water temperatures from extreme heat can be compounded by rainfall that falls on impervious surfaces during hot summer months and becomes superheated runoff that flows into streams, shocking aquatic life.[455]
  - [Heavy Precipitation/Coastal Flooding]: Heavy precipitation along with coastal flooding could lead to destruction of habitat from either complete inundation or by creating inhospitable conditions for existing species, leading to loss of biodiversity. Over time, this can lead to changes and losses in species distribution and ecosystem services.

(*For detailed, sector-specific sensitivities, please see the Vulnerability Assessment).*

Trees and Forests: Extreme Heat and Drought; Extreme Heat and Heavy Precipitation [Top Score: Moderate; Moderate]

- **Economic Impact and Service Loss [N/A]:** Not applicable or insufficient information.
- **Costs to Repair [N/A]:** Not applicable or insufficient information.
- **Public Health and Safety [Moderate]:** Tree death resulting from either hazardous condition can result in falling trees and potential public safety consequences.
- **Environmental Impact [Moderate]:**
  - [Extreme Heat/Drought] Extreme heat can cause heat stress and die off in trees, particularly younger trees.[456] Enhanced evaporation can lead to soil stress by killing vital living soil ecosystems. Drought compounds these stressors to ecosystems. Extreme heat and drought can also cause trees to become more susceptible to pests and other infestations.[457]
  - [Extreme Heat/Heavy Precipitation] Heavy precipitation resulting in flooding can weaken trees, making them more susceptible to further damage through heat stress.[458]

(For detailed, sector-specific sensitivities, please see the Vulnerability Assessment).

Agricultural Districts and Farms: Extreme Heat and Drought; Severe Storms and Heavy Precipitation: [Top Score: High; High]

- **Economic Impact and Service Loss [High]:**
  - [Extreme Heat/Drought]: Extreme heat and drought can have compounding effects on agricultural systems. Extreme heat increases the need for irrigation, which is more challenging during drought conditions. Uneven water availability and high temperatures can impact quality of final produce. There may also be an impact on livestock mortality if livestock are unable to find relief.
  - [Severe Storms/Heavy Precipitation]: Severe storms including strong winds combined with heavy precipitation can damage crops, especially early in the growing season. Severe storms and heavy precipitation can also inhibit working in the fields.
- **Costs to Repair [Moderate]:**
  - [Severe Storms/Heavy Precipitation] Severe storms including strong winds along with heavy precipitation can damage farm infrastructure.
- **Public Health and Safety [N/A]**:
  - Not applicable or insufficient information.
- **Environmental Impact [Moderate]:**
  - [Extreme Heat/Drought]: Extreme heat, droughts, and greater evaporation can lead to soil stress by killing vital living soil ecosystems.
  - [Severe Storms/Heavy Precipitation]: Severe storms combined with heavy precipitation can damage soils through increased runoff and potential exposure to pollutants in ponding areas. Severe storms and heavy precipitation can also exacerbate erosion.[459]

(For detailed, sector-specific sensitivities, please see the Vulnerability Assessment)

Parks and Recreation: Extreme Heat; Severe Storms, and Heavy Precipitation: [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:**
  - [Extreme Heat, Severe Storms, Heavy Precipitation]: These hazards may reduce visitation and use of outdoor areas and recreation facilities affecting revenue. To protect public health, outdoor park closures or restrictions may occur. Additionally, increased maintenance needs may have financial implications for park facilities.
- **Costs to Repair: [Moderate]:**
  - [Extreme Heat]: Extreme heat can degrade trail pavements and may increase need for field maintenance.
  - [Severe Storms, Heavy Precipitation]: Severe storms combined with heavy precipitation can waterlog and damage parks and recreational facilities, and can create storm debris, creating the need for additional maintenance costs.
- **Public Health and Safety: [Moderate]:**
  - [Extreme Heat]: Extreme heat increases the risk of heat-related illnesses for visitors engaged in outdoor activities.
  - [Severe Storms, Heavy Precipitation]: Severe storms and heavy precipitation can create public health and safety risks during and after such events.
- **Environmental Impact: [Moderate]:**
  - [Extreme Heat, Severe Storms, Heavy Precipitation]: Each of these hazards stresses natural systems such as trees, vegetation, and species found within the parks. Native species may not be as viable in extreme heat conditions, which could lead to environmental impacts (ranging from minimal/reversible to irreversible depending on the degree and duration of the climate hazard).

(For detailed, sector-specific sensitivities, please see the Vulnerability Assessment)

Total Risk – Combined Climate Hazards on Natural Systems

For this section, likelihood could not be calculated because multiple climate hazard combinations are plausible in the future. Therefore, the risk assessment score is based solely on the severity of consequence scores.

Table 33: Total Risk

Sector/Subsector	Hazards	Qualitative Risk Score
Water Bodies	Extreme Heat/Heavy Precipitation Heavy Precipitation/Coastal Flooding	High
Wetlands and Environmentally Sensitive Areas (ESAs)	Extreme Heat/Heavy Precipitation Heavy Precipitation/Coastal Flooding	High
Trees and Forests	Extreme Heat/Drought Extreme Heat/Heavy Precipitation	Moderate
Agricultural Districts and Farms	Extreme Heat/Drought Severe Storms/Heavy Precipitation	High
Parks and Recreation	Extreme Heat	Moderate

This qualitative screening scored Water Bodies, Wetlands and Environmentally Sensitive Areas (ESAs), and Agricultural Districts and Farms as high risk to combined climatic stress. Trees and Forests and Parks and Recreation scored as moderate risk.

III. STORMS AND WINDS CAUSING DEBRIS, DAMAGE, AND UNSAFE CONDITIONS

High Risk Sub-Sectors for this Category
- Buildings
- Health and Community Services
- Roadways
- General Population
- Vulnerable Populations
- Public Transit

Severe storm and wind events include hazards such as tropical cyclones, derechos, tornadoes, severe thunderstorms, and severe winter storms, among other storm types. "Storm and wind events" are evaluated separately from "heavy precipitation" because while these two hazards often overlap, they may also occur separately, with separate impacts.

In the Vulnerability Assessment, severe storm and wind events were found to cause top vulnerabilities across numerous sectors. However, these top storm-related vulnerabilities were found to be of two different types: those relating to debris, damage, and unsafe conditions, and those relating to power outages. This section discusses the first type.

Subsectors Evaluated – Storms and Wind – Debris, Damage, Safety

In the Vulnerability Assessment, the following sub-sectors showed moderately-high to high vulnerabilities to storms and winds relating to debris, damage, and unsafe conditions. Therefore, these sub-sectors are included in this subsequent Risk Assessment:

- Emergency Services (27)
- Buildings (18)
- Health and Community Services (18)
- Roadways (18)
- Tree Canopy (18)
- Vulnerable Populations (18)
- General Population (12)
- Bicycle and Pedestrian Infrastructure (12)
- Cultural and Historic Resources (12)
- Parks and Recreation (12)
- Public Transit (12)
- Telecommunications (12)

Likelihood of Occurrence – Storms and Wind – Debris, Damage, Safety

Likelihood of occurrence is based on both likelihood that the hazard will occur, and likelihood that each sub-sector will be affected.

Likelihood that the Hazard Will Occur – Storms and Wind - Debris, Damage, Safety Risk

There is a high likelihood that severe storms and wind will occur and increase in intensity in Fairfax County, causing debris, damage, and safety concerns. As detailed in the Resilient Fairfax Climate Projections Report, storm and wind events are projected to increase in intensity and frequency in Fairfax County, which has historically and recently experienced significant damage from storms.

Fairfax County typically experiences a range of storm events each year, including thunderstorms and mid-latitude cyclones. These events have become more frequent over the last 40-50 years. Fairfax County also experiences blizzards, tropical cyclones, flooding, tornadoes, and high wind events.[460] The 2017 National Climate Assessment Report projects the following:

- **Tropical cyclones:** Projections suggest that tropical cyclones will be more intense but less frequent over time.[461] Confidence is low for the Atlantic basin, however, due to limited studies analyzing these conditions and the competing conditions that may reduce overall storm frequency but increase storm intensity.

- **Severe Thunderstorms:** Studies suggest an overall increase in the frequency of severe thunderstorm environments, particularly in the U.S. Midwest and southern Great Plains. There is a gap in studies exploring long-term trends in wind events including derechos.
- **Winter Storms:** An increase in storms is projected over the eastern United States with the higher scenario (RCP 8.5) projecting the most intense of these storms.

Quantifying how storms may change under a future climate is an area of active research. However, the literature generally suggests stronger winds and heavier precipitation.[462] Additionally, the Virginia 2018 Hazard Mitigation Plan suggests Fairfax County's overall risk to storms and winds causing debris, damage, and unsafe conditions is high. Storm and wind events can knock down trees or other large objects and structures, causing damage to private and public property, injuring individuals, and blocking access across transportation routes that can reduce economic productivity and hinder emergency response.

Likelihood that the Sub-Sectors Will be Affected – Storms and Wind – Debris, Damage, Safety

There is a high likelihood that any given area of the county (and any exposed assets) will be affected by severe storms and wind causing debris, damage, and safety concerns. For this analysis, storm events causing debris, damage, and unsafe conditions are considered equally plausible across the entire county and could occur in any given year, assigning a high likelihood score of occurrence to all sub-sectors. Given the difficulty of predicting the probability and intensity of a future storm event in a specific location, there is no particular location within Fairfax County that will be more susceptible to these storms, and as a result, susceptibility is uniform across the County. Storm events are typically not geographically isolated events and are likely to occur county-wide; it is not possible to identify certain areas that are more prone to these events than others. This approach is consistent with the Northern Virginia Hazard Mitigation Plan 2017, which found that the widespread nature of this hazard means that the likelihood of occurrence is uniform across all Northern Virginia jurisdictions.

Severity of Consequence – Storms and Wind – Debris, Damage, Safety

For each sub-sector that was deemed in the Vulnerability Assessment to have moderately high or high vulnerability to this hazard, severity of consequence was assessed, as described in this section. Consequences consider impacts beyond the loss of the asset, including impacts to the economy, environment, and community.

For each sub-sector, each consequence category was ranked low, moderate, or high for four categories:

- Economic Impact and Service Loss
- Costs to Repair
- Public Health and Safety
- Environmental Impact

The highest scoring consequence category for each subsector was used as the top score to determine the severity of consequences.

Table 34: Severity of Consequence – Storms and Wind – Debris, Damage, Safety

Sector/Subsectors	Risk: Severity of Consequence – Storms and Wind Causing Debris, Damage, Safety				
	Economic Impact & Service Loss	Cost to Repair	Public Health & Safety	Environmental Impact	Top Score
Emergency Services	N/A	Moderate	Moderate	N/A	Moderate
Buildings	Moderate	High	High	N/A	High
Health and Community Services	High	Moderate	Moderate	N/A	High
Roadways	High	High	High	N/A	High
Trees and Forests	N/A	Low	Moderate	Moderate	Moderate
Vulnerable Populations	High	High	High	N/A	High
General Populations	Moderate	High	High	N/A	High
Bicycle and Pedestrian Infrastructure	Moderate	Moderate	Moderate	N/A	Moderate
Cultural and Historic Sites	Moderate	High	N/A	N/A	High
Parks and Recreation	Moderate	Moderate	Moderate	Moderate	Moderate
Public Transit	Moderate	High	High	N/A	High
Telecommunications	Moderate	Moderate	Moderate	N/A	Moderate

Emergency Services – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: Moderate]

- **Economic Impact and Service Loss [N/A]:** Not applicable or insufficient information.
- **Costs to Repair [Moderate]:** Severe storms could damage to 911 towers, emergency response vehicles such as fire trucks, fire stations, police stations, evacuation routes, and evacuation centers.
- **Public Health and Safety [Moderate]:** Delayed response to emergency calls during high wind and severe storm events may occur. This is in accordance with protocols meant to protect emergency responders' safety, but could have public health and safety impacts to residents. Additionally, high allocation of emergency response resources during severe storm and wind events can lead to fewer resources available to respond to non-storm related calls. This can impact public health and safety.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Buildings– Severity of Consequence – Storms and Wind – Debris, Damage, Safety [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Damage to buildings from severe storms can inhibit functionality, economic productivity, and service loss during and after a storm event. Significant damage could also result in reduction of overall property value.
- **Costs to Repair [High]:** Debris and wind from severe storms can damage or cause structural failure of buildings. Buildings have a high cost to repair.

- **Public Health and Safety [High]:** Significant damage to buildings could pose risk to populations within the buildings, potentially resulting in injury or loss of life.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Health and Community Services – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [High]:** Severe storms may disrupt public health, healthcare, and community services both during and after the event. Fairfax County service providers may not be able to travel to provide services during and post event. This may restrict access to essential services like food distribution centers,[463] child daycare, financial services, adult care facilities, transportation access services, workforce development services, or mental health facilities. These services are critical to a healthy economy.
- **Costs to Repair [Moderate]:** Health and community services facilities may be damaged during event and require repairs to resume full functionality.
- **Public Health and Safety [Moderate]:** Severe storm and wind damage, closures, and loss of health and community service may limit residents' ability to access services for domestic violence and sexual assault services, food services, inspection services, health clinics, and housing assistance services, among others.
- **Environmental Impact [N/A]**: Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Roadways – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [High]:** Significant debris on roadways can block and/or disrupt travel, limiting access for neighborhoods, manufacturing/production, supply chains, and essential services, taking more than three days to remove.
- **Costs to Repair [High]:** Severe storm and wind events causing debris and damage lead to high costs to the county and other agencies for debris clean up and repair of roads following a storm event. Costs to repair damage from storm to roads, culverts, and bridges can be substantial.
- **Public Health and Safety [High]:** Extreme storms and wind can disrupt travel and compromise safety by downing power lines, trees, other structures, and creating hazardous conditions and limiting travel.
- **Environmental Impact [N/A]**: Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Trees and Forests– Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Storm and wind damage to trees can have economic impacts for timber production and other tree-related economic activities.
- **Costs to Repair [Low]:** Trees damaged or felled in public areas and rights-of-way likely need to be cleared and replaced.

- **Public Health and Safety [Moderate]:** Falling branching and/or trees can create unsafe conditions that may lead to injury or potentially a fatality.
- **Environmental Impact [Moderate]:** High winds can injure and kill trees. High winds can also cause tree uprooting, breakage and loss of minor and major branches, and stem breakage causing downed trees and debris.

(For direct sensitivities, please see the Vulnerability Assessment).

Vulnerable Populations – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [High]:** Workers, particularly non-salaried workers, may lose income during and after severe storm and wind events due to closures, blockage of transportation routes and supply chains, lack of mobility, and/or damage to buildings. Following storm events, possible disruptions to public transit operations could increase difficulty for vulnerable populations to commute to work or meet other daily needs.
- **Costs to Repair [High]:** Vulnerable populations may have a greater potential for property damage due to compromised housing conditions or lower-quality buildings structures. Vulnerable populations may have fewer financial means to devote income towards hardening, increasing the resilience of their homes, or completing needed repairs. This may result in greater damage to homes from severe storms. Additionally, vulnerable populations may be less able to afford homeowners or renters insurance, leading to higher repair costs following damage. Lower-income populations may also have less money in savings that can be used for emergency repair purposes. More assistance may be needed for low-income, communities of color, and other disadvantaged groups with rebuilding and recovery.
- **Public Health and Safety [High]:** Severe storm and wind events may cause mortality or injury due to outdoor exposure to storm events, building damage, or other exposure to unsafe conditions. Outdoor workers and those experiencing homelessness may face increased risk of mortality or injury due to increased outdoor exposure during a storm. Lower rates of car-ownership amongst vulnerable populations complicates evacuation to emergency shelters or out of the storm's path. Mental health impacts to vulnerable populations, such as adding to chronic stress or post-traumatic stress disorder, may also occur.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

General Populations – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Severe storm and wind events can cause economic impacts to the general population due to damage to businesses, disruption of supply chains, debris blockage to roads, and loss of services to neighborhoods during and after events.
- **Costs to Repair [High]:** Severe storm and wind events can cause significant property damage.
- **Public Health and Safety [High]:** Severe storm and wind events may cause mortality or injury due to outdoor exposure to storm events, building damage, or other exposure to unsafe conditions. Additionally, experiencing severe hazards such as hurricanes (and the associated

loss) may negatively impact mental health through impacts such as chronic stress or post-traumatic stress disorder.

- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Bicycle and Pedestrian Infrastructure– Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: Moderate]

- **Economic Impact and Service Loss [Low]:** Bicycle and pedestrian infrastructure may be out of service during and after severe storm and wind events due to debris or damage. Those relying on bicycle and pedestrian infrastructure may experience loss of accessibility and associated economic impacts; however, such reliance is estimated to be a small portion of economic impacts.
- **Costs to Repair [Moderate]:** Severe storms may cause damage to, debris on, and accelerated erosion and deterioration of the quality of bicycle and pedestrian infrastructure.
- **Public Health and Safety [Moderate]:** Pedestrians and bicyclists may experience public health and safety risks due to storm and wind-related debris, damage, and exposure to unsafe conditions.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Cultural and Historic Sites– Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Revenue will be impacted if sites are closed to visitors. May also impact any nearby stores that rely on tourist dollars.
- **Costs to Repair [High]:** Severe storms may damage archaeological and historic sites. Damage to assets that are irreplaceable may not be easily repaired or quantifiable.
- **Public Health and Safety [N/A]:** Not applicable or insufficient information.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Public Transit – Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Severe storm and wind events that cause debris, damage, and unsafe conditions may affect operations and inflict damage on WMATA, VRE, and Fairfax Connector infrastructure. Such loss of service can have notable economic impacts and loss of productivity for the region. Rail and transit infrastructure located in areas with significant tree cover are vulnerable to debris and blockages from downed trees or branches, resulting in delay or loss of service. In severe events, the Governor could issue a state of emergency or travel ban which could further impact the level of service of public transit. Given the high priority of public transit operations, it is assumed service would return within three days of the storm, rendering the loss “moderate” rather than “high.”

- **Costs to Repair [High]:** Storm and wind damage to platforms, stations, or other public transit infrastructure could require significant repairs, which are often expensive.
- **Public Health and Safety [High]:** Damage to public transit infrastructure could result in unsafe conditions for users and staff, particularly if event leads to derailment or accidents.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For direct sensitivities, please see the Vulnerability Assessment).

Parks and Recreation– Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Loss of use of outdoor parks and facilities during severe storms may affect revenue for parks and recreation. Parks are designated as receiving grounds in the county's Debris Management Plans. Such debris storage may limit the ability of parks and recreational facilities to operate normally.
- **Costs to Repair [Moderate]:** Severe storms can cause significant damage to stream valley parks and trails. Damaged trails, parks, or other facilities may result in notable cost to repair.
- **Public Health and Safety [Moderate]**: Use of parks and recreation facilities during or after severe storms can create public health and safety risks.
- **Environmental Impact [Moderate]:** Damage to parks and recreation facilities can also mean damage to critical natural environments and habitats.

(For direct sensitivities, please see the Vulnerability Assessment).

Telecommunications– Severity of Consequence – Storms and Wind – Debris, Damage, Safety: [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Falling trees, icing and breakage, and extreme winds can prevent transmission of telecommunications, affecting service.[464]
- **Costs to Repair: [Moderate]:** Severe storms can damage telephone lines, cell towers, and other telecommunication infrastructure.
- **Public Health and Safety: [Moderate]:** Disruption to telephone lines can seriously threaten human safety by delaying or preventing emergency communication.
- **Environmental Impact [N/A]:** Not applicable.

(For direct sensitivities, please see the Vulnerability Assessment).

Total Risk – Storms and Wind – Debris, Damage, Safety

Risk is a combination of likelihood and severity of consequence. The qualitative risk scores are summarized in the table below.

Table 35: Total Risk

Sector/Subsector	Likelihood	Severity of Consequence	Qualitative Risk Score
Emergency Services	High	Moderate	**Moderate/High**
Buildings	High	High	**High**
Health and Community Services	High	High	**High**
Roadways	High	High	**High**
Trees and Forests	High	Moderate	**Moderate/High**
Vulnerable Populations	High	High	**High**
General Populations	High	High	**High**
Bicycle and Pedestrian Infrastructure	High	Moderate	**Moderate/High**
Cultural and Historic Sites	High	High	**Moderate/High**
Parks and Recreation	High	Moderate	**Moderate/High**
Public Transit	High	High	**High**
Telecommunications	High	Moderate	**Moderate/High**

In addition to evaluating individual sub-sectors, it is important to consider impacts that are amplified because they impact multiple sectors. The results of this qualitative analysis suggest that for severe storm and wind impacts from debris, damage, and unsafe conditions, there are important combined concerns including but not limited to the following:

- Potential of significant costs to repair buildings and infrastructure;
- Vulnerable populations affected by disruptions to public health and county services, ability to financially sustain property damages, ability to evacuate prior to or post storm event, reduced mobility magnified by potential service disruption to public transit;
- Public health and safety concerns regarding mortality and injury, disruption to operations provided by health and community services, and reduced mobility on roadways.

IV. STORMS AND WINDS CAUSING VULNERABILITIES DUE TO POWER OUTAGES

High Risk Subsectors in this category
- Electrical Infrastructure
- General Population
- Vulnerable Population
- Drinking Water
- Emergency Response
- Health and Community Services

Severe storm and wind events include hazards such as tropical cyclones, derechos, tornadoes, severe thunderstorms, and severe winter storms, among other storm types. "Storm and wind events" are evaluated separately from "heavy precipitation" because while these two hazards often overlap, they may also occur separately, with separate impacts.

In the Vulnerability Assessment, severe storm and wind events were found to cause top vulnerabilities across numerous sectors. However, these top storm-related vulnerabilities were found to be of two different types: those relating to debris, damage, and unsafe conditions, and those relating to power outages. This section discusses the second type: those relating to power outages.

Subsectors Evaluated – Storms and Wind – Power Outages

In the Vulnerability Assessment, the following sub-sectors showed moderately-high to high vulnerabilities to increasing storms and winds due to power outages specifically. Therefore, these sub-sectors are included in this subsequent Risk Assessment:

- Emergency Services (27)
- Electrical Infrastructure (18)
- Buildings (18)
- Drinking Water Infrastructure (18)
- Health and Community Services (18)
- Vulnerable Populations (18)
- General Population (12)
- Telecommunications (12)
- Public Transit (12)

Likelihood of Occurrence – Storms and Wind – Power Outages

Likelihood that the Hazard Will Occur – Storms and Wind – Power Outages

As detailed in the Resilient Fairfax Climate Projections Report, storm and wind events are projected to increase in intensity and frequency in Fairfax County. Fairfax County typically experiences a range of storm events each year, including thunderstorms, tropical cyclones, high wind events, and mid-latitude frontal storms. For more information on the projected frequency of such events, please see the section above, "Storms and Winds Causing Debris, Damage and Safety Risks."

Such events have historically led to power outages across the county due to downed power lines. Examples of past severe storm events in Fairfax County with power outage impacts include:

- In 2015, a severe thunderstorm knocked down Dominion Energy poles and wires, which affected about 8,000 customers.[465]
- On May 14, 2018, a line of severe thunderstorms tracked over 400 miles, producing high winds and wind damage from Ohio through Virginia.[466] Within Fairfax County, there were reported downed trees, siding, and roofing shingles in the streets. Tens of thousands of power outages occurred within both Fairfax County and Loudon County.[467]

- In April 2021, two cold fronts brought wind gusts of 40 to 60 mph, which knocked down power lines around Fairfax County, leaving 44,000 Dominion Energy customers without power, including more than 25,000 in Fairfax County.[468]

Likelihood that the Sub-Sectors Will be Affected – Storms and Wind – Power Outages

For this analysis, storm events causing power outages are considered equally plausible across the entire county and could occur in any given year, leading to a high likelihood score of sector/subsectors being affected. Given the difficulty of predicting the probability and intensity of a future storm event in a specific location, there is no particular location within Fairfax County that will be more susceptible to these storms, and as a result susceptibility is uniform across the county. Storm events and high winds are typically not geographically isolated events and are likely to occur county-wide; it is not possible to identify certain areas that are more prone to these events than others. This approach is consistent with the Northern Virginia Hazard Mitigation Plan 2017, which found that the widespread nature of this hazard means that the likelihood of occurrence is uniform across all Northern Virginia jurisdictions.

While certain communities may be more susceptible to power outages than others, further evaluation and collection of information of power-outage prone neighborhoods is required to support more granular planning. A detailed study of existing infrastructure conditions and locations would be required to determine site-specific risks. (*For exposure levels of specific sub-sectors to this hazard, please see the Vulnerability Assessment).*

Severity of Consequences – Storms and Wind – Power Outages

For each sub-sector that was deemed in the Vulnerability Assessment to have moderately high or high vulnerability to this hazard, severity of consequence was assessed. Consequences consider impacts beyond the loss of the asset, including impacts to the economy, environment, and community.

The highest scoring consequence category for each subsector was used as the top score to determine the severity of consequences.

Table 36: Severity of Consequences – Storms and Wind – Power Outages

Sector/Subsectors	Severity of Consequence – Storms and Wind – Power Outages				
	Economic Impact & Service Loss	Cost to Repair	Public Health & Safety	Environmental Impact	Top Score
Emergency Response and Management Services	Moderate	N/A	High	N/A	High
Electrical Infrastructure	High	High	Moderate	Low	High
Buildings	Moderate	Moderate	Moderate	N/A	Moderate
Drinking Water	Moderate	UK	High	N/A	High
Health and Community Services	Moderate	N/A	High	N/A	High
Vulnerable Populations	Moderate	Moderate	High	N/A	High
General Populations	Moderate	Moderate	High	N/A	High
Telecommunications	Moderate	N/A	Moderate	N/A	Moderate
Public Transit	Moderate	UK	Moderate	N/A	Moderate

Emergency Services – Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Severe storms may result in loss of power at emergency facilities such as fire stations or evacuation centers. Facilities would not be able to operate as designed during power outage.
- **Costs to Repair [N/A]:** Not applicable or insufficient information.
- **Public Health and Safety [High]:** Loss of power to emergency facilities can reduce capacities of emergency responders, impacting public health and safety. Loss of power can also translate to loss of water availability for fire response.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Electrical Infrastructure – Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [High]:** Severe storms can cause older or less sturdy electricity infrastructure to fall or collapse, resulting in power outages. Power outages have significant economic impacts and loss of service throughout many sectors. Electricity utilities may preemptively shut off power to certain areas to mitigate risk of damages or fires from downed lines.
- **Costs to Repair [High]:** Severe storms can cause older or less sturdy electricity infrastructure to fall or collapse. Trees or other large structures/objects can collapse on to and damage nearby electricity infrastructure assets. There could be increased costs to utilities to maintain and/or rebuild electricity infrastructure assets damaged during storm events.
- **Public Health and Safety [Moderate]:** Downed power lines present a safety risk as lines may still have live current.
- **Environmental Impact [Low]:** Downed power lines can ignite forest fires under certain conditions.

(For detailed sensitivities, please see the Vulnerability Assessment).

Buildings – Severity of Consequence – Storms and Wind – Power Outages [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Power outages to buildings used for industrial, mixed-use, and commercial purposes may affect businesses and associated services.
- **Costs to Repair [Moderate]:** Downed distribution lines in neighborhoods could cause damage to buildings and potentially residential fires.
- **Public Health and Safety [Moderate]:** Loss of power to residential and commercial buildings could affect residents' ability to purchase food and supplies during and after the event. Loss of power during extreme heat or extreme cold can create public health dangers.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Drinking Water– Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Fairfax County drinking water infrastructure is dependent on power to function. Power outages from severe storms could result in service loss of drinking water.
- **Costs to Repair:** The costs associated with repair of drinking water facilities due to power outages specifically is unknown.
- **Public Health and Safety [High]:** Power outages from severe storms could result in service loss of drinking water, which would have significant public health impacts.
- **Environmental Impact [N/A]:** Not applicable or insufficient information.

(For detailed sensitivities, please see the Vulnerability Assessment).

Health and Community Services– Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Power outages may impact the operations of essential services like food distribution centers,[469] child daycare, adult care facilities, or mental health facilities. It is assumed essential services would be prioritized in repairing power outages within three days of event, making the impacts "moderate" rather than "high."
- **Costs to Repair [N/A]:** Not applicable.
- **Public Health and Safety [High]:** Power outages may result in loss of air conditioning of facilities supporting public health and human service. System failure is particularly dangerous in hospitals and urgent care centers[470] where medical services may be disrupted or compromised by heat-induced power outages or other events. Power outages may also limit access to services for domestic violence and sexual assault services, health clinics, and housing assistance services, among others. Within Fairfax County, there are existing power outage issues in health and community services buildings, including the Public Health Lab, New Hope Housing Mondloch House, Patrick Henry Family Shelter, and Health Department Clinic and Vaccine Services.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Vulnerable Populations– Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Loss of power in places of employment can hinder services and productivity. Hourly wage workers may lose income if there are closures during power outages. Power outages without backup power can result in loss of goods requiring refrigeration.
- **Costs to Repair [Moderate]:** Power outages without backup power can result in loss of goods requiring refrigeration, such as food or medication. Low-income populations may have less financial ability to replace such items.
- **Public Health and Safety [High]:** Vulnerable populations may not have backup power generators, resulting in longer spans of time without power during blackouts. This can result in increased risk for hypothermia or heat stroke during cold and warm periods, respectively, when

there are power outages. Populations may not have access to emergency information if communication lines are disrupted.

- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

General Populations– Severity of Consequence – Storms and Wind – Power Outages [Top Score: High]

- **Economic Impact and Service Loss [Moderate]:** Loss of power due to severe storms cause closures of places of employment and service, hinder services and productivity. Power outages without backup power can result in loss of goods requiring refrigeration
- **Costs to Repair [Moderate]:** Power outages without backup power can result in loss of goods requiring refrigeration, such as food or medication.
- **Public Health and Safety [High]:** Populations may not have backup power generators, resulting in longer spans of time without power during blackouts. This can result in increased risk for hypothermia or heat stroke during cold and warm periods, respectively, when there are power outages. Residents may not have access to emergency information if communication lines are disrupted.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Telecommunications– Severity of Consequence – Storms and Wind – Power Outages [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Power outages can cause loss of telecommunications service, which can have notable economic impacts.
- **Costs to Repair [N/A]:** Not applicable or insufficient information.
- **Public Health and Safety [Moderate]:** Disruption to telephone lines can cause serious threat to human safety by delaying or preventing emergency communication.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Public Transit– Severity of Consequence – Storms and Wind – Power Outages [Top Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Transit systems rely on the local energy grid. Power outages could lead to loss of service of public transit systems, such as Metrorail and Metrorail stations. Power outages could also result is loss of revenue due to loss of service.
- **Costs to Repair [N/A]:** Not known.
- **Public Health and Safety [Moderate]:** During power outages, there are occupational hazards to staff and riders. Additionally, power outages could magnify health related issues for passengers and staff if power outage occurs during extreme heat and/or cold events.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Total Risk - Storms and Wind – Power Outages

The qualitative risk scores for each of the sub-sectors evaluated for this vulnerability (storms and wind causing power outage impacts) are summarized in the table below. Emergency services, electrical infrastructure, drinking water infrastructure, health and community services, vulnerable populations, and general populations all scored as high risk. Buildings, telecommunications, and public transit scored as moderate/high risk.

Table 37: Total Risk – Storms and Wind – Power Outages

Sector/Subsector	Qualitative Risk Score
Emergency Response and Management Services	**High**
Electrical Infrastructure	**High**
Buildings	**Moderate/High**
Drinking Water Infrastructure	**High**
Health and Community Services	**High**
Vulnerable Populations	**High**
General Populations	**High**
Telecommunications	**Moderate/High**
Public Transit	**Moderate/High**

V. EXTREME HEAT CAUSING HEALTH-RELATED IMPACTS

High Risk Sub-sectors for this category

- General Population
- Vulnerable Populations
- Emergency Response and Management Services
- Public Transit
- Health and Community Services

FEMA and the CDC define extreme heat as "a period of high heat and humidity with temperatures above 90°F for at least two to three days."[471] In the Vulnerability Assessment, extreme heat was found to cause top vulnerabilities across numerous sub-sectors, particularly for heat-related health impacts. Numerous sub-sectors are affected by this vulnerability because the sub-sectors involve outdoor activity and exposure to extreme heat conditions. For example, emergency responders, bicyclists, pedestrians, outdoor workers, public transit riders, and those visiting parks and recreation can all be highly exposed to extreme heat conditions when they occur. Certain populations are more vulnerable to these extreme heat conditions, based on age, socioeconomic status, and/or pre-existing health conditions.

This section qualitatively describes the risk (likelihood and severity) of extreme heat on these vulnerable sub-sectors.

For detailed analysis of exposure, sensitivity, and adaptive capacity to extreme heat for all sectors, please see the Vulnerability Assessment.

Subsectors Evaluated – Extreme Heat Causing Health-Related Impacts

In the Vulnerability Assessment, the following subsectors showed moderately high or high vulnerability to extreme heat, specifically for heat-related health impacts:

- Vulnerable Populations (27)
- Emergency Services (18)
- Public Transit (18)
- General Population (12)
- Health and Community Services (12)
- Bicyclists and Pedestrians (12)
- Parks and Recreation (12)
- Bicycle and Pedestrian
- Waste Management (12)

Likelihood of Occurrence – Extreme Heat Causing Health-Related Impacts

Likelihood that the Hazard Will Occur – Extreme Heat

Extreme heat is highly likely to occur and increase in Fairfax County. As detailed in the Resilient Fairfax Climate Projections Report, Fairfax County already experiences extreme heat during the summer months. On average, Fairfax County experiences almost one month of days at or above 90°F each year with average summer humidity between 70% to 90%.[472] By 2050, the number of days above 90°F is projected to double, with an additional 30 additional days or more per year of extreme heat. An increase in the prevalence of hot days in Fairfax County can have serious health implications for the general population. Days above 95°F and 105°F are also projected to become more common in the summer. In addition, there will be longer heat waves (consecutive days of extreme heat) as opposed to intermittent hot days. This, along with less relief available as summertime nights continue to warm, is particularly concerning as the human body will not have nighttime temperature breaks to cool down. Prolonged heat waves, along with warming nights, can have detrimental impacts on human health and lead to serious health concerns as well as reduced quality of life.

In addition to general warming, the Urban Heat Island effect (UHI) can magnify the temperatures experienced during extreme heat events. Urban areas of the county with substantial built environment and impervious surfaces absorb and retain heat at higher rights than areas with ample green space.

Likelihood that the Subsectors will be Affected – Extreme Heat Causing Health Impacts

It is highly likely that each of the subsectors evaluated will be affected by extreme heat conditions. Extreme heat affects all exposed subsectors of the county. The projected increases in extreme heat will also affect all subsectors of the county. The UHI effect further exacerbates extreme heat conditions for assets located within UHIs. As demonstrated in the Vulnerability Assessment, each of the subsectors evaluated in this Risk Assessment section are highly exposed to extreme heat effects and the UHI effect. "High UHI" was defined as locations within the county with average summer land surface temperatures that are at least 9°F higher than reference locations.

Because general countywide extreme heat applies to all sub-sectors, variation in impact for extreme heat can only be estimated using the UHI. Therefore, the likelihood scores for whether subsectors will be affected align with the "exposure" calculations from the Vulnerability Assessment, as follows:

- **High Likelihood**: In addition to general countywide extreme heat, at least 10% of the subsector is exposed to high UHI.
- **Moderate Likelihood:** In addition to general countywide extreme heat, 1-10% of the subsector is exposed to high UHI.
- **Low Likelihood**: In addition to general countywide extreme heat, less than 1% of the subsector is exposed to high UHI.

These scores were then applied in the following table.

(*For detailed information on exposure, sensitivity, and adaptive capacity for each subsector, please see the Vulnerability Assessment).*

Table 38: Likelihood of Occurrence – Extreme Heat Causing Health-Related Impacts

Sector/Subsector	Description	Likelihood of Occurrence
Vulnerable Population	An estimated 303,366 people (**91%** of the county's population classified as "vulnerable" by One Fairfax) are exposed to High UHI, as calculated by household.	High
Emergency Services	19 police stations (**100%**), 43 fire stations (**100%**) and 4 emergency management facilities (**100%**) are exposed to High UHI.	High
Public Transit Users	10 Metrorail Stations (**100%**), 1,282 Metrobus stops (**85%**), 2,679 Fairfax Connector bus stops (**87%**), and 5 VRE Stations (**100%**) are exposed to High UHI.	High
General Population	An estimated 855,904 people (**73%** of the county population) are exposed to High UHI, as calculated by household.	High
Health and Community Services	50 community centers (**98%**), 46 hospitals and urgent cares (**100%**), 23 libraries (**100%**), and 93 Health and Human Service Facilities (**98%**) are exposed to High UHI. Additionally health and community service workers conducting outdoor work duties such as inspections or services to people experiencing homelessness are highly exposed to extreme heat conditions.	High

Sector/Subsector	Description	Likelihood of Occurrence
Bicyclists and Pedestrians	1,115 miles of bicycle routes, (**71%**), 487 miles of bicycle trails (**51%**), 3,412 miles of walkways (**83%**), and 52 Capital Bike Share locations (**96%**) are highly exposed to UHI.	High
Parks and Recreation	79.1 miles of county trails (**23%**), 132.4 miles of non-county trails (**44%**), 5.15 square miles of county parks (**14%**), and 2.86 square miles of non-county parks (**9%**) are exposed to High UHI.	High
Waste Management Workers	1.34 square miles of landfill area (**76%**) are exposed to High UHI. Additionally, waste management workers are highly likely to be exposed to extreme heat on waste collection routes.	High

Severity of Consequences – Extreme Heat Creating Health-Related Impacts

Potential direct and indirect consequences were assessed for each vulnerable subsector. Consequences consider impacts to the economy, environment, and community. For each subsector, each consequence category was ranked low, moderate, or high for four categories:

- Economic Impact and Service Loss
- Costs to Repair
- Public Health and Safety
- Environmental Impact

The highest scoring consequence category for each subsector was used as the top score to determine the severity of consequence of inland flooding. The table below summarizes these qualitative scores. Vulnerable populations, emergency services, public transit, general population, and health and community services all had at least one consequence category that scored high. Bicyclists and pedestrians, parks and recreation, and waste management all scored moderate.

Table 39: Severity of consequence – Extreme Heat Creating Health-Related Impacts

Sector/Subsectors	Severity of Consequence				
	Economic Impact & Service Loss	Cost to Repair	Public Health & Safety	Environmental Impact	Top Score
Vulnerable Population	Moderate	N/A	High	N/A	High
Emergency Services	High	N/A	High	N/A	High
Public Transit	High	High	High	N/A	High
General Population	Moderate	N/A	High	N/A	High
Health and Community Services	High	N/A	High	N/A	High
Bicycle and Pedestrian	N/A	Low	Moderate	N/A	Moderate
Parks and Recreation	Moderate	Low	Moderate	N/A	Moderate
Waste Management	N/A Unknown	N/A	Moderate	N/A	Moderate

Vulnerable Population– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: High]

- **Economic Impact and Service Loss [Moderate]:** Extreme heat may result in increased need for indoor cooling and an increase in energy costs for residents and businesses.
- **Costs to Repair [N/A]**: Not applicable.
- **Public Health and Safety [High]:** Vulnerable populations who live in sub-standard housing without adequate cooling or homeless populations subjected to the heat can be at higher risk of heat-related illness. Heat exposure and inaccessibility of air conditioning is a concern for at-risk populations unable to effectively regulate body temperature, such as young children, pregnant women, and older adults. Existing health conditions (such as kidney disease, pulmonary disease, or cardiovascular disease) can be exacerbated in extreme heat.
- **Environmental Impact [N/A]**: Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Emergency Services– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: High]

- **Economic Impact and Service Loss [High]:** Equipment such as radio and IT rooms at can overheat during an extreme heat event, causing malfunctions and delays in emergency response. If the heat event lasts for more than three days, the intermittent loss of services would be considered a high impact.
- **Costs to Repair [N/A]:** Not applicable.
- **Public Health and Safety [High]**: Extreme heat may cause an increase in medical emergencies and an increased demand for medical services. When power is lost, the facility and staff are exposed to extreme heat without relief. The use of PPE can increase heat-related health impacts on responders. Additionally, an increase in heat can lead to an increase in aggressive behavior, causing a greater need for emergency response services.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Public Transit– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: High]

- **Economic Impact and Service Loss [High]**: Decreased reliability of rail during heat events impacts the use of public transit. Increased discomfort of users during heat events may results in lower ridership.
- **Costs to Repair: [N/A]**: Extreme heat can cause physical damage to rail infrastructure. However, this section is focused on heat-related *health* impacts specifically.
- **Public Health and Safety [High]**: Fairfax individuals that rely on public transit may experience increased discomfort, and even life-threatening heat, at transportation stations and unsheltered stops and be impacted by decreased reliability and safety of transportation vehicles.
- **Environmental Impact [N/A]**: Not applicable.

General Population – Severity of Consequence – Extreme Heat Health Impacts: [Total Score: High]

- **Economic Impact and Service Loss [Moderate]:** Extreme heat-related health impacts may result in healthcare costs. Extreme heat may also result in increased need for indoor cooling and an increase in energy costs for residents and businesses.
- **Costs to Repair [N/A]:** Not applicable.
- **Public Health and Safety [High]:** There may be an increase in medical emergencies due to heat-related illness including heat stress and dehydration. Interactions between heat and pollutants, like car exhaust and power plant emissions, can increase unhealthy outdoor air quality days. Poor air quality can result in negative health impacts. FEMA's National Risk Analysis suggests a total of 1,081,725 people are exposed to heat waves leading to a $8.2T population equivalence, while the expected annual loss is $716,867 population equivalence. [473]
- **Environmental Impact [N/A]**: Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Health and Community Services– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: High]

- **Economic Impact and Service Loss [High]:** Extreme heat-related health impacts can increase the need for health and community services, increasing costs. Heat-related power outages can impact health and community service availability. Cooling centers in Fairfax County, including community centers and libraries, that are made available during heat advisory events, may experience an influx of users that could exceed capacity.
- **Costs to Repair [N/A]:** Not applicable.
- **Public Health and Safety [High]:** Heat-induced power outages may cause system failure in critical buildings, like hospitals and urgent care centers. An influx of heat-related illnesses in hospitals and urgent care facilities can limit availability of healthcare for other needs.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Bicycle and Pedestrian– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: Moderate]

- **Economic Impact and Service Loss [N/A]:** Not applicable.
- **Costs to Repair [N/A]:** Extreme heat may cause concrete sidewalks, crosswalks, or other active transportation infrastructure to experience faster wear and tear, such as buckling, requiring more frequent maintenance. However, this section is focused on *health-related* heat impacts.
- **Public Health and Safety [Moderate]:** Extreme heat causes air quality to worsen, impacting bicyclists and pedestrians. Health risks for bicyclists and pedestrians from extreme heat related health conditions, particularly lower income people who are more vulnerable to the outdoors.
- **Environmental Impact [N/A]**: Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Parks and Recreation– Severity of Consequence – Extreme Heat Health Impacts: [Total Score: Moderate]

- **Economic Impact and Service Loss [Moderate]:** Extreme heat, particularly when accompanied by poor air quality, can necessitate outdoor park closures and restrictions to protect public health. Even without closures, extreme heat may reduce visitation and use of outdoor areas and recreation facilities. Revenue may be impacted during hottest months of the year, which can overlap with the busiest season for outdoor activities and use of parks and recreation facilities. Decreases in revenue could result in future funding limitations.
- **Costs to Repair [N/A]:** Extreme heat degrades trail pavement and could increase maintenance implications and associated costs. Negative ecological effects on natural resources present in parks can increase the need for field maintenance. However, this section is focused on *health-related* heat risks.
- **Public Health and Safety [Moderate]**: Extreme heat can increase risk of heat-related illnesses for those engaged in outdoor activities and recreation.
- **Environmental Impact [N/A]:** Extreme heat can cause ecological impacts. However, this section is focused on *health-related* heat risks.

(For detailed sensitivities, please see the Vulnerability Assessment).

Waste Management: [Total Score: Moderate]

- **Economic Impact and Service Loss [N/A]:** Not known.
- **Costs to Repair [N/A]:** Not applicable.
- **Public Health and Safety [Moderate]:** Extreme heat can place waste management workers at risk of heat-related illness.
- **Environmental Impact [N/A]:** Not applicable.

(For detailed sensitivities, please see the Vulnerability Assessment).

Total Risk – Extreme Heat Causing Health-Related Impacts

The qualitative risk scores for each of the sub-sectors evaluated for this vulnerability (extreme heat causing health-related impacts) are summarized in the table below.

Table 40: Total Risk – Extreme Heat Causing Health-Related Impacts

Subsector	Likelihood	Severity of Consequence	Qualitative Risk Score
Vulnerable Population	High	High	High
Emergency Services	High	High	High
Public Transit	High	High	High
General Population	High	High	High
Health and Community Services	High	High	High
Bicycle and Pedestrian	High	Moderate	Moderate/High
Parks and Recreation	High	Moderate	Moderate/High
Waste Management	High	Moderate	Moderate/High

The greatest health-related risks to the county during extreme heat events include:

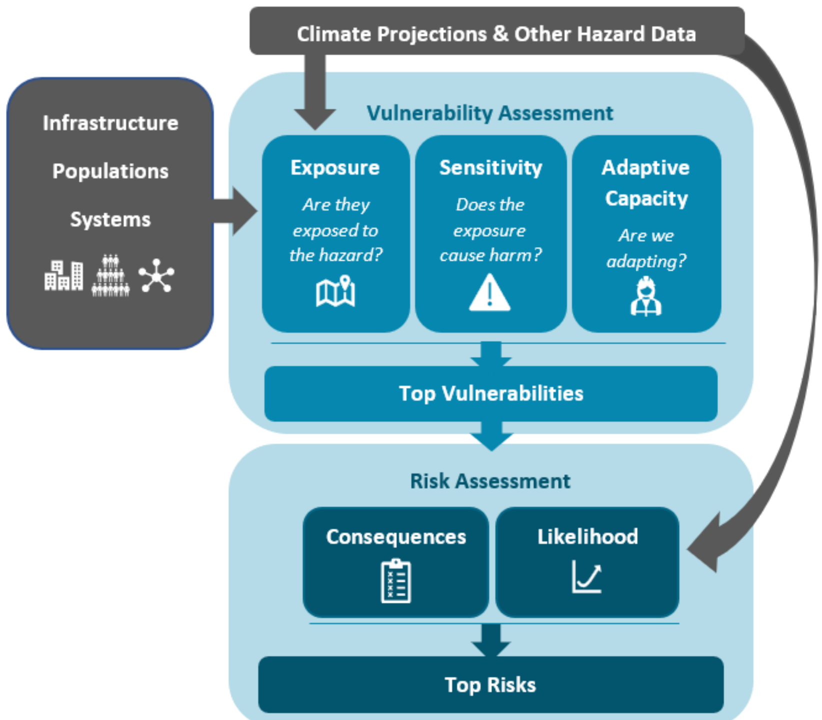
- Increased medical emergencies, particularly for vulnerable populations with existing health conditions and/or without access to air conditioning
- Poor air quality
- Increased demand for emergency planning such as cooling centers
- Unsafe working conditions
- Heat-induced power outages that may affect critical buildings such as hospitals and urgent care centers
- Reduced access to air conditioning;
- Transit customers, bicyclists, pedestrians, and parks and recreation visitors may experience heat-related illness at unsheltered spots.

(For detailed information on heat exposure, sensitivity, and adaptive capacity, please see the Vulnerability Assessment).

APPENDIX 1- DETAILED METHODOLOGY

Overview

The Resilient Fairfax Vulnerability and Risk Assessment involved two major components: the **Vulnerability Assessment** and the **Risk Assessment.** Figure 1 provides an overview of the Vulnerability and Risk Assessment process.



The **Vulnerability Assessment** helped the county identify which Fairfax County infrastructure, systems, and populations are *most exposed, most sensitive, and least adaptive* to the projected climate hazards. The infrastructure, populations, and systems were categorized into seven sectors and 21 subsectors. The Vulnerability Assessment included a scoring system to help the county qualitatively identify top climate-related vulnerabilities. The scoring approach used in this Vulnerability Assessment was adapted from the methodology developed by the Association of Climate Change Officers (ACCO).

Vulnerability = Exposure x Sensitivity x Adaptive Capacity

The **Risk Assessment** qualitatively evaluated the top vulnerabilities to determine which of these top vulnerabilities is *most likely to impact* and *most severe in consequence.*

Risk = Likelihood x Severity of Consequence

The findings of the Vulnerability and Risk Assessments were used to inform the county's development of climate adaptation and resilience strategies. The Vulnerability and Risk Assessment methodologies are described in greater detail below.

Sectors, Subsectors, and Assets

For the purposes of this analysis, "assets" refer to buildings, infrastructure, populations, public services, and natural features that may be vulnerable to climate hazards. Assets provide critical functions, services, or have inherent value. These assets are organized into categories, called "sectors." These categories are broken down into "sub-sectors." The following sectors and sub-sectors were included in this analysis:

1. **Populations**
   - 1.1 General Population
   - 1.2 Vulnerable Populations
2. **Public Services**
   - 2.1 Health and Community Services
   - 2.2 Emergency Response and Management Services
   - 2.3 Parks and Recreational Services
   - 3.4 Waste Management Services
3. **Buildings**
   - 3.1 (One sub-sector) Residential, Commercial, Industrial, Mixed-Use, Public Buildings, Parking Garages, and Other Buildings
4. **Water Infrastructure**
   - 4.1 Drinking Water Infrastructure
   - 4.2 Stormwater Infrastructure
   - 4.3 Wastewater Infrastructure
5. **Energy and Communication Infrastructure**
   - 5.1 Electricity Infrastructure
   - 5.2 Natural Gas Infrastructure
   - 5.3 Telecommunications Infrastructure
6. **Transportation Infrastructure**
   - 6.1 Roadways and Bridges
   - 6.2 Rail and Public Transit
   - 6.3 Bicycle and Pedestrian Infrastructure
7. **Natural and Cultural Resources**
   - 7.1 Water Features
   - 7.2 Wetlands and Environmentally Sensitive Aras
   - 7.3 Trees and Forested Areas
   - 7.4 Agricultural Areas and Farms
   - 7.5 Cultural and Historic Resources

Fairfax County Geographic Information Systems (GIS) data was available for the majority of the sectors and sub-sectors used in this analysis. Fairfax County's equity assessment data, the "One Fairfax Vulnerability Index" was used as a base layer in the identification of potentially vulnerable populations. The use of this vetted equity layer ensures consistent messaging and socioeconomic analyses across county plans, programs, and activities. The specific datasets with GIS data available to use for this analysis are shown in Table A-1 below. This GIS data was supplemented with robust stakeholder input from the Planning Team (20 county departments), the Infrastructure Advisory Group (utilities and infrastructure managers from all levels of government), the Community Advisory Group, and the public.

Table A-1: Asset Data Used for Exposure Analyses

Sector	Sub-Sector	Asset Data Used for Exposure Analyses
Populations	**General Population**	• **Population by Census Tract**: 2019 Census Data • **Population by Household** : Fairfax County GIS – « Households » layer (for number of Households) combined with « Buildings » layer (for polygon locations). An assumption of 2.8 persons per household on average was used. Note : the « Forecast Households » layer was not used because it was found to be unrealistic in terms of building locations.
Populations	**Vulnerable Populations**	• **Vulnerable Population by Census Tract** : 2019 Census Data combined with One Fairfax Vulnerability Index. Vulnerable populations were defined as populations within Census Tracts where the One Fairfax vulnerability indicator is greater than or equal to a score of 3.14. • **Vulnerable Population by Household** : Fairfax County GIS – « Households » layer (for number of Households), combined with « Buildings » layer (for polygon locations), selected within Vulnerable Census Tracts as identified by One Fairfax.
Public Services	**Health and Community Services**	• **Community Centers :** Fairfax County GIS « Community Centers » points layer combined with « Buildings » layer for polygons. • **Hospitals and Urgent Care :** Fairfax County GIS «Hospitals and Urgent Care Facilities» points layer, combined with « Buildings » layer for polygons. • **Libraries :** Fairfax County GIS « Libraries » points layer, combined with « Buildings » layer for polygons. • **Health and Human Services Facilities :** HHS spreadsheet of facilities, mapped as points by address, and converted to polygons through combination with the « Buildings » layer.
Public Services	**Emergency Operations**	• **Police Stations :** Fairfax County GIS « Police Stations » points layer, clipped to County borders, and combined with « Buildings » layer for polygons. • **Fire Stations :** Fairfax County GIS « Fire Stations » points layer, clipped to County borders and combined with "Buildings » layer for polygons. • **Emergency Management Facilities :** Buildings selected from Fairfax County GIS « Buildings » layer known to house emergency management and planning services.

Sector	Sub-Sector	Asset Data Used for Exposure Analyses
Public Services	**Parks and Recreation**	• **County Trails** : Fairfax County « County Trails » layer, clipped to County borders • **Non-County Trails** : Fairfax County « Non-County Trails » layer, clipped to County borders • **County Parks** : Fairfax County « County Parks » layer, clipped to County borders. • **Non-County Parks** : Fairfax County « Non-County Parks » layer, clipped to County borders. (For recreational centers, please see « Community Centers » under « Health and Community Services. »)
Public Services	**Waste Management**	• **Landfills** : Fairfax County GIS « Landfills » layer
Buildings	**Buildings**	• **Buildings** : Fairfax County GIS « Buildings » layer, clipped to County borders and categorized by type.
Water Infrastructure	**Drinking Water Infrastructure**	• **Griffith Water Treatment Plant** : Selection of buildings from the Fairfax County « Buildings » layer that compose the treatment plant. • **James J Corbalis Jr Water Treatment Plant** : Selection of buildings from the Fairfax County « Buildings » layer that compose the treatment plant. • **Fairfax Water Headquarters** : Selection of Fairfax Water Headquarters building from the Fairfax County « Buildings » layer. • **Fairfax Water Other Buildings**: Selection of buildings from the Fairfax County "Buildings" layer that are located on parcels identified as being owned by Fairfax County Water Authority. • **Drinking Water Lines**: Drinking water lines GIS layer (internal).

Sector	Sub-Sector	Asset Data Used for Exposure Analyses
Water Infrastructure	**Storm Water Infrastructure**	• **Stormwater Management Facilities :** Selection of relevant polygons from the Internal Fairfax County GIS « Stormwater Management Facilities » layer. Farm ponds were removed. Facilities include Amended Soil, Bioretention, Constructed Wetland, Dry Pond, Flood Control Structures FC-NONPL and FC-PL566, Floating Wetland, Forebay, Government Facility, Green Roof, Manufactured BMP, Open Space, Parking Lot, Pervious Pavement, Reforestation, Roof Top, Sand Filter, Tree Box Filter, Trench, Underground, Vegetative Filter, Vegetative Swale, Wet Pond, and Other Types. • **Stormwater Pipes and Conveyance :** Selection of relevant lines from the internal Fairfax County GIS « Stormwater Arcs » layer. These lines include Bioretention, Culvert, Dry Pond, Grass Swale, Improved Channel, Natural Channel, No Draw, Other SWM/BMP, Other Type, Paved Ditch, Perforated Pipe, Pipe, RipRap, Roadside Ditch, Sand Filter, Slotted Drain, Trench, Trickle Ditch, Underdrain, Underground, Unknown, and Wet Pond line features • **Stormwater Nodes :** Selection of relevant points from the internal Fairfax County GIS « Stormwater Nodes » layer. Farm ponds were removed. These points include curb inlets, yard inlets, unlets, bilco doors, bioretention features, control structures, dry ponds, grate inlets, junction boxes, MS4 outfalls, MS4 piped discharge, manholes, manufactured BMPs, Other SWM/BMP, unlets, rooftops, sand filters, special structures, tree box filters, trenches, and other features. • **Service Requests :** Selection of relevant points from the Internal Fairfax County GIS « Service Requests » layer.
Water Infrastructure	**Wastewater Infrastructure**	• **Noman Cole Wastewater Treatment Plant :** Selection of buildings from the Fairfax County « Buildings » layer that compose the treatment plant. • **Upper Occoquan Sewage Treatment Plant :** Selection of buildings from the Fairfax County « Buildings » layer that compose the treatment plant. • **Sewer Structures :** Points from the internal Fairfax County « Sewer structures » layer. • **Sewer Lines** : Lines from the internal Fairfax County « Sewer Lines » layer. • **Wastewater Pump Stations** : Points from the internal Fairfax County « Wastewater Pump Stations » layer. • **Wastewater Encasements** : Lines from the internal Fairfax County « Wastewater Encasements » layer.
Energy And Communications Infrastructure	**Electricity Infrastructure**	• **Major Electricity Transmission Lines** : Lines selected from the Fairfax County GIS « Major Utility Lines » layer • **Electric Utility Owned Assets** : Structures selected from the Fairfax County GIS « Buildings » layer that were located on parcels identified as being owned by Dominion Energy, NOVEC, Virginia Power, or other electricity utilties.

Sector	Sub-Sector	Asset Data Used for Exposure Analyses
Energy And Communications Infrastructure	**Natural Gas Infrastructure**	• **Major Natural Gas Transmission Lines** : Lines selected from the Fairfax County GIS « Major Utility Lines » layer • **Natural Gas Owned Assets** : Structures selected from the Fairfax County GIS « Buildings » layer that were located on parcels identified as being owned by Washington Gas, Columbia Gas, or other natural gas utilties.
Energy And Communications Infrastructure	**Communications Infrastructure**	• **Major Telephone Lines** : Lines selected from the Fairfax County GIS « Major Utility Lines » layer • **Communications Utility Owned Assets** : Structures selected from the Fairfax County GIS « Buildings » layer that were located on parcels identified as being owned by Verizon, Comcast, Cox, or other communications utilities. • **Communications Towers** : Polygons from the internal Fairfax County GIS "Communications Towers" layer.
Transportation Infrastructure	**Roadway Transportation**	• **Roadways** : Lines from the Fairfax County GIS « Roadway Centerlines » layer. • **Bridge segments** : Bridge polygons selected from the Fairfax County GIS « Roadways and Bridges » layer. • **Electrical Vehicle Charging Stations** : Points from MWCOG's electrical vehicle charging stations layer, clipped to county borders.
Transportation Infrastructure	**Transit and Rail Infrastructure**	• **Metrorail :** Lines from Fairfax County GIS « Metrorail » layer, clipped to county borders. • **Metrorail Stations** : Points from Fairfax County GIS « Metrorail Stations » layer, clipped to county borders, then converted to polygons by combining with the « Buildings » layer. • **Metro Bus Lines** : Lines from Open Data DC's "Metro Bus Lines" layer, clipped to county borders. • **Metro Bus Stops** : Points from Open Data DC's "Metro Bus stops" layer, clipped to county borders. • **Fairfax Connector Bus Stops** : Points obtained from Fairfax County DOT. • **Private Railroads** : Private lines selected from Fairfax County GIS "Railroads" layer, clipped to county borders, and with abandoned lines removed. • **Virginia Railway Express Stations** : Points from Open Data DC's "VRE stations" layer, clipped to county borders.
Transportation Infrastructure	**Bicycle And Pedestrian Infrastructure**	• **Bicycle Routes** : Lines from Fairfax County GIS « Bicycle Routes » layer, clipped to county borders. • **Bicycle Trails** : Lines from Fairfax County GIS « Bicycle Trails » layer, clipped to county borders. • **Walkways :** Lines from internal Fairfax County GIS « Walkways » layer, clipped to county borders • **Capital Bike Share** : Points from Open Data DC's Capital Bike Share layer, clipped to county borders.

Sector	Sub-Sector	Asset Data Used for Exposure Analyses
Natural And Cultural Resources	**Water Bodies**	• **Water Bodies (lakes, ponds, rivers, streams, swamps)** : selected from Fairfax County's « Water Features – Polys » layer.
	Wetlands And Environmentally Sensitive Areas	• **Wetlands :** Polygons selected from the US Fish and Wildlife Service Wetlands layer, clipped to county borders. • **Environmentally Sensitive Areas :** Polygons from the Fairfax County GIS "Environmentally Sensitive Areas" layer. Note: The Wetlands Zoning layer was not used, because that layer was less comprehensive.
	Tree Canopy	• **Tree Cover:** Polygons from Fairfax County GIS « Tree Cover 2015 » layer.
	Agricultural Districts And Farms	• **Agricultural and Forestal Districts :** Polygons from the Fairfax County GIS « Agricultural and Forestal Districts » layer. • **Potential Agricultural Use Parcels** : Polygons selected from the Fairfax County GIS « Parcels » layer that meet Zoning Ordinance requirements for agricultural uses : zoned R-E, R-A, R-C, or R-1, and 7 acres or larger in size. Removed public land.
	Cultural And Historic Resources	• **Historic Sites :** Polygons from the Fairfax County GIS internal « Inventory of Historic Sites » layer. • **Historic Buildings :** Polygons selected from the Fairfax County GIS « Buildings » layer categorized as Public Buildings : Historic Site/Point of Interest. Note : the Historic Overlay District layer was not used, because the « Inventory of Historic Sites » layer was more comprehensive and site-specific.

Climate Hazards

Each of the above sectors and sub-sectors were assessed for exposure to the following climate hazards:

- **Extreme heat**
- **Heavy precipitation and inland flooding**
- **Severe storm and wind events**
- **Extreme cold**
- **Coastal flooding**
- **Drought**

The *Resilient Fairfax: Climate Projections Report* presents the methodology and findings of current and future projections of the following climate hazards. Under future climate projections for Fairfax County, all these hazards, except extreme cold and drought, are projected to intensify and/or become more frequent in the next few decades. Extreme cold events are projected to become less frequent as temperatures rise, while drought, defined as meteorological drought, is not projected to substantially increase from today's conditions. It should be noted that these projections apply to the Fairfax County specifically. Other regions will see notably different projections.

Vulnerability Assessment Methodology

The Vulnerability Assessment identified which sectors and subsectors were both exposed, sensitive, and less able to adapt to relevant climate hazards in Fairfax County. This assessment was qualitative in nature. It was intended to identify high-level vulnerabilities that may need further county attention and analysis.

Vulnerability = Exposure x Sensitivity x Adaptive Capacity

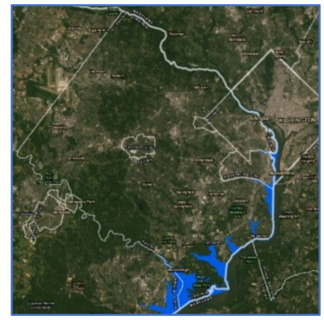
Exposure considers whether a sector/subsector may be exposed to a climate hazard. For example, a building that is located along the shoreline may be exposed to coastal flooding, whereas a building located far inland would not be exposed to coastal flooding. Exposure was determined in two ways, depending on the type of hazard. Some hazards, like severe wind/storms and drought occur county-wide, so the entire county's assets, systems, and populations are considered exposed, especially if they are above ground. Other hazards, like coastal flooding or urban heat island effect, have location-specific spatial overlays to determine projected future exposure for specific areas of the. Please note that some climate projections available in map format or modeling software cannot be comprehensively shown here in document format.

- County-wide vulnerabilities: Extreme storms, wind events, extreme cold, and drought were considered at the county scale, as opposed to specific locations within the county, because there is limited confidence in the spatial variability across the county for these hazards and/or the range in future values across the county is small. If the range in future values is small, focusing on small differences (such as an increase of 30 days versus 32 days of extreme heat during the summer) distracts from the reality that the entire county is projected to be exposed to the hazard at hand.
- Spatial overlay analysis: Inland flooding, coastal flooding, and the Urban Heat Island (UHI) effect are hazards where geospatial analysis provided important information for understanding geographic exposure and vulnerabilities. Geospatial data was used for flood hazards and the UHI effect to investigate whether there were geographically based exposures for specific sectors and sub-sectors across the county. Specifically:
  - For **inland flooding**, this analysis used the FEMA's floodplain layers developed in June 2021, the county's recorded floodplains, and a parcel-by-parcel analysis of properties for 10 flood-prone factors.

    - **FEMA 100-year floodplain layer**: FEMA's maps of the 1% annual chance of flooding in any given year, also referred to as the 100-year flood (see Figure 2); and
    - **FEMA 500-year floodplain layer**: FEMA's maps of the 0.2% annual chance of flooding in any given year, also referred to as the 500-year flood.
    - **County Recorded Floodplain**: county floodplain locations as shown on record plats studied during the development process.
    - **Flood Score**: A preliminary map of flood scores for each parcel based on 10 factors. This data is actively being developed and improved and may be subject to change. The 10 factors include: structures within 30 feet of a recorded floodplain, structures within 30 feet of a FEMA floodplain, structures in a 25-foot stream buffer, parcel in sump, structure in sump, subdivision age older than 1972 (likely to lack sufficient stormwater infrastructure), subdivision without storm facility, subdivision outside Facility Drainage

Area, infill lots, and parcel has submitted a stormwater service request. Based on these 10 factors, each parcel was given a score from 1-10. To categorize these parcels into groups, the exposure analysis considered parcels that scored >=2, >=4, and >=6.

- For **coastal flooding**, this analysis used NOAA and USACE GIS layers of sea level rise and coastal storm surge (see Figure 3):
  - **Today's tidal flooding**: NOAA's Sea level rise layer of 0 feet at mean high- high water (MHHW),
  - **2050 sea level rise (lower scenario)**: NOAA's Sea level rise layer of 1 foot to represent the lower scenario of inundation by 2050.
  - **2050 sea level rise (higher scenario)**: NOAA's Sea level rise layer of 3 feet to represent the higher scenario of inundation by 2050.



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  - **Coastal storm surge**: USACE Category 2 hurricane storm surge extent map developed for the 2015 North Atlantic Coat Comprehensive Study (NAACS). This layer has also been considered representative of the FEMA 100-year base flood elevation, with an additional 3 feet of sea level rise to represent 2050 conditions.
  - For coastal flooding, it should be noted that following this assessment, NOAA released updated 2022 sea level rise projections that show a slight change in the increase curve, where sea level rise starts at a slower rate and then accelerates. This means that while the ultimate sea level projections are similar, the near-term levels are now projected to be lower.
- For the **urban heat island (UHI) effect,** this study integrated work conducted through a partnership with Fairfax County Office of Environmental and Energy Coordination (OEEC) and NASA DEVELOP. These data provide high-resolution average land surface temperatures from 2013-2020 during the summer months. This Urban Heat Island effect data shows locations that are currently (and will continue to) experience higher land surface temperatures than the county average due to built environment features that absorb and retain heat. Specifically

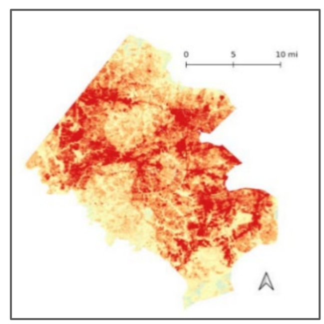


Figure 4: NASA Develop Urban Heat Island Map

  - **High UHI**: Locations where temperatures were estimated to be above 9° Fahrenheit (F) compared to the surrounding countryside. The increase of 9°F was chosen as this number indicates higher than average difference in land surface temperature due to UHI.
  - **Moderate UHI**: Locations where temperatures were estimated to be up to 9°F hotter compared to the surrounding countryside.
  - **Low UHI**: Locations that were not estimated to experience hotter temperatures compared to surrounding countryside

County-scale maps cover a large geographic area and can be challenging to effectively convey exposure. Therefore, this assessment provided tables (Appendix 3) that summarize the amount and percentage of subsector GIS data (for example, miles of county trail) exposed to the various hazard layers. In some cases, where exposure was significant and data were available, maps of hazard exposure were provided (Appendix 2).

Sensitivity measures how sensitive a sector/sub-sector is to the climate hazard. For example, some infrastructure may shut down when exposed to flooding, whereas other infrastructure continues to operate. Sensitivity was determined based on information gathered from county, regional, state, and federal departments and agencies, infrastructure managers, and prior published research and governmental publications on sensitivities such as the Fourth National Climate Assessment report. Similarly, some populations may be at greater risk to climate hazards than others (e.g., populations with pre-existing health conditions may be more sensitive to extreme heat than others). One Fairfax's Vulnerability Index was used to determine locations of potentially vulnerable populations. The Index aggregates the following socioeconomic, health-related, and other pre-existing sensitivities data: income, poverty, lack of high school diploma, age, disability, limited English proficiency, race, ethnicity, lack of vehicle access, severely burdened renters, multi-unit structures, overcrowded units, lack of health insurance, and pre-existing health conditions.

Adaptive capacity measures the capacity of infrastructure managers, populations, or the asset at hand to adapt to or enhance resilience to these hazards. Adaptive capacity was determined based on assessments of actions taken and planned by Fairfax County, asset owners, and other county stakeholders. It should be noted that adaptive capacity has a reverse score. A low score indicates higher (or better) adaptive capacity.

To qualitatively prioritize the most severe vulnerabilities, each sub-sector was given a vulnerability "score" as shown in Table 2. For each hazard and each subsector, exposure, sensitivity, and adaptive capacity were each scored on a scale of 1 to 3. The exposure, sensitivity, and adaptive capacity scores were then multiplied for a total vulnerability score: Vulnerability = Exposure x Sensitivity x Adaptive Capacity.

The best possible score suggesting no vulnerability is zero, which means no exposure, no sensitivity, and perfect adaptive capacity (0 x 0 x 0 = 0). The worst possible score suggesting extremely high vulnerability is 27 (that is, 3 x 3 x 3 = 27). These scores provide a relative indication of vulnerabilities across 21 subsectors and six climate hazards. These scores are qualitative, and as such, can introduce some level of subjectivity. The scores are intended to be used only to help the county qualitatively identify areas that may need additional county attention. It is arguably more important to consider the descriptions of the vulnerabilities presented in this document rather than the scores themselves. These descriptions may be revisited over time as institutional knowledge changes. To guide these scores, the following methodology was used. This methodology was adapted from ACCO methodology.

Table A- 1: Description of Scoring Methodology for the Vulnerability Assessment (adapted from ACCO)

	EXPOSURE	SENSITIVITY	ADAPTIVE CAPACITY
High (3)	Future projections are significant and the asset/system/population is completely exposed to this hazard. No protection exists.	This hazard would cause <u>complete failure</u> (shut down for more than 24 hours) of this system/ asset/ service or could cause mortalities in the county's population.	Zero of the four adaptive capacity statements below are true (indicating poor adaptive capacity): *1) There are no barriers that prohibit adaptation,* *2) the asset has existing ability to accommodate changes naturally,* *3) there are maintenance activities ongoing to offset any potential impacts and/or* *4) there are sufficient efforts underway to address threats of climate-related hazards.*

	EXPOSURE	SENSITIVITY	ADAPTIVE CAPACITY
Moderate (2)	Future projections are significant/moderate and the asset/ system/population is somewhat exposed to this hazard. There are protections, but not enough to avoid impacts.	This hazard would cause temporary operational failure of this system/ asset/ service or could cause harm to the county's population requiring emergency visits.	One to two of the adaptive capacity statements are true.
Low (1)	Future projections are insignificant or future projections are moderate/significant but the asset's exposure to this hazard is low/minor. It is mostly protected, but not fully.	This hazard would cause reduced operational capacity or could create or exacerbate existing health issues for the county's populations.	Three to four of the adaptive capacity statements are true.
None (0)	Future projections suggest improved hazard conditions or there is no asset exposure to this hazard.	This hazard would cause no impacts at all to this asset/ system/ infrastructure/ service	All four adaptive capacity statements are true, and actions are being taken "above and beyond" what is needed.

The results of the Vulnerability Assessment highlighted the subsectors that may be most vulnerable to a changing climate and provided a generalized understanding of current and future threats to the county. The assessment process also identified existing gaps in knowledge and data that the county may wish to address in the future.

Risk Assessment Methodology

The Risk Assessment provided further analyses of the top vulnerabilities that were identified in the Vulnerability Assessment. The Risk Assessment assessed likelihood that the vulnerabilities will occur, and the severity of consequences should they occur. This Risk Assessment provides a qualitative evaluation of the top vulnerabilities, to determine which may present the greatest risk.

Risk = Likelihood of Occurrence x Severity of Consequence

This analysis was completed county-wide, using available data, information, and analyses. As more data and information become available, additional risk assessments may be completed that provide more granular information (such as monetized losses) to inform decision making. The risk methodology applied the following definitions to assign a "low," "moderate," or "high" rating:

Likelihood of occurrence is the probability that the climate change hazard will impact the subsector. Likelihood was determined by considering the probability of the hazard occurring and the portion of the subsector that is exposed.

Severity of Consequences describes the potential severity of impact. Consequence categories included the following: Economic impact and Service Loss, Cost to Repair, Public Health and Safety, and Environmental Impacts. The consequence categories were applied, as shown in Table A-3, to evaluate the degree of consequence that could occur as a result of the impact. Consequences extend beyond the loss of any given asset. This analysis drew upon the recently released National Risk Index from FEMA that provides county-scale risk data.

Table A-3. Level of Consequence Scoring for the Risk Assessment.

LEVEL OF CONSEQUENCE	ECONOMIC IMPACT AND SERVICE LOSS	COST TO REPAIR	PUBLIC HEALTH AND SAFETY	ENVIRONMENTAL
High	Shut down of services/ stores for more than 3 days; significant impact on economic drivers; significant impact on livelihoods	>$1M	Multiple fatalities or major injuries requiring hospitalizations	Irreversible environmental impact
Moderate	1-3 days of impact before back to normal business conditions; moderate impact on economic drivers; moderate impact on livelihoods	$100k-$1M	A single fatality or multiple injuries/ illnesses	Reversible significant environmental impact
Low	No impact	< $100k	Minimal injuries or illness	Minimal to no environmental impact

Table A-4. Total Risk Assessment Scoring

		Severity of Consequences		
		Low	**Moderate**	**High**
Likelihood of Occurrence	High	Moderate	Moderate/High	High
	Moderate	Low/Moderate	Moderate	Moderate/High
	Low	Low	Low/Moderate	Moderate

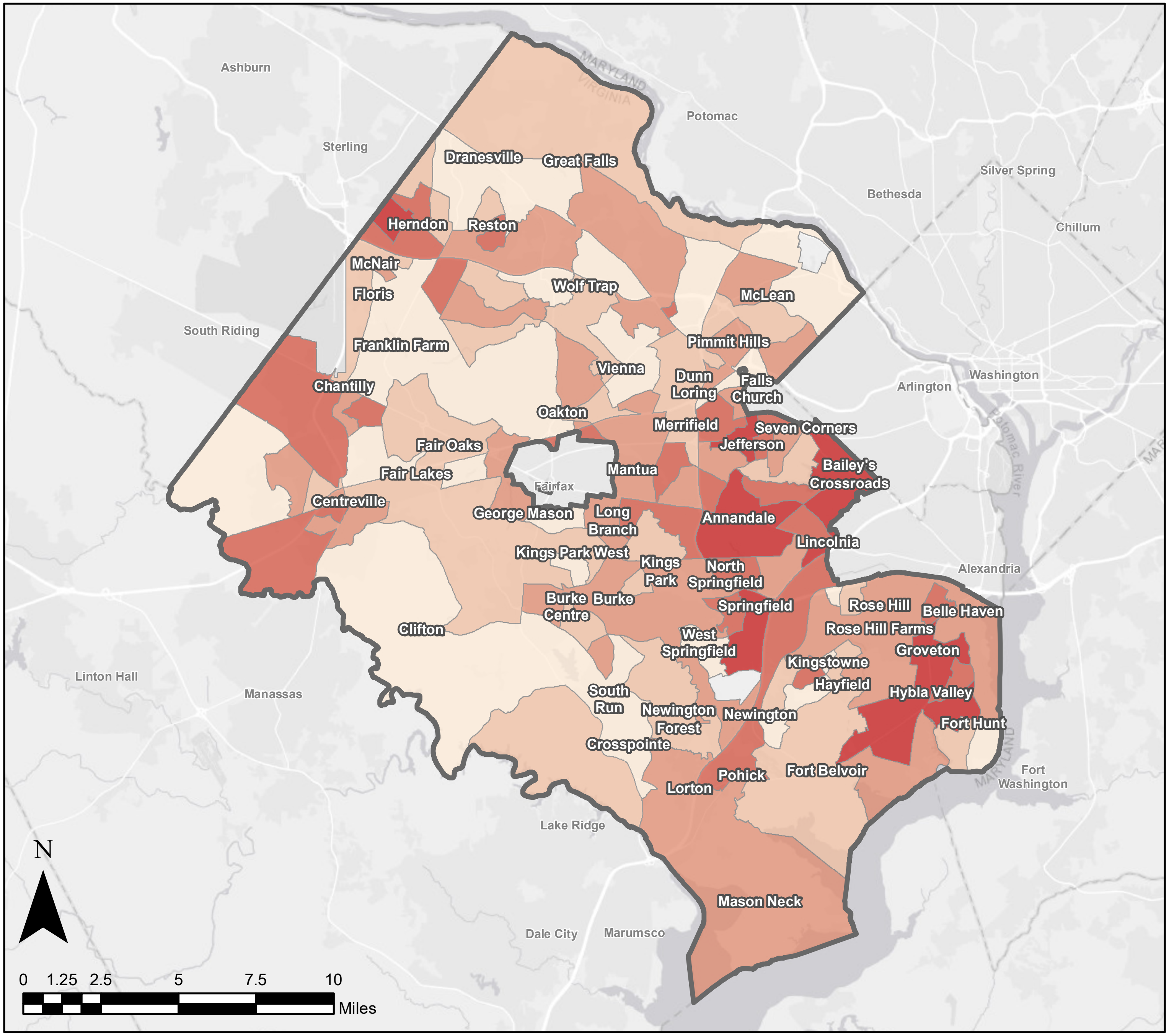
For each top vulnerability, the “likelihood” and “severity of consequence” scores were combined to create total risk score. This Risk Assessment was used to identify minor, moderate, and high risks to the county.

For additional information, please contact the Fairfax County Office of Environmental and Energy Coordination at ResilientFairfax@fairfaxcounty.gov.

APPENDIX 2 – MAP BOOK

Table of Contents

Population Sensitivity by Census Tract



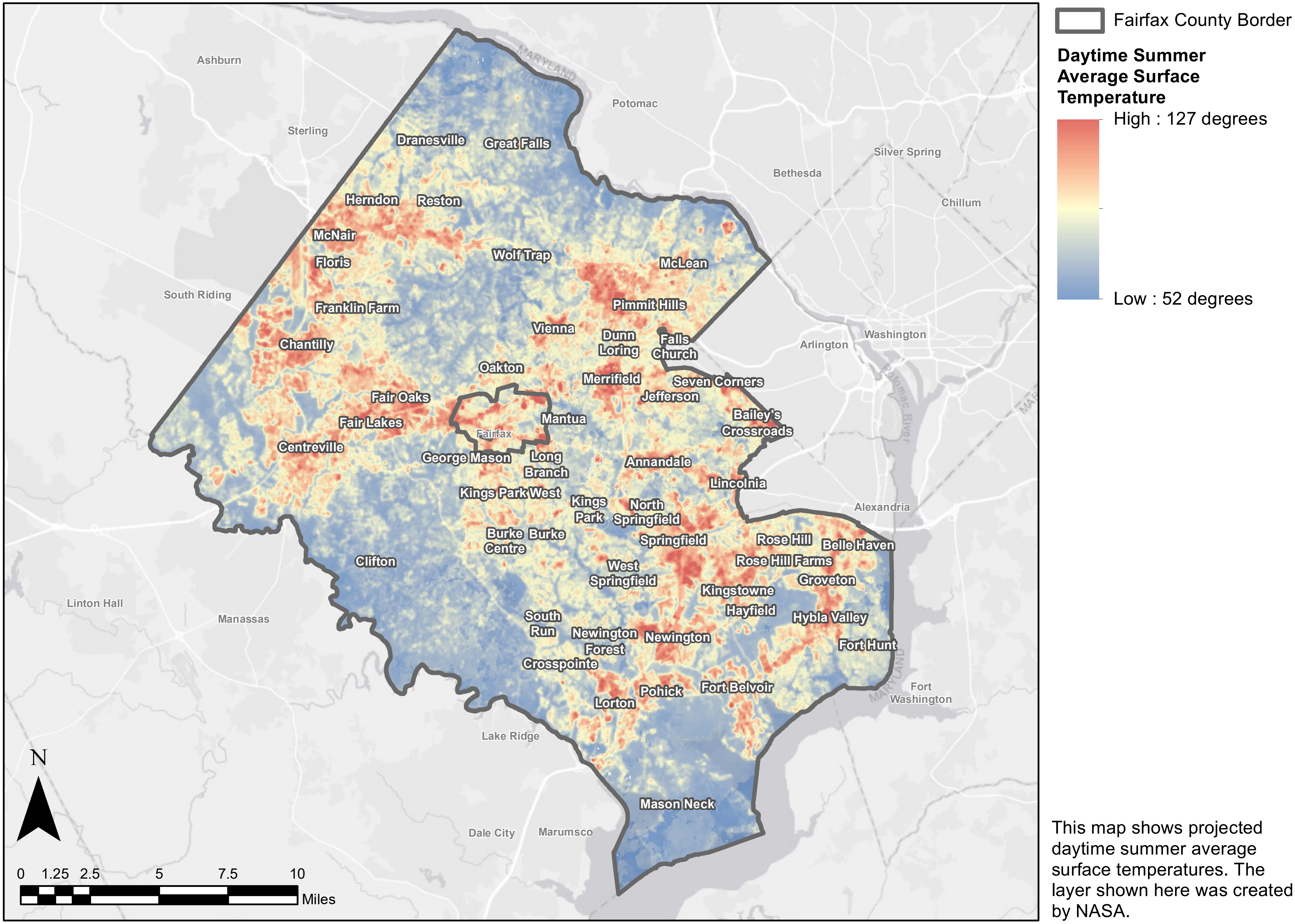
Fairfax County Border

Sensitivity by Census Tract

- Very Low
- Low
- Moderate
- High
- Very High

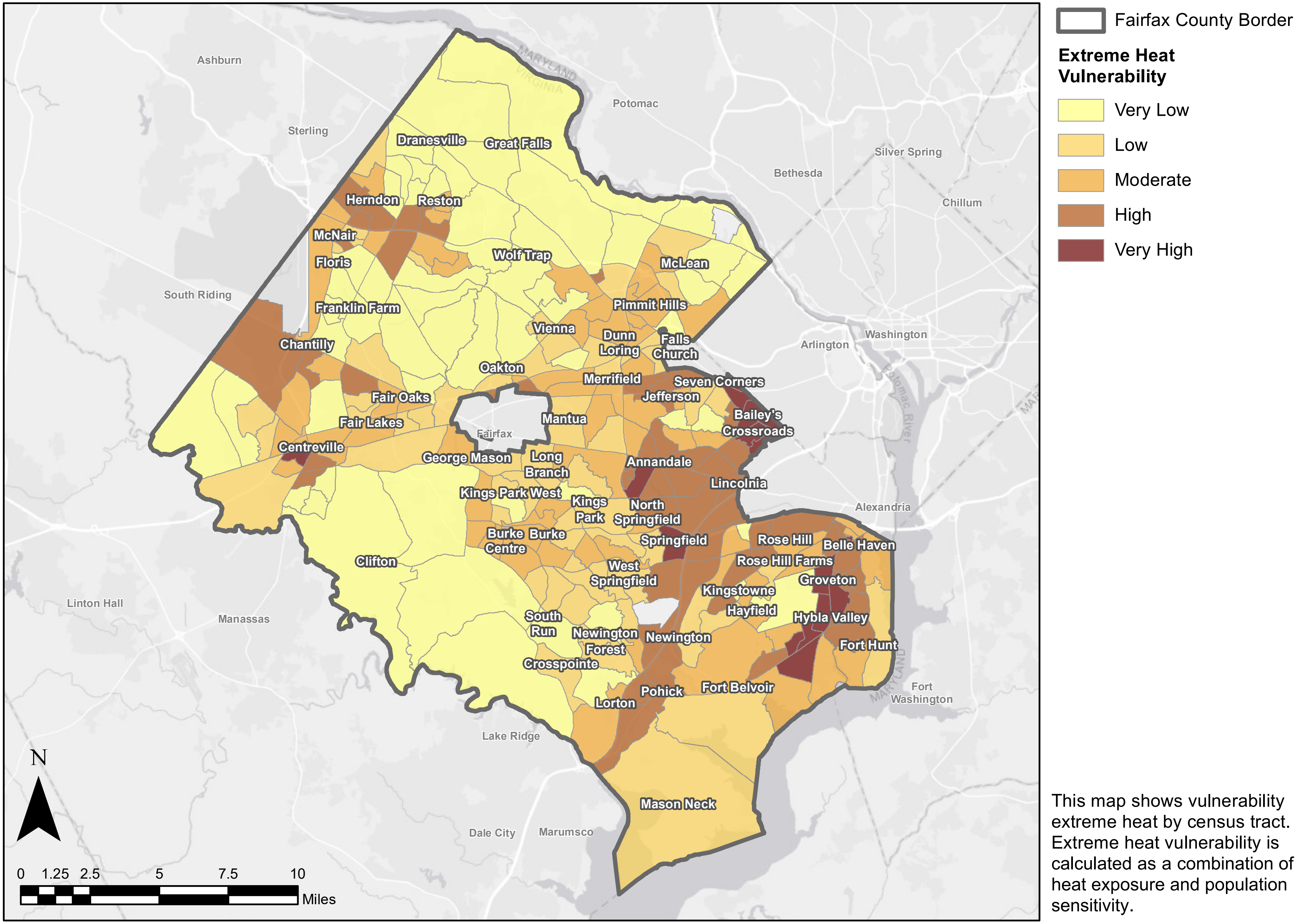
Some populations may be at a greater disadvantage to climate hazards than others. This map shows socioeconomic, health-related, and other pre-existing sensitivities in the Fairfax County population. Data is from One Fairfax's Vulnerability Index and includes: income, poverty, lack of high school diploma, age, disability, limited English proficiency, race, ethnicity, lack of vehicle access, severely burdened renters, multi-unit structures, overcrowded units, lack of health insurance, and pre-existing health conditions.

Heat Exposure: Average Surface Temperatures



This map shows projected daytime summer average surface temperatures. The layer shown here was created by NASA.

Vulnerability to Extreme Heat by Census Tract



This map shows vulnerability extreme heat by census tract. Extreme heat vulnerability is calculated as a combination of heat exposure and population sensitivity.

Community Effects from Extreme Heat - Tysons Corner Area

Fairfax County Border

Community Center

Hospital or Urgent Care

Library

Health and Human Services Facility

Police Station

Fire Station

Building Footprint

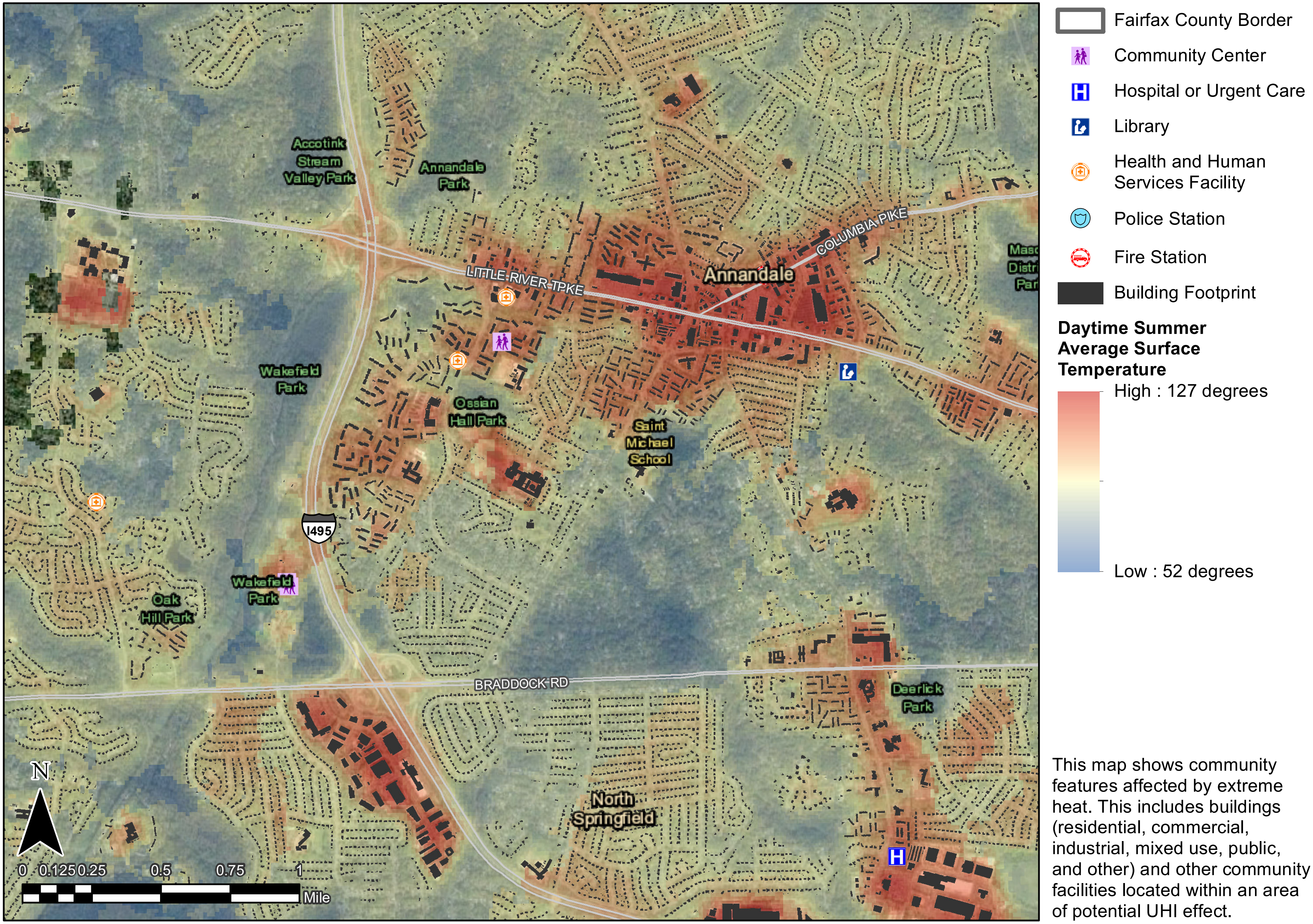
Daytime Summer Average Surface Temperature

High : 127 degrees

Low : 52 degrees

This map shows community features affected by extreme heat. This includes buildings (residential, commercial, industrial, mixed use, public, and other) community facilities located within an area of potential UHI effect.

Community Effects from Extreme Heat - Annandale Area



This map shows community features affected by extreme heat. This includes buildings (residential, commercial, industrial, mixed use, public, and other) and other community facilities located within an area of potential UHI effect.

Community Effects from Extreme Heat - Springfield Area

Fairfax County Border
Community Center
Hospital or Urgent Care
Library
Fire Station
Building Footprint

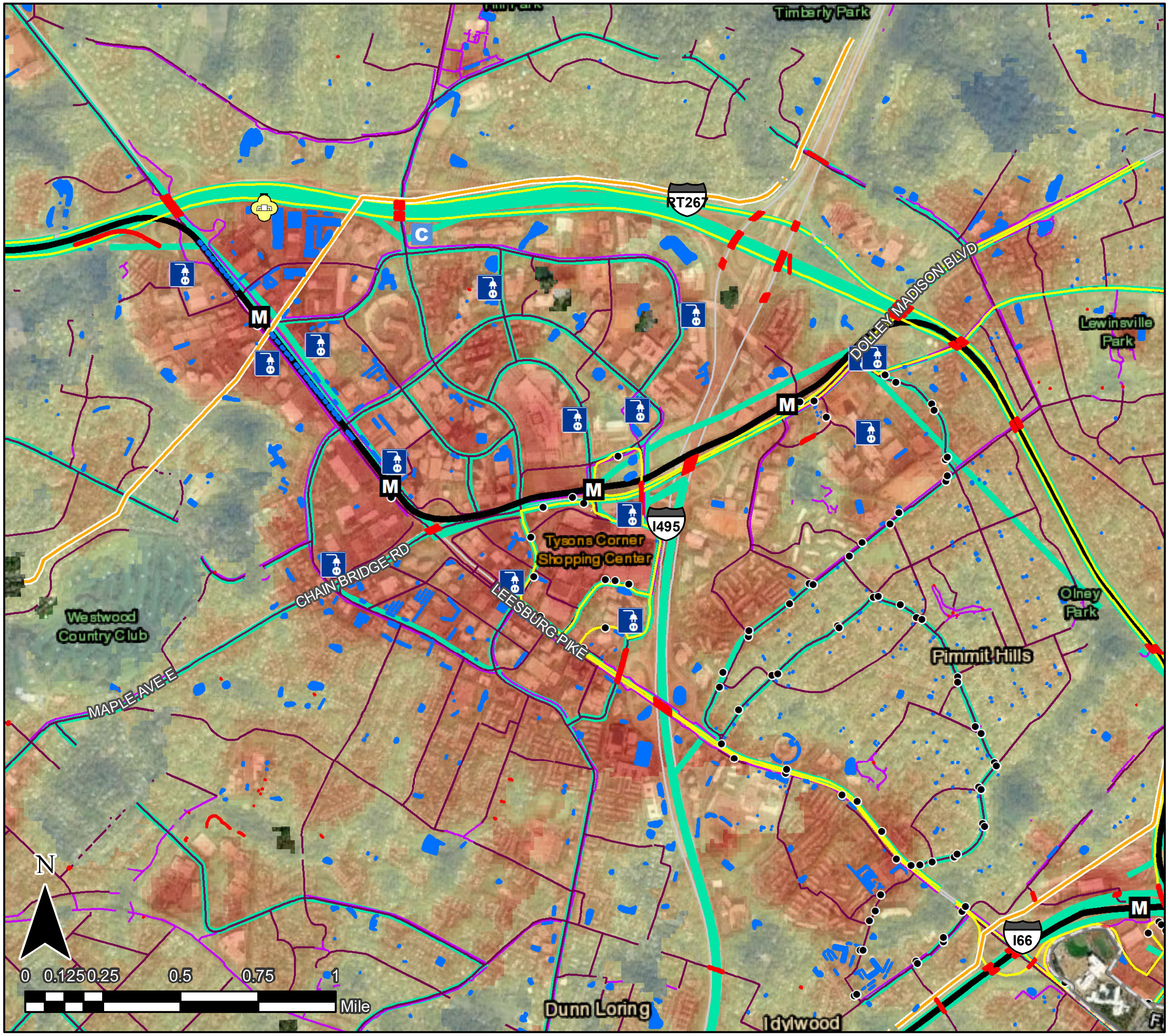
Daytime Summer Average Surface Temperature

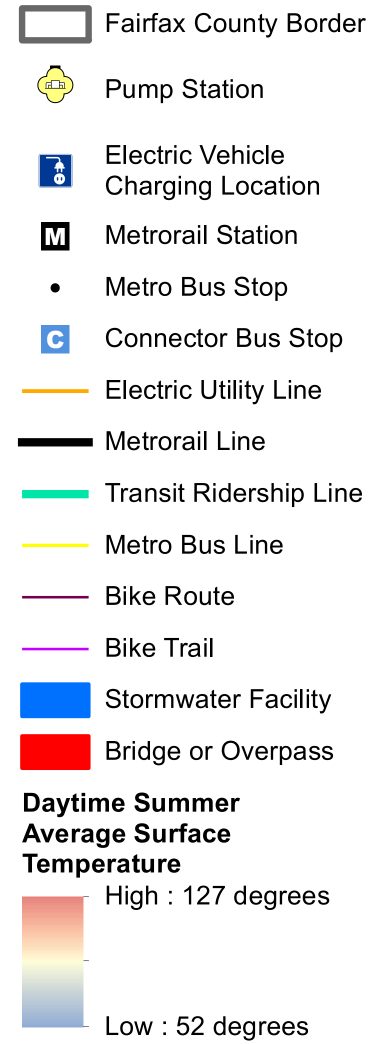
High : 127 degrees

Low : 52 degrees

This map shows community features affected by extreme heat. This includes buildings (residential, commercial, industrial, mixed use, public, and other) and other community facilities located within an area of potential UHI effect.

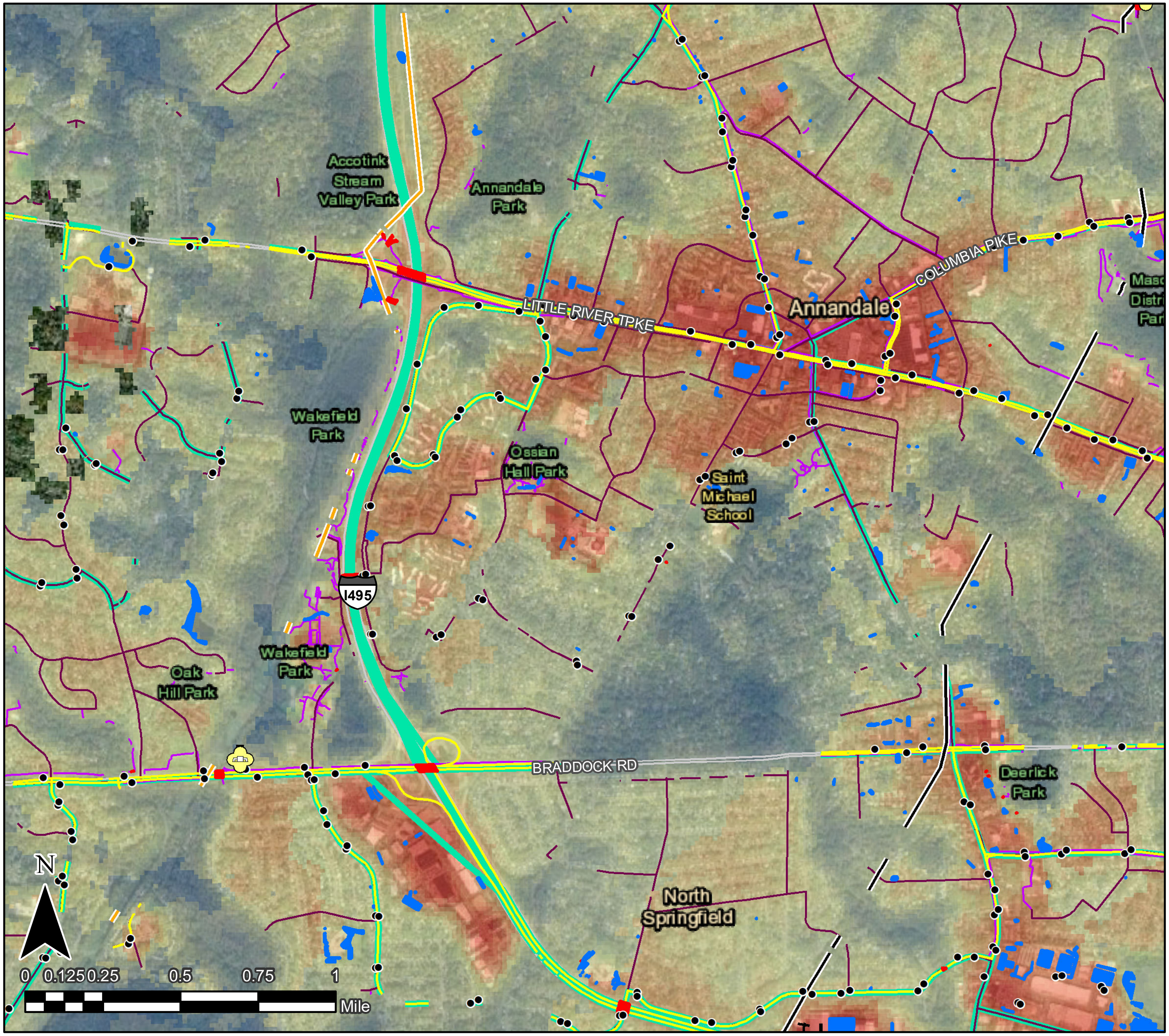
Infrastructure Effects from Extreme Heat - Tysons Corner Area





This map shows infrastructure related features affected by extreme heat.

Infrastructure Effects from Extreme Heat - Annandale Area



Fairfax County Border

Pump Station

Metro Bus Stop

Electric Utility Line

Telephone Utility Line

Transit Ridership Line

Metro Bus Line

Private Railroad Line

Bike Route

Bike Trail

Stormwater Facility

Bridge or Overpass

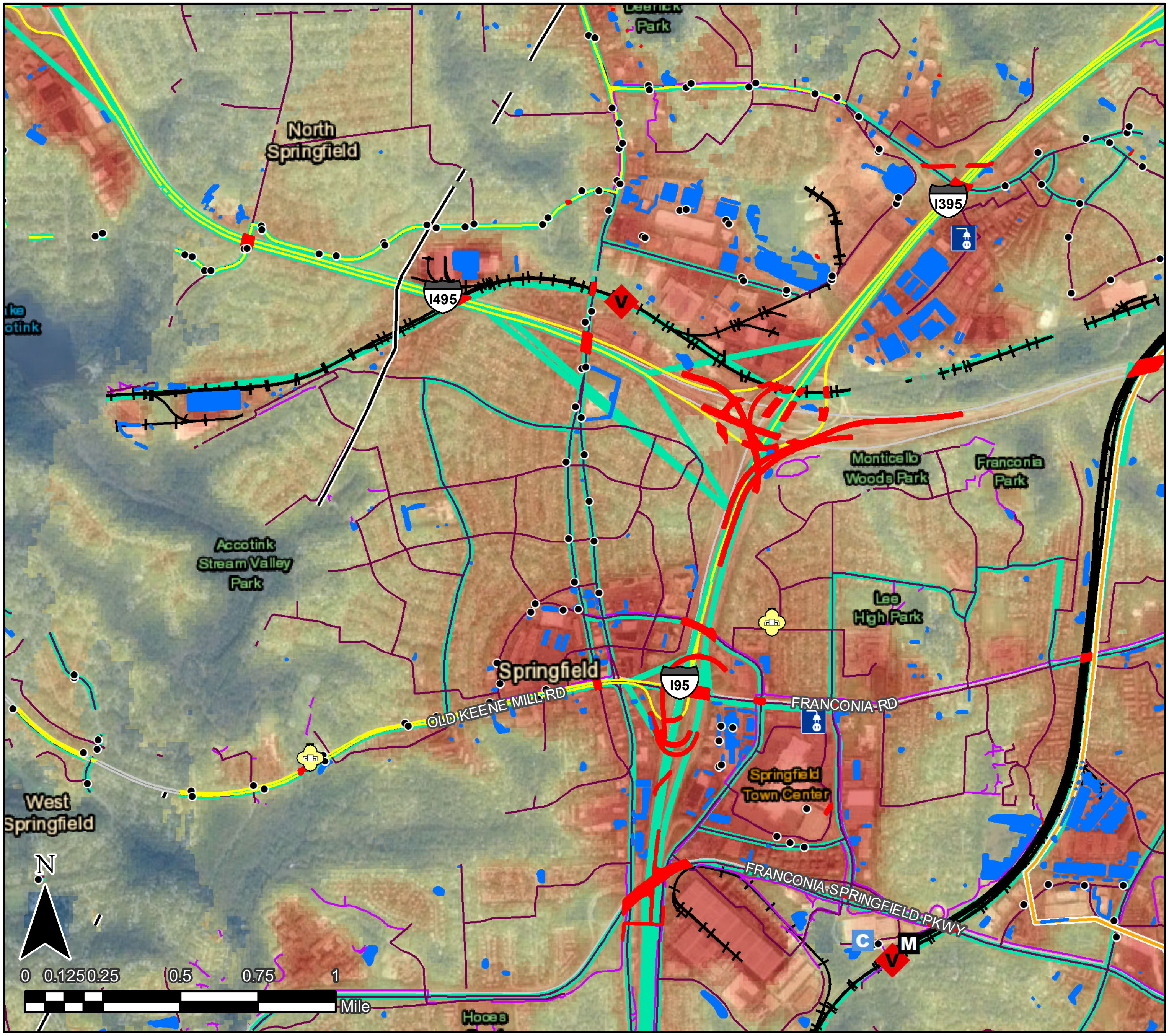
Daytime Summer Average Surface Temperature

High : 127 degrees

Low : 52 degrees

This map shows infrastructure related features affected by extreme heat.

Infrastructure Effects from Extreme Heat - Springfield Area



Fairfax County Border
Pump Station
Electric Vehicle Charging Location
Metrorail Station
Metro Bus Stop
Connector Bus Stop
Virginia Railway Express Station
Electric Utility Line
Telephone Utility Line
Metrorail Line
Transit Ridership Line
Metro Bus Line
Private Railroad Line
Bike Route
Bike Trail
Stormwater Facility
Bridge or Overpass

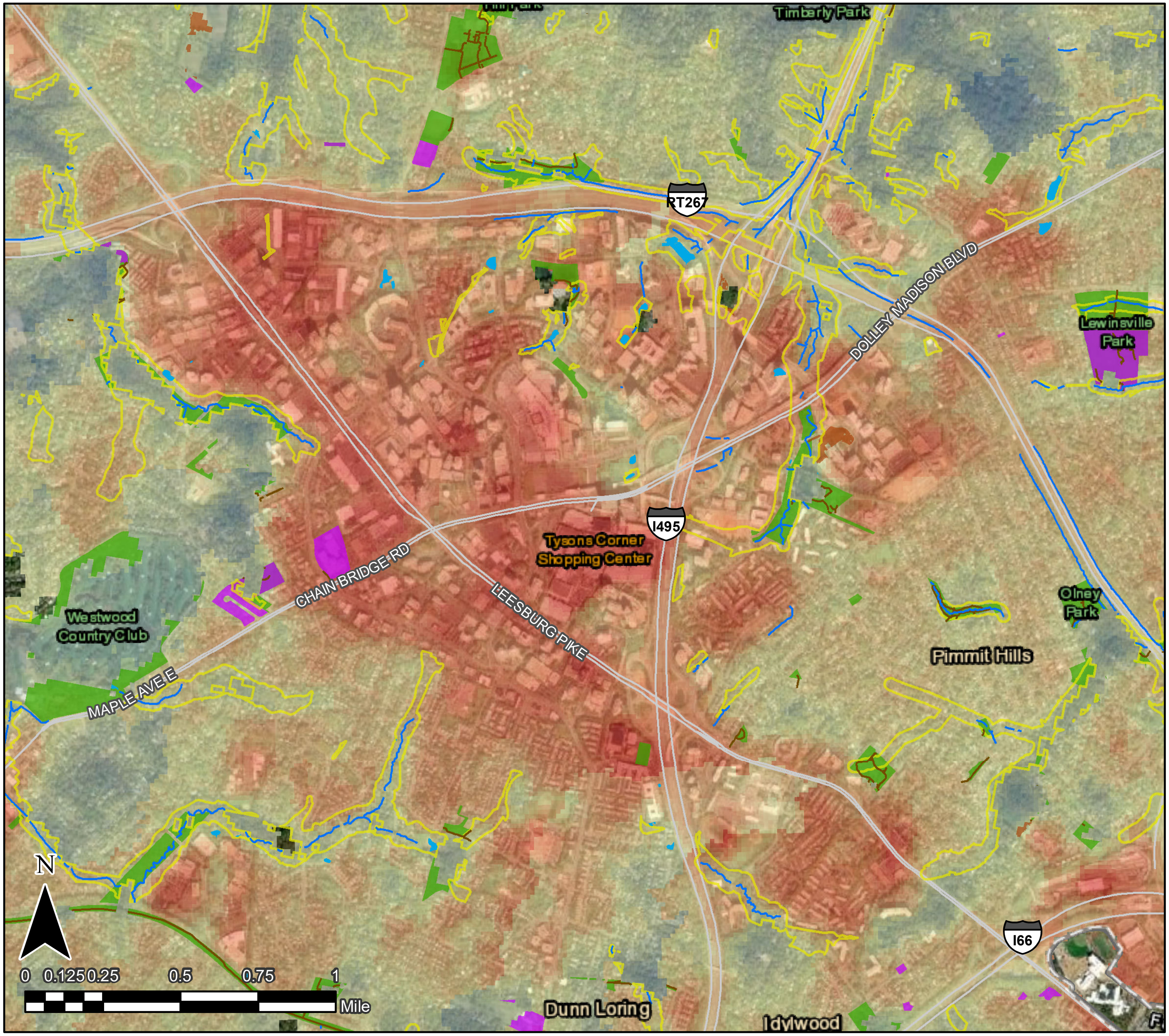
Daytime Summer Average Surface Temperature

High : 127 degrees

Low : 52 degrees

This map shows infrastructure related features affected by extreme heat.

Natural and Cultural Effects from Extreme Heat - Tysons Corner Area



Fairfax County Border

Stream

Trail

Lake or Pond

Environmentally Sensitive Area

Pasture or Cropland

Historic Resource

Park

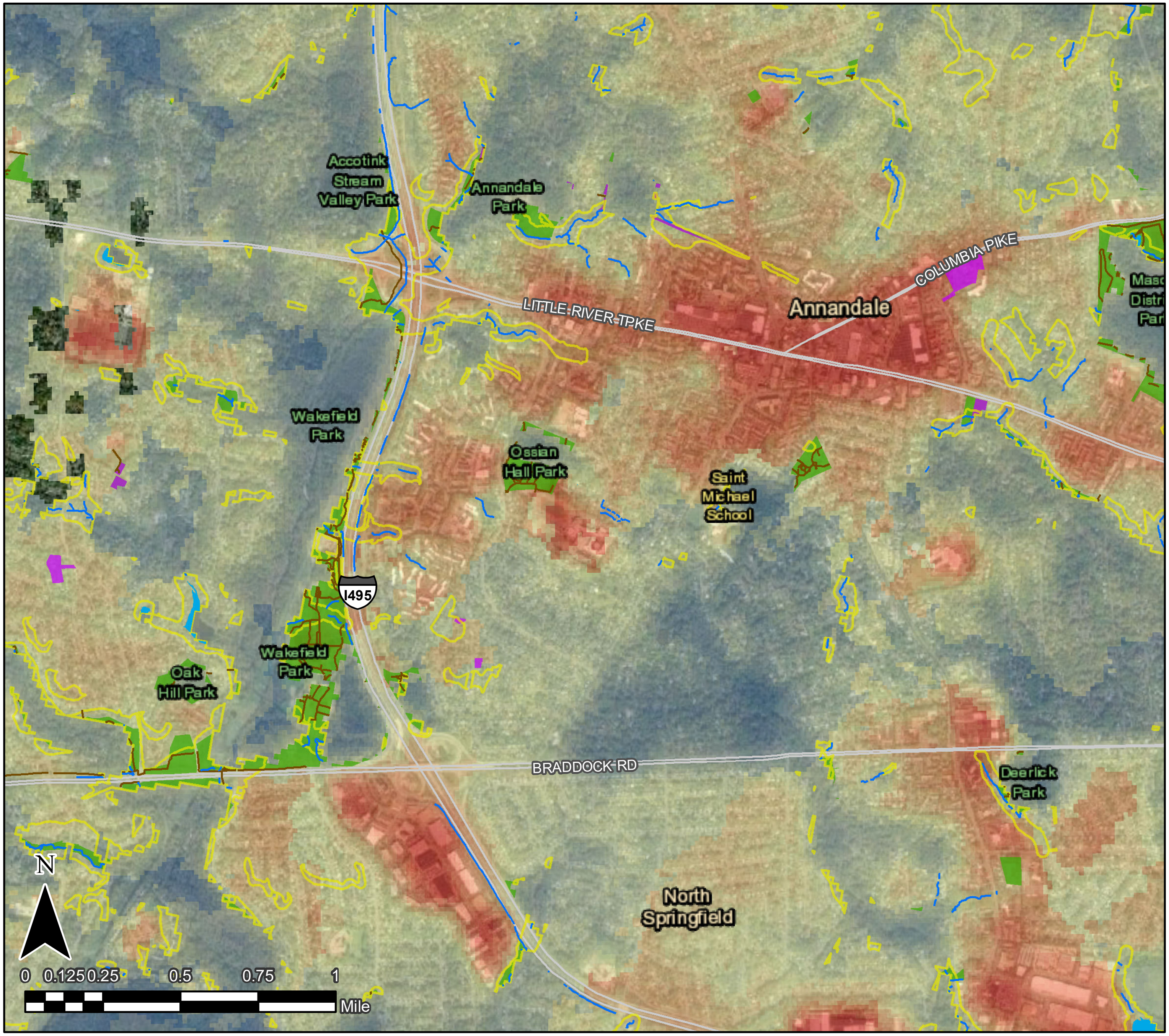
Daytime Summer Average Surface Temperature

High : 127 degrees

Low : 52 degrees

This map shows natural and cultural features affected by extreme heat.

Natural and Cultural Effects from Extreme Heat - Annandale Area



Fairfax County Border

Stream

Trail

Lake or Pond

Environmentally Sensitive Area

Historic Resource

Park

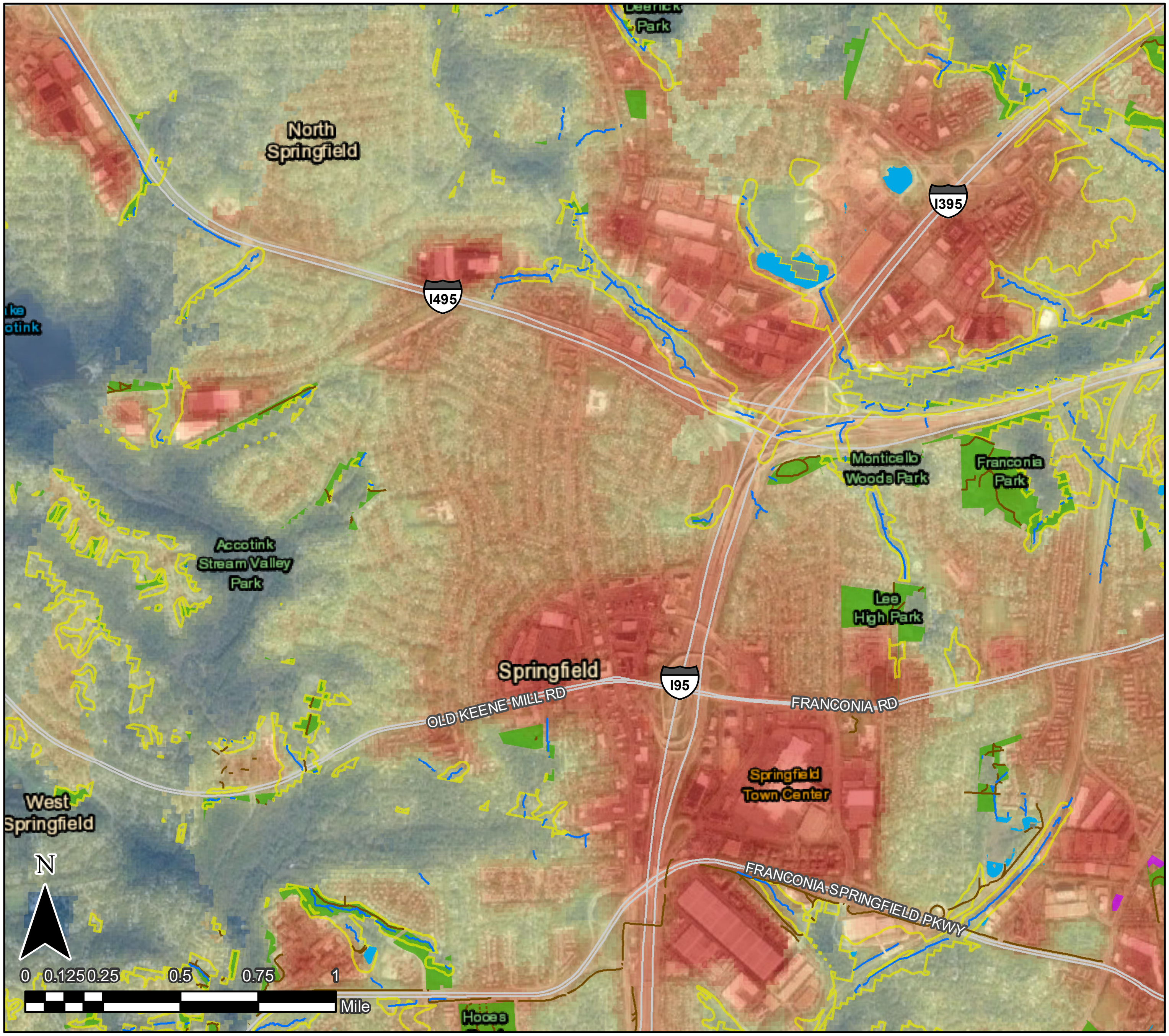
Daytime Summer Average Surface Temperature

High : 127 degrees

Low : 52 degrees

This map shows natural and cultural features affected by extreme heat.

Natural and Cultural Effects from Extreme Heat - Springfield Area

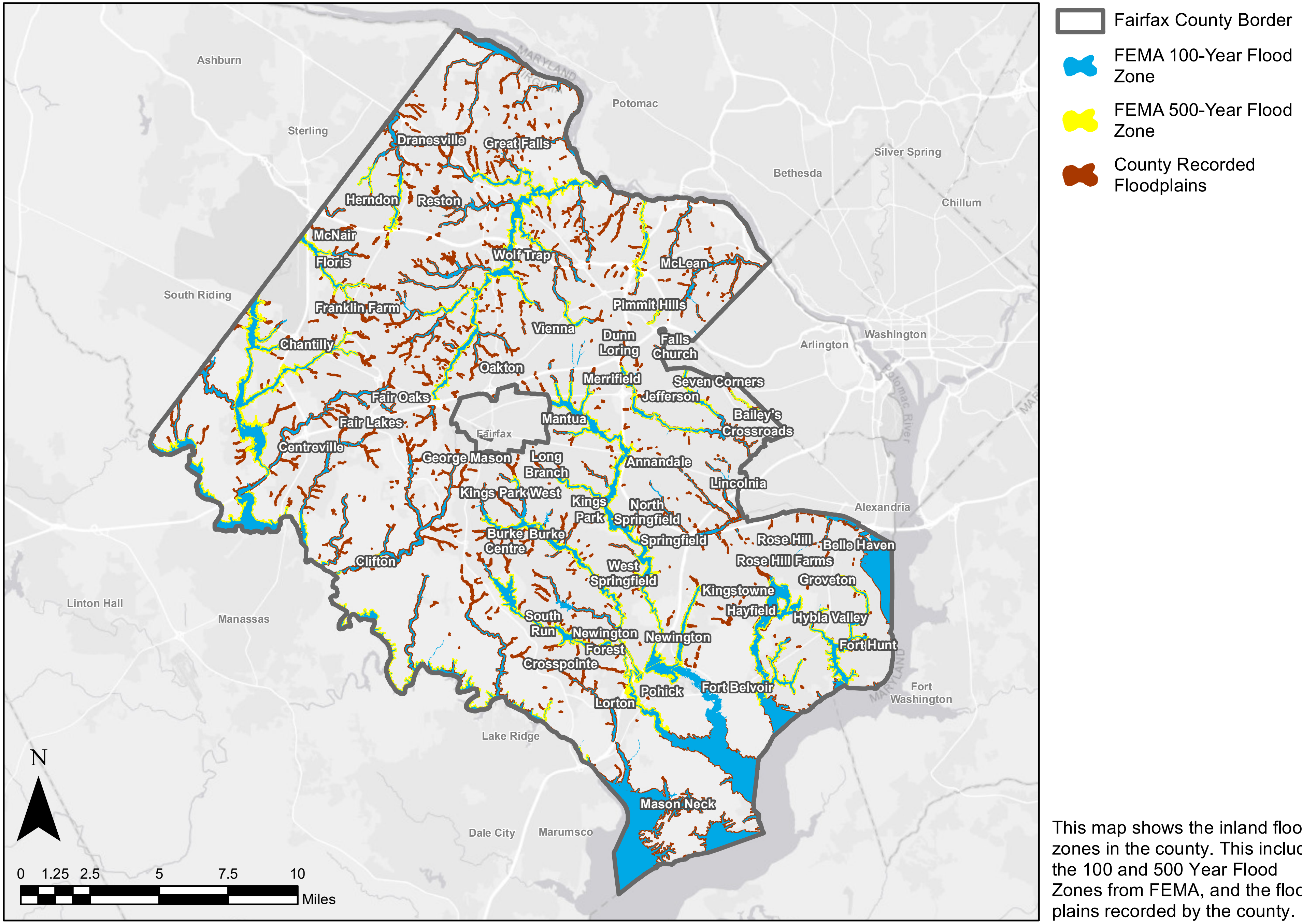


Fairfax County Border
Stream
Trail
Lake or Pond
Environmentally Sensitive Area
Historic Resource
Park

Daytime Summer Average Surface Temperature
High : 127 degrees
Low : 52 degrees

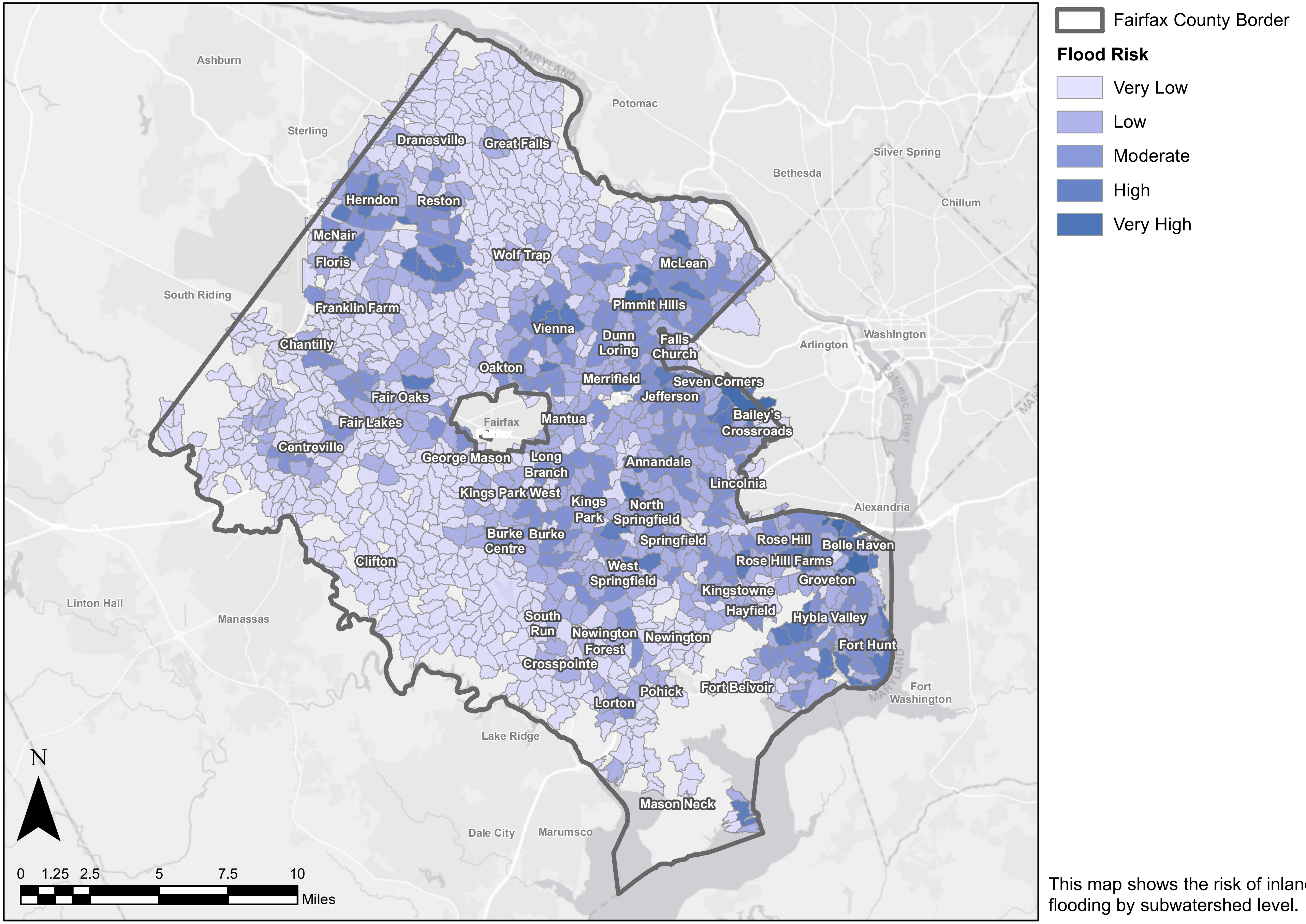
This map shows natural and cultural features affected by extreme heat.

Flooding Exposure: Floodplains in Fairfax County



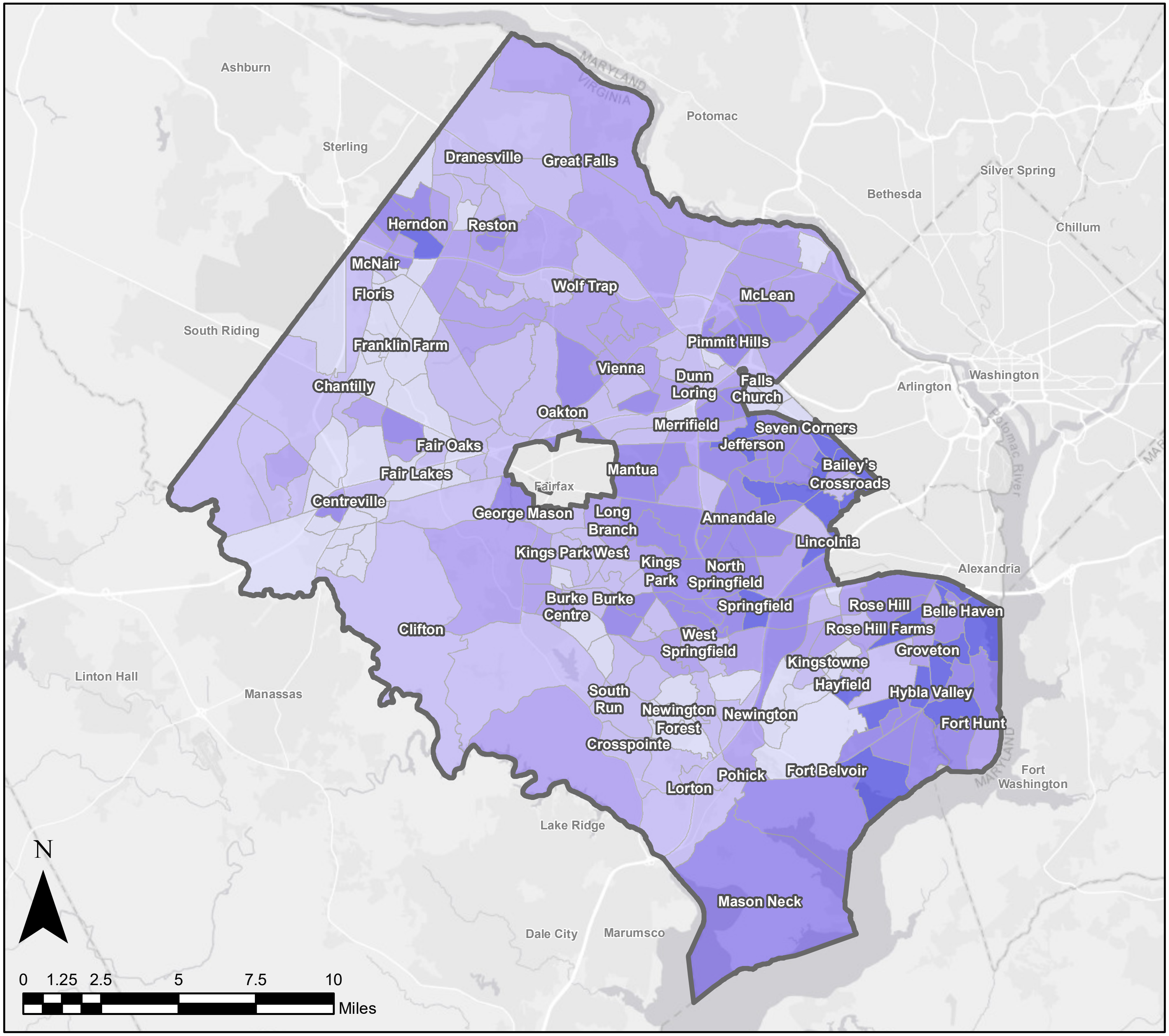
This map shows the inland flood zones in the county. This includes the 100 and 500 Year Flood Zones from FEMA, and the flood-plains recorded by the county.

Flooding Exposure: Flood Risk by Subwatershed



This map shows the risk of inland flooding by subwatershed level.

Inland Flooding Vulnerability by Census Tract



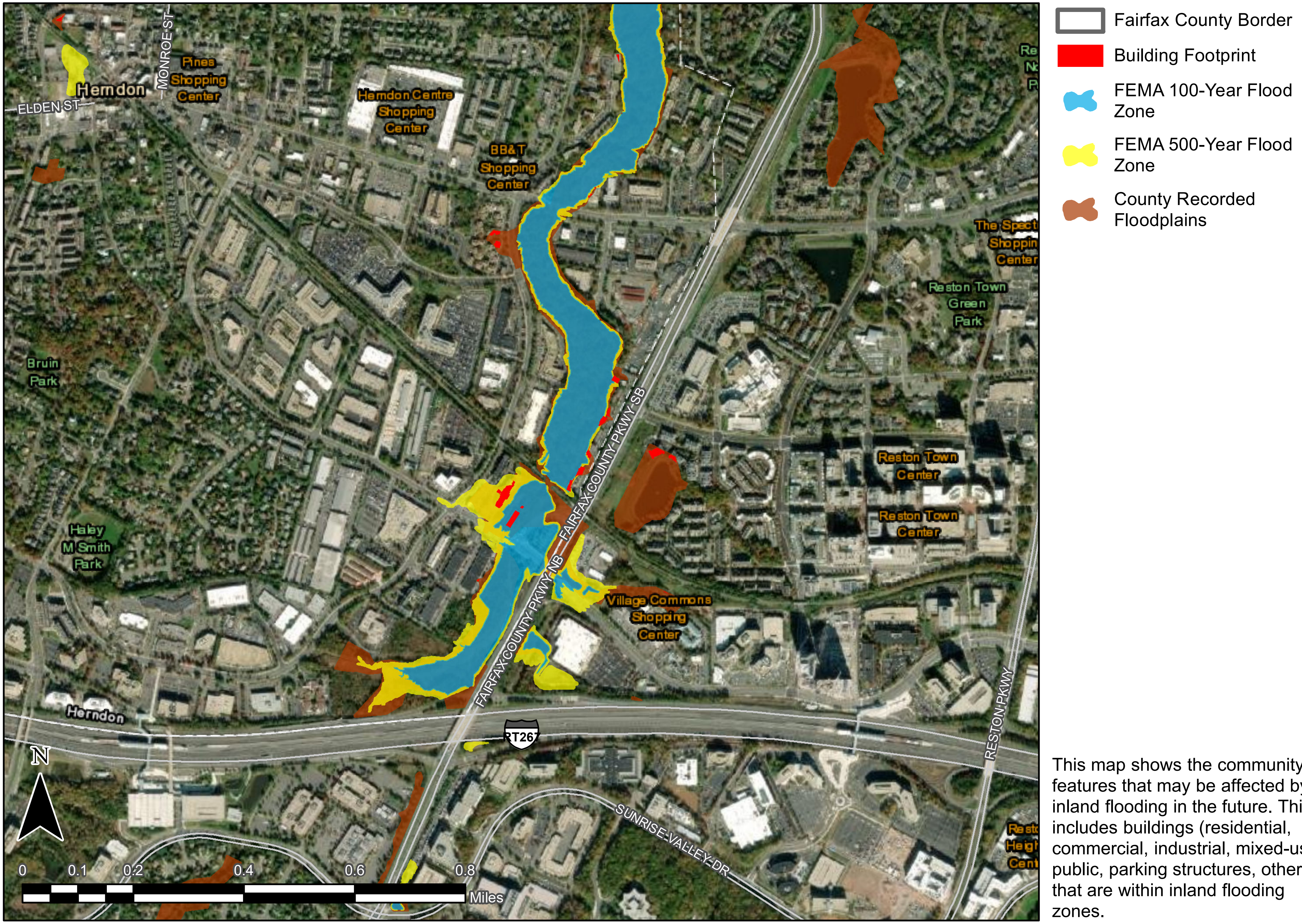
Fairfax County Border

Flooding Vulnerability by Census Tract

- Very Low
- Low
- Moderate
- High
- Very High

This map shows inland flooding vulnerability by census tract. Vulnerability is calculated as a combination of inland flooding exposure and population sensitivity.

Inland Flooding Effects on Communities - Herndon Area



This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Communities - Little Pimmit Run Area

Fairfax County Border

Building Footprint

FEMA 100-Year Flood Zone

FEMA 500-Year Flood Zone

County Recorded Floodplains

This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Communities - Pimmit Run Area

Fairfax County Border

Building Footprint

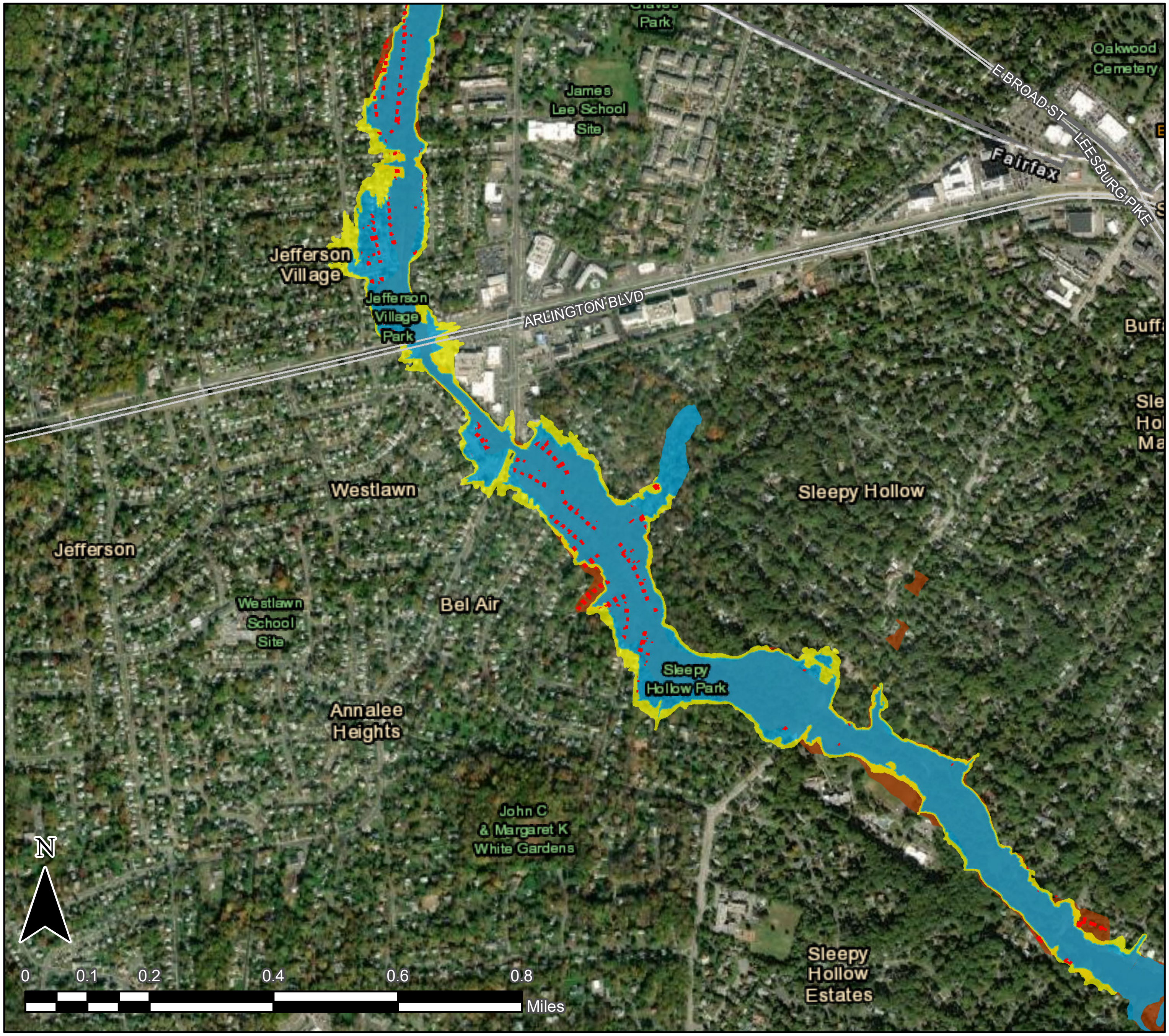
FEMA 100-Year Flood Zone

FEMA 500-Year Flood Zone

County Recorded Floodplains

This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Communities - Tripps Run Area



Fairfax County Border

Building Footprint

FEMA 100-Year Flood Zone

FEMA 500-Year Flood Zone

County Recorded Floodplains

This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Communities - Hybla Valley Area

Fairfax County Border
Building Footprint
FEMA 100-Year Flood Zone
FEMA 500-Year Flood Zone
County Recorded Floodplains

This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Communities - Cub Run Area

Fairfax County Border

Building Footprint

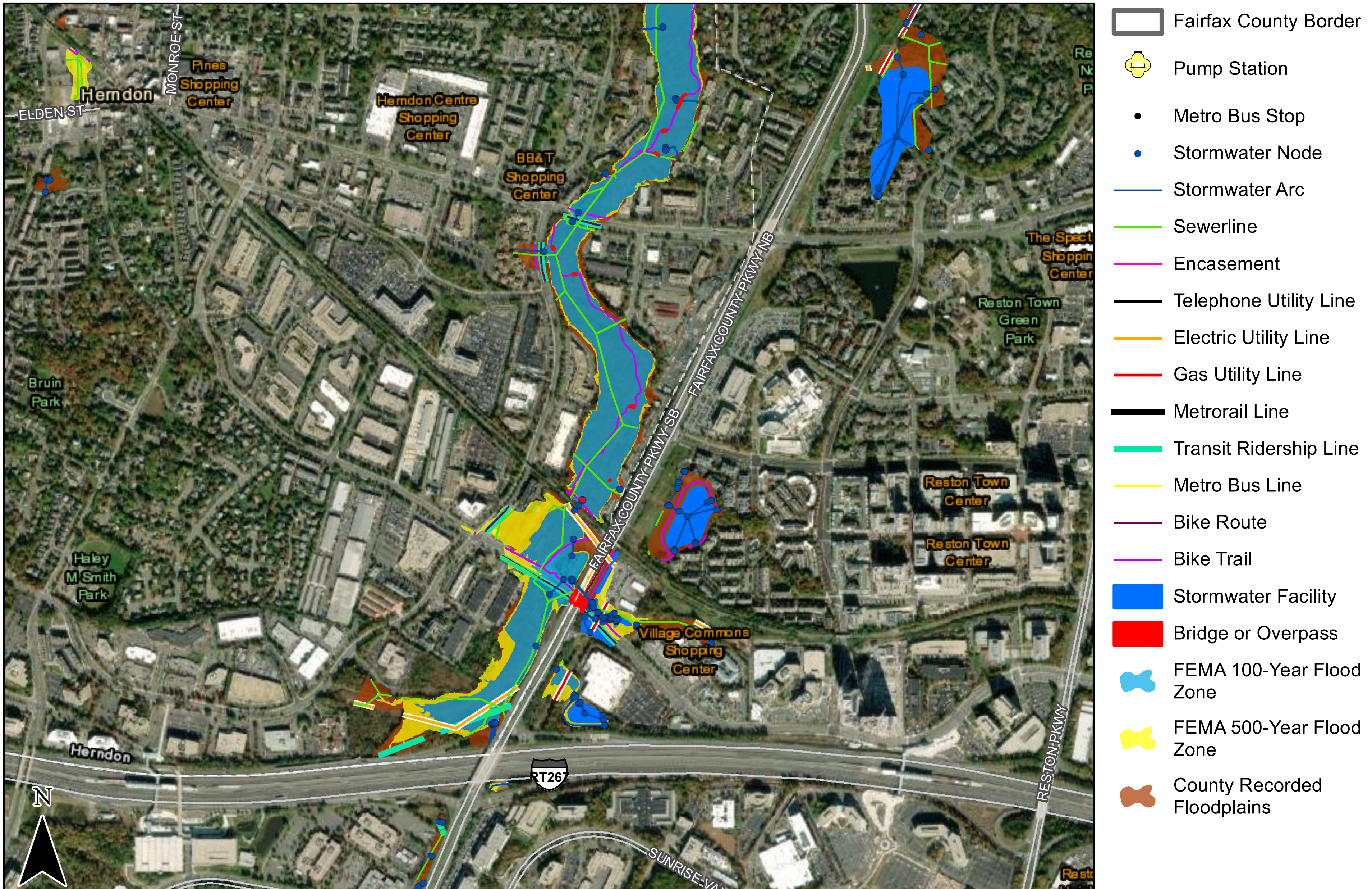
FEMA 100-Year Flood Zone

FEMA 500-Year Flood Zone

County Recorded Floodplains

This map shows the community features that may be affected by inland flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other) that are within inland flooding zones.

Inland Flooding Effects on Infrastructure - Herndon Area



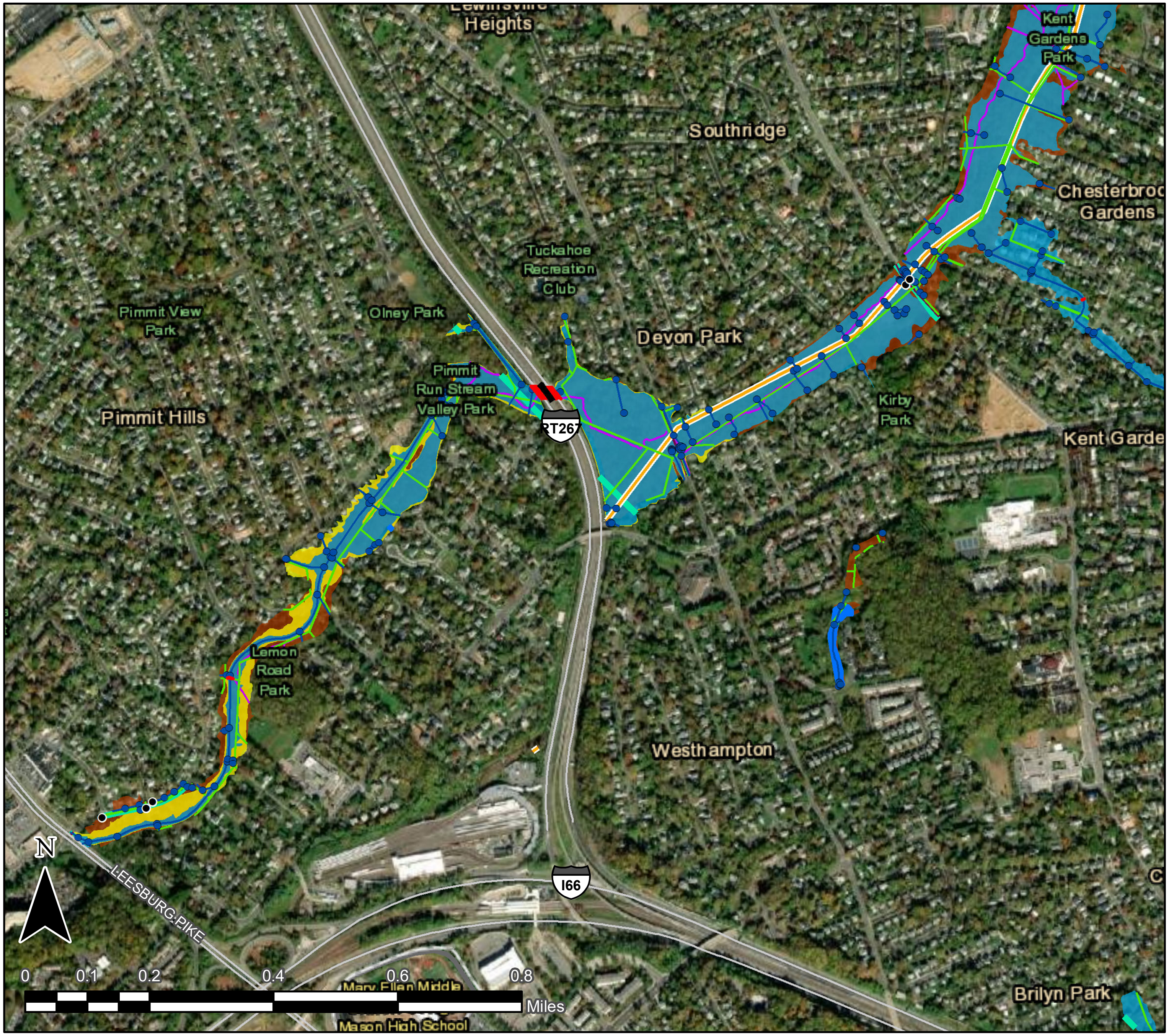
This map shows infrastructure features that may be affected by inland flooding in the future.

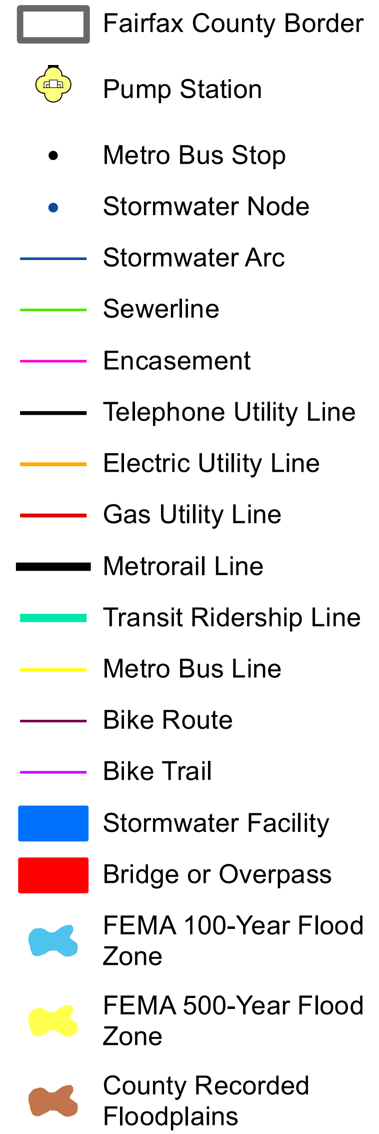
Inland Flooding Effects on Infrastructure - Little Pimmit Run Area

Fairfax County Border
Pump Station
Metro Bus Stop
Stormwater Node
Stormwater Arc
Sewerline
Encasement
Telephone Utility Line
Electric Utility Line
Gas Utility Line
Metrorail Line
Transit Ridership Line
Metro Bus Line
Bike Route
Bike Trail
Stormwater Facility
Bridge or Overpass
FEMA 100-Year Flood Zone
FEMA 500-Year Flood Zone
County Recorded Floodplains

This map shows infrastructure features that may be affected by inland flooding in the future.

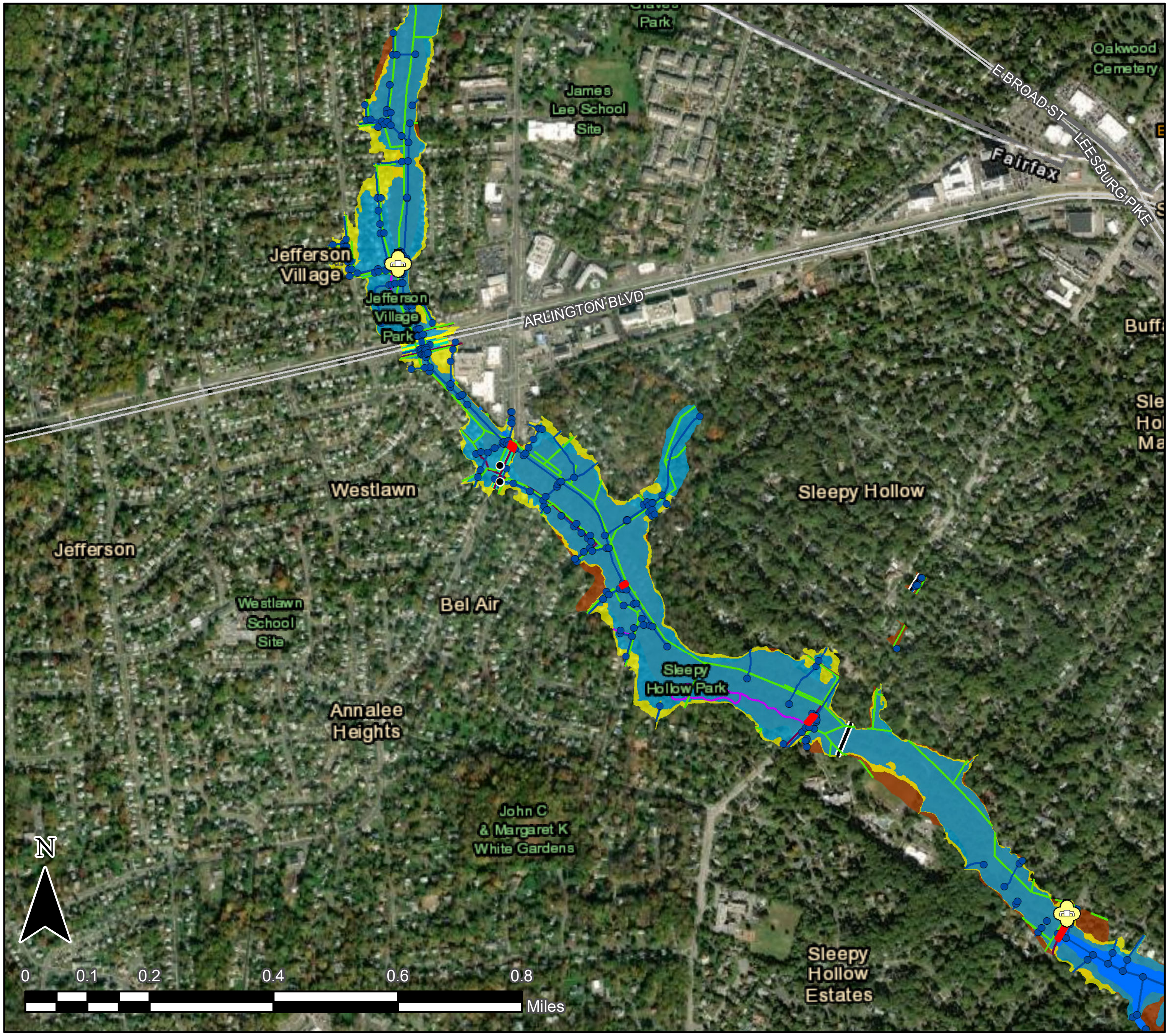
Inland Flooding Effects on Infrastructure - Pimmit Run Area





This map shows infrastructure features that may be affected by inland flooding in the future.

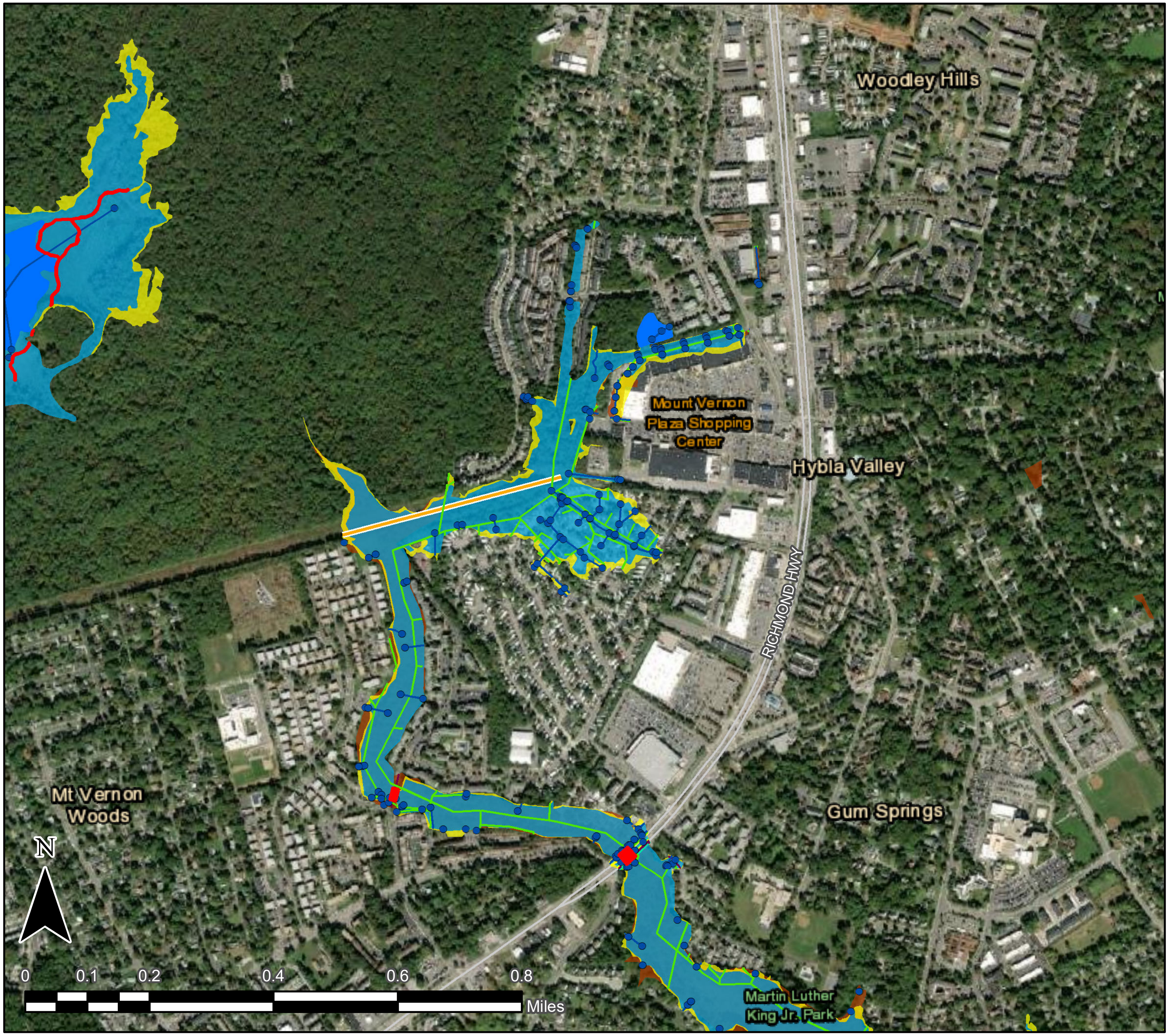
Inland Flooding Effects on Infrastructure - Tripps Run Area



Fairfax County Border
Pump Station
Metro Bus Stop
Stormwater Node
Stormwater Arc
Sewerline
Encasement
Telephone Utility Line
Electric Utility Line
Gas Utility Line
Metrorail Line
Transit Ridership Line
Metro Bus Line
Bike Route
Bike Trail
Stormwater Facility
Bridge or Overpass
FEMA 100-Year Flood Zone
FEMA 500-Year Flood Zone
County Recorded Floodplains

This map shows infrastructure features that may be affected by inland flooding in the future.

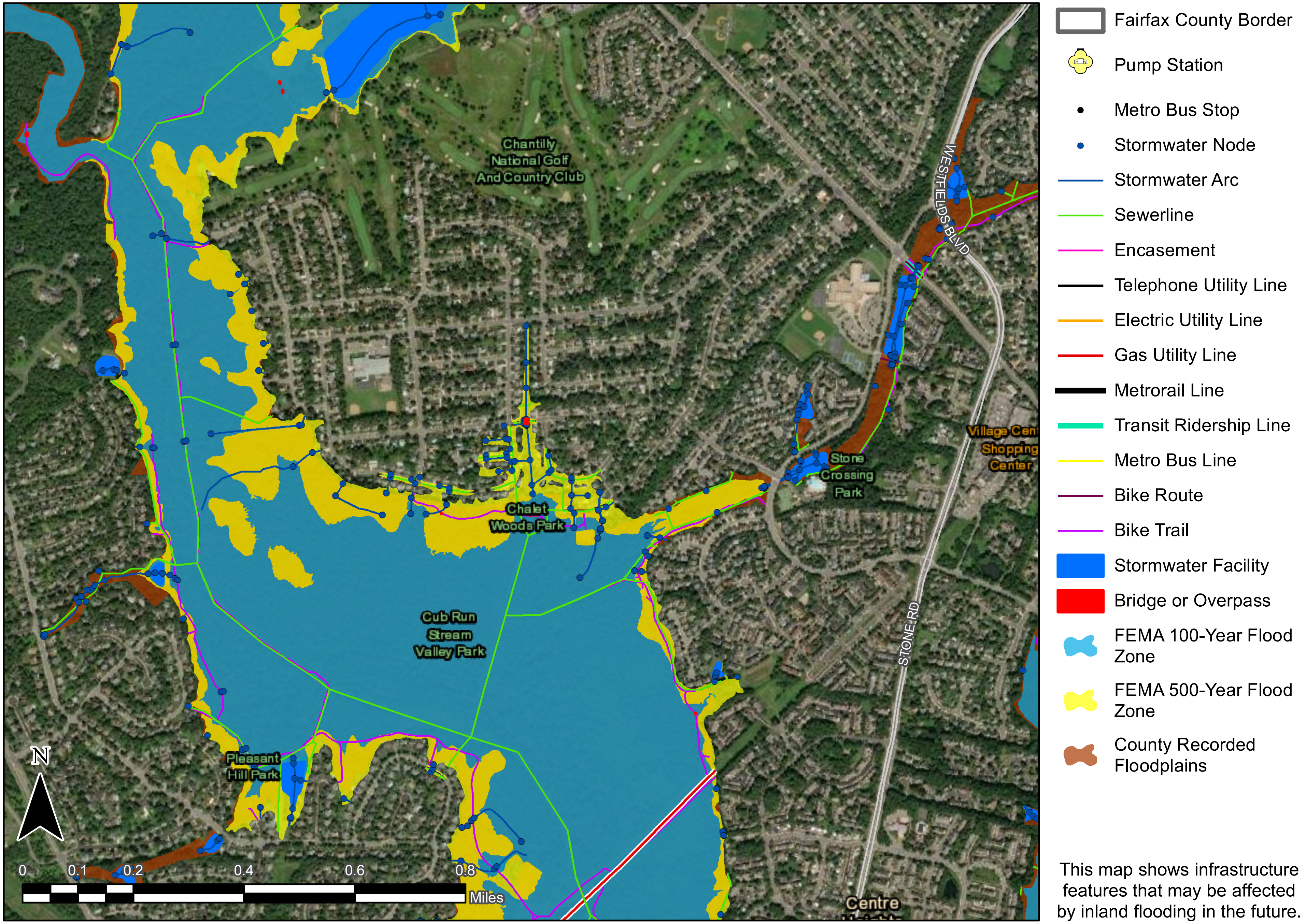
Inland Flooding Effects on Infrastructure - Hybla Valley Area



Fairfax County Border
Pump Station
Metro Bus Stop
Stormwater Node
Stormwater Arc
Sewerline
Encasement
Telephone Utility Line
Electric Utility Line
Gas Utility Line
Metrorail Line
Transit Ridership Line
Metro Bus Line
Bike Route
Bike Trail
Stormwater Facility
Bridge or Overpass
FEMA 100-Year Flood Zone
FEMA 500-Year Flood Zone
County Recorded Floodplains

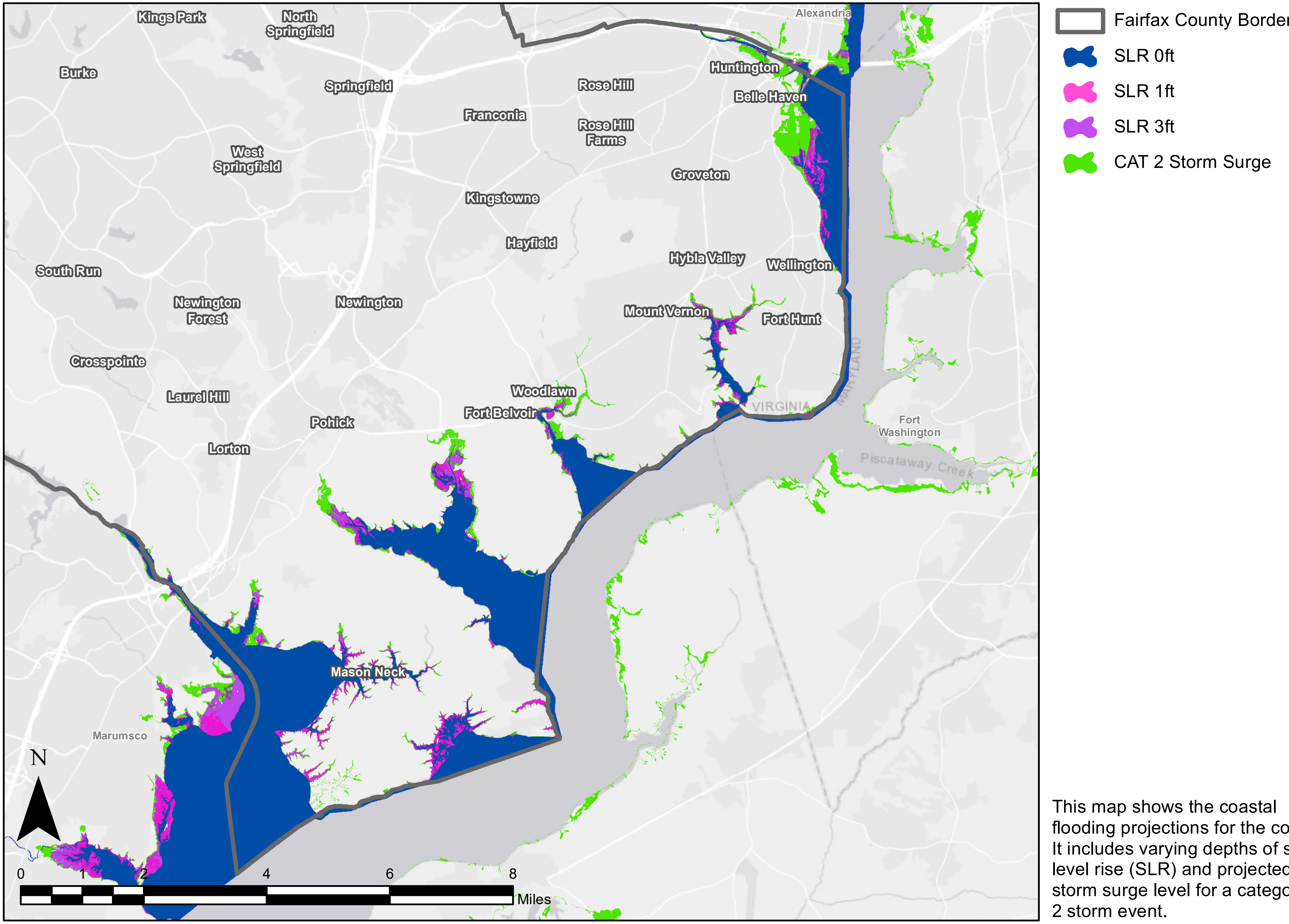
This map shows infrastructure features that may be affected by inland flooding in the future.

Inland Flooding Effects on Infrastructure - Cub Run Area



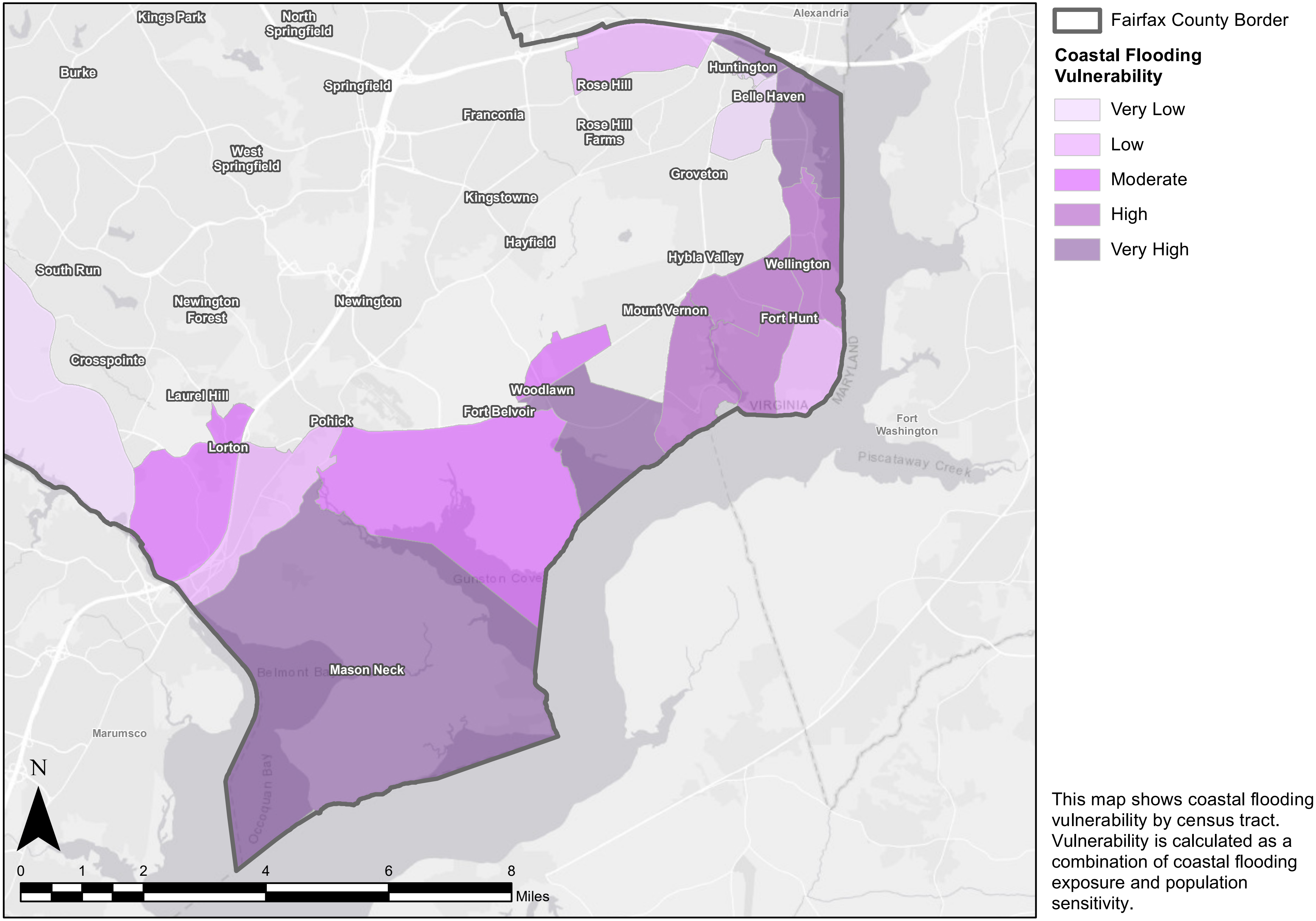
This map shows infrastructure features that may be affected by inland flooding in the future.

Coastal Flooding Exposure: Sea Level Rise and CAT 2 Storm Surge



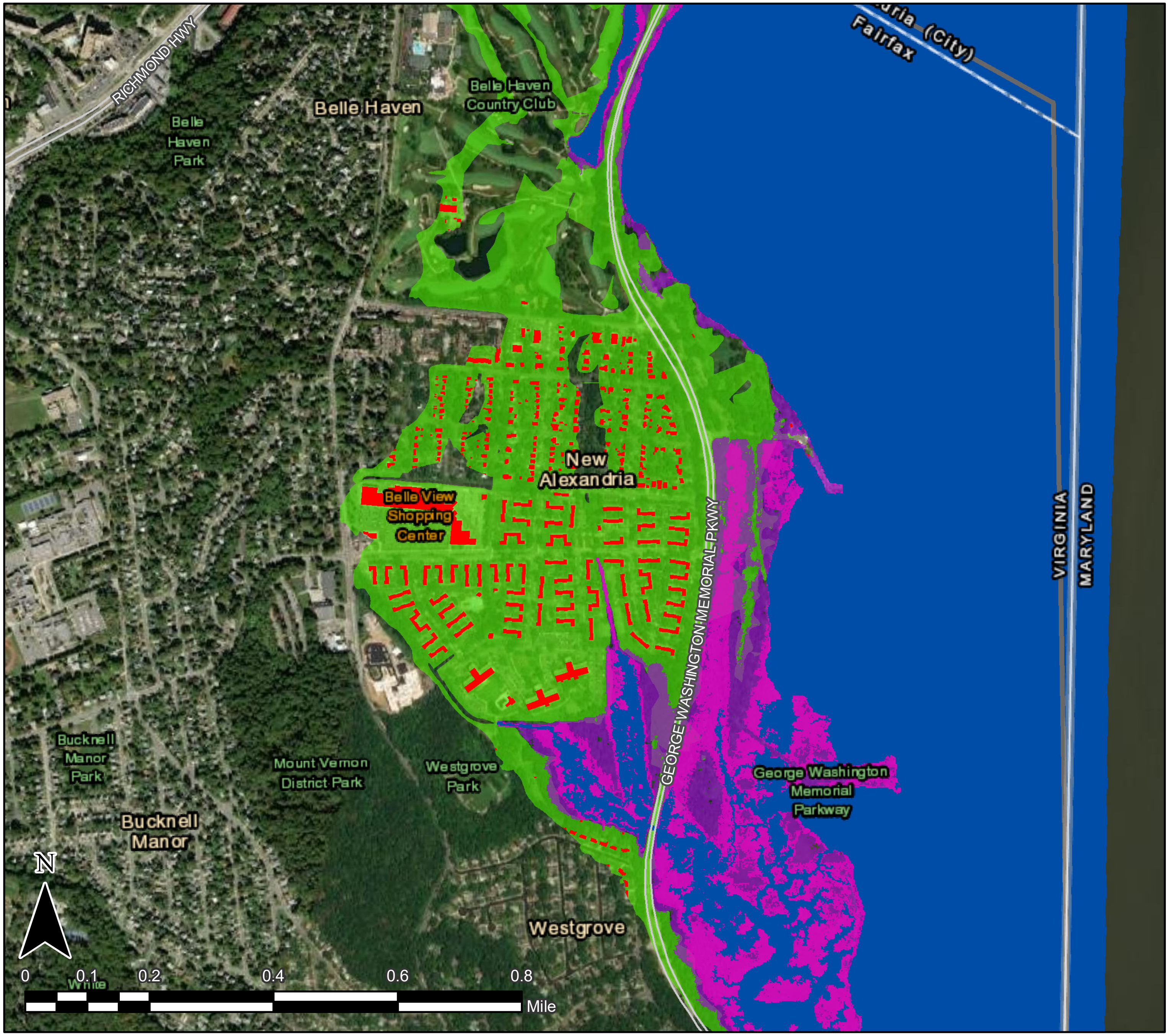
This map shows the coastal flooding projections for the county. It includes varying depths of sea level rise (SLR) and projected storm surge level for a category 2 storm event.

Vulnerability to Coastal Flooding by Census Tract



This map shows coastal flooding vulnerability by census tract. Vulnerability is calculated as a combination of coastal flooding exposure and population sensitivity.

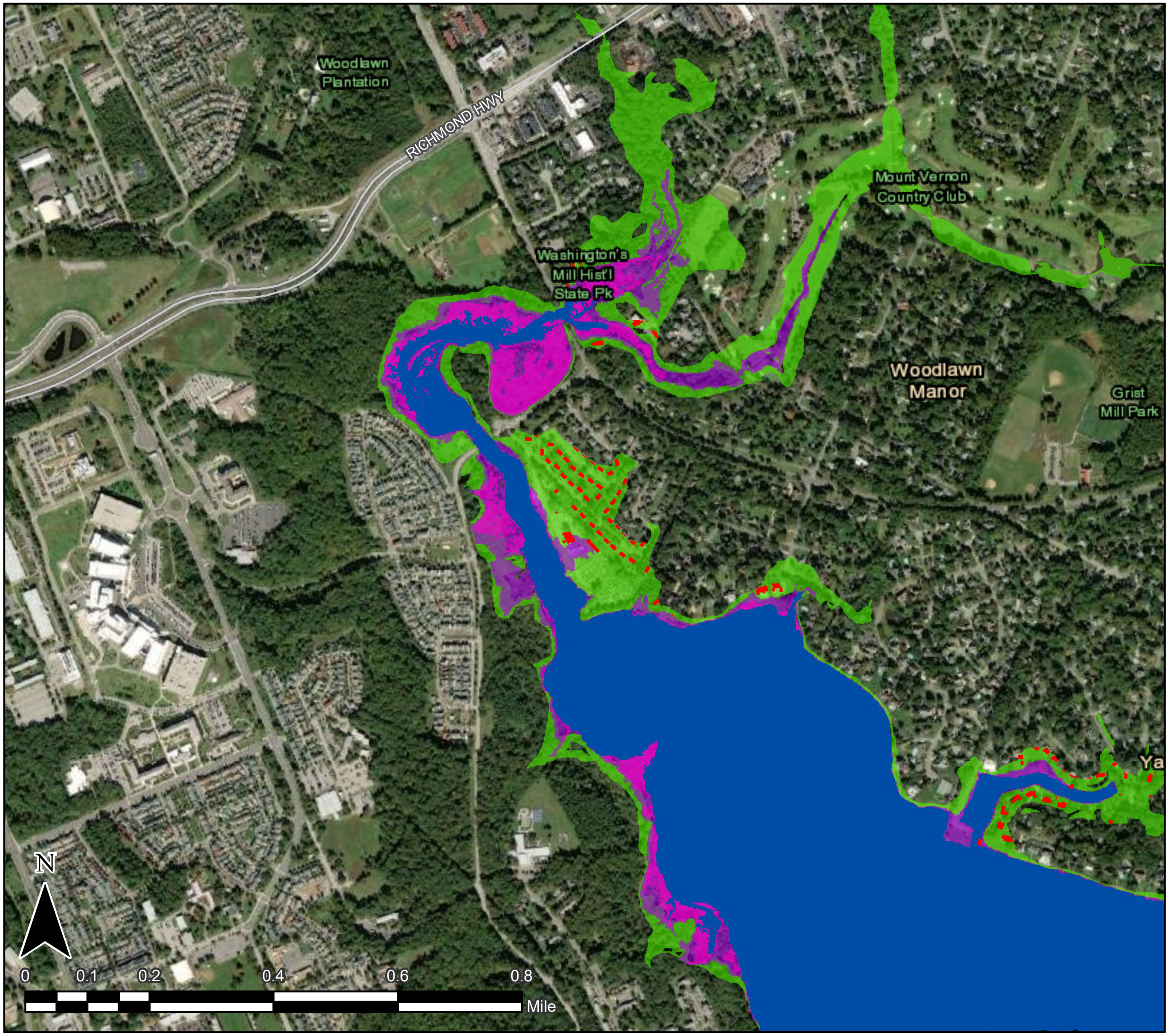
Coastal Flooding Effects on Communities - Belle Haven/New Alexandria Area



Fairfax County Border
Building Footprint
SLR 0ft
SLR 1ft
SLR 3ft
CAT 2 Storm Surge

This map shows the community features that may be affected by coastal flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other), within coastal flooding zones.

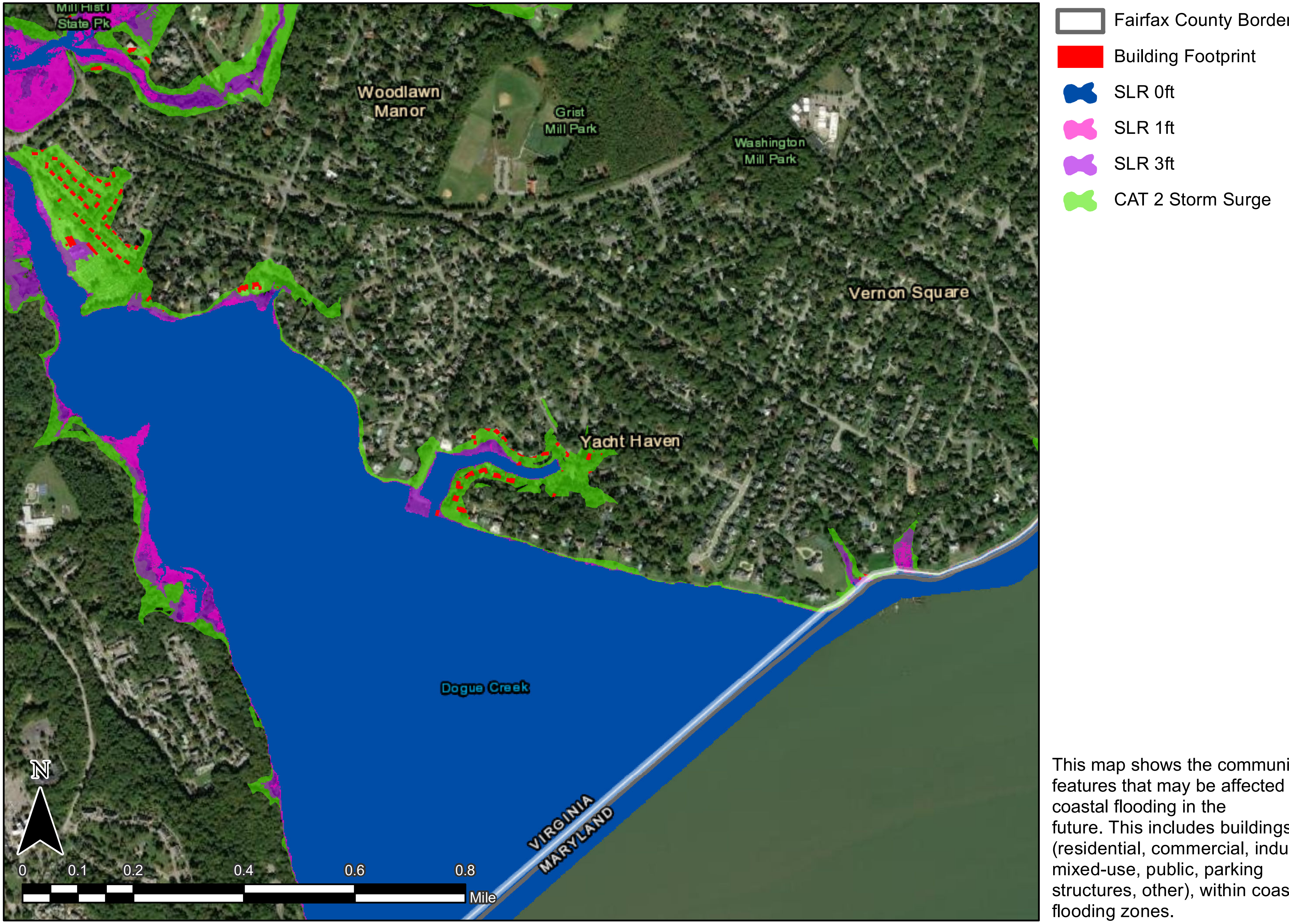
Coastal Flooding Effects on Communities - Woodlawn Area



Fairfax County Border
Building Footprint
SLR 0ft
SLR 1ft
SLR 3ft
CAT 2 Storm Surge

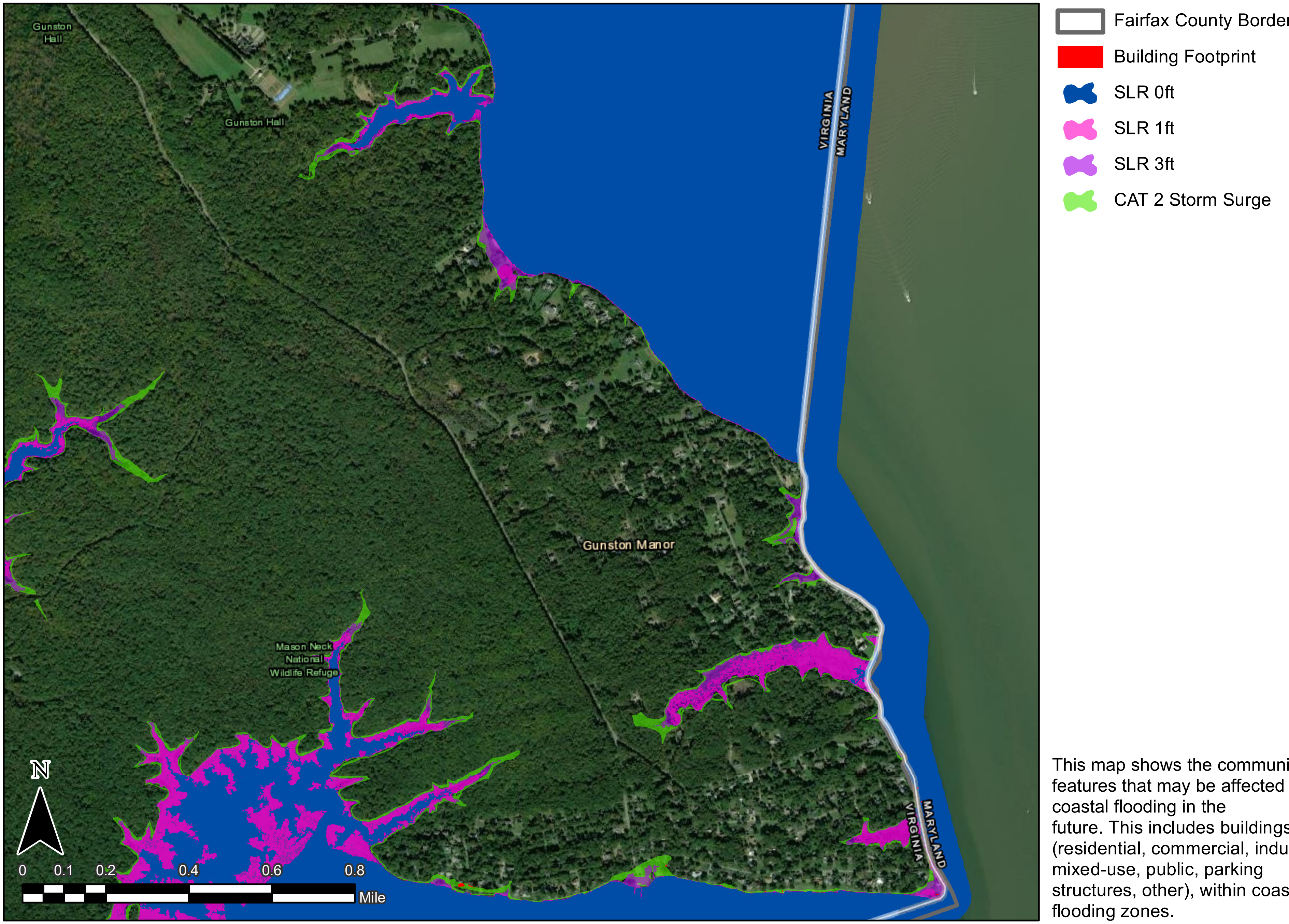
This map shows the community features that may be affected by coastal flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other), within coastal flooding zones.

Coastal Flooding Effects on Communities - Yacht Haven Area



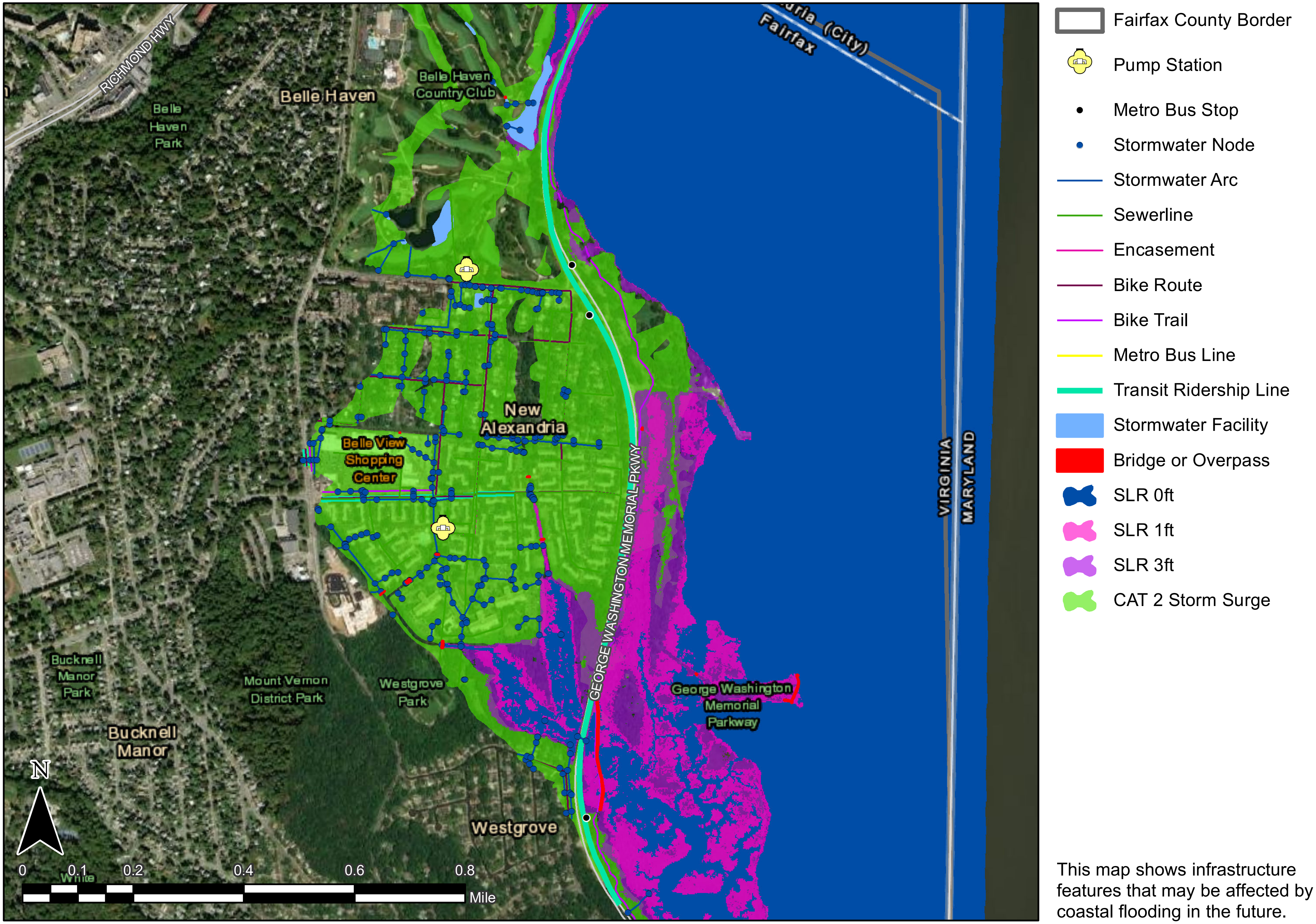
This map shows the community features that may be affected by coastal flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other), within coastal flooding zones.

Coastal Flooding Effects on Communities - Gunston Cove Area



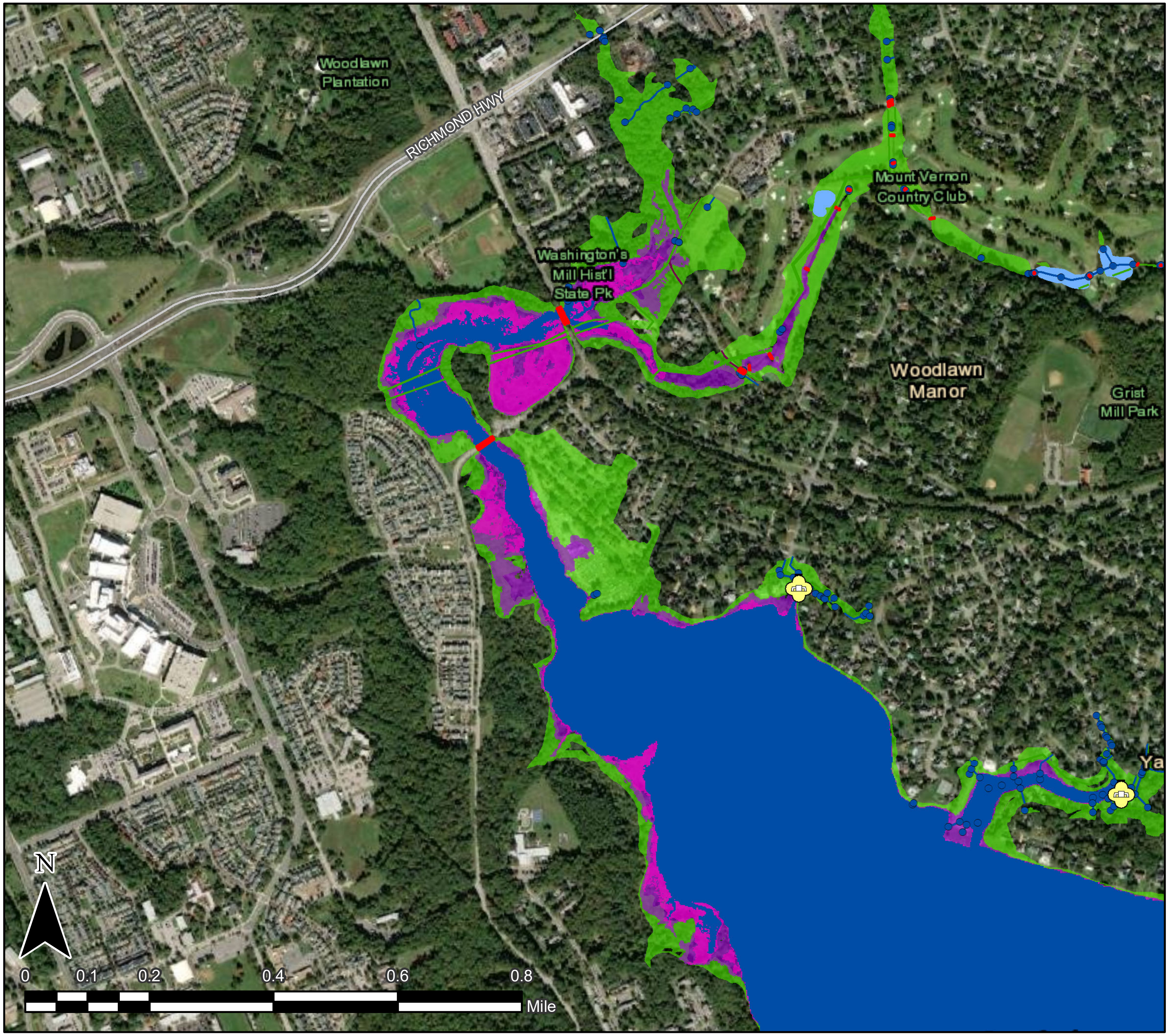
This map shows the community features that may be affected by coastal flooding in the future. This includes buildings (residential, commercial, industrial, mixed-use, public, parking structures, other), within coastal flooding zones.

Coastal Flooding Effects on Infrastructure - Belle Haven/New Alexandria Area



This map shows infrastructure features that may be affected by coastal flooding in the future.

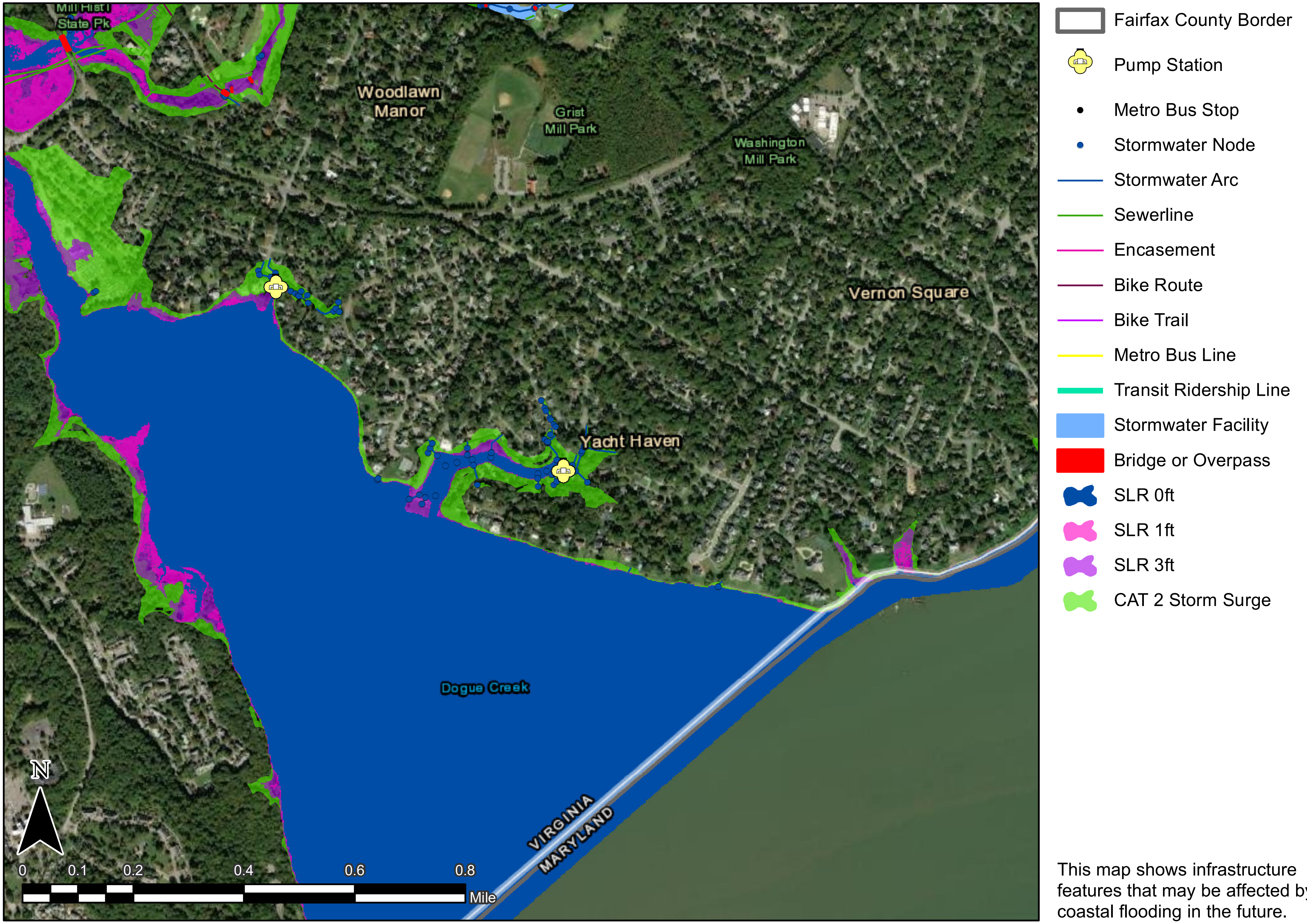
Coastal Flooding Effects on Infrastructure - Woodlawn Area



Fairfax County Border
Pump Station
Metro Bus Stop
Stormwater Node
Stormwater Arc
Sewerline
Encasement
Bike Route
Bike Trail
Metro Bus Line
Transit Ridership Line
Stormwater Facility
Bridge or Overpass
SLR 0ft
SLR 1ft
SLR 3ft
CAT 2 Storm Surge

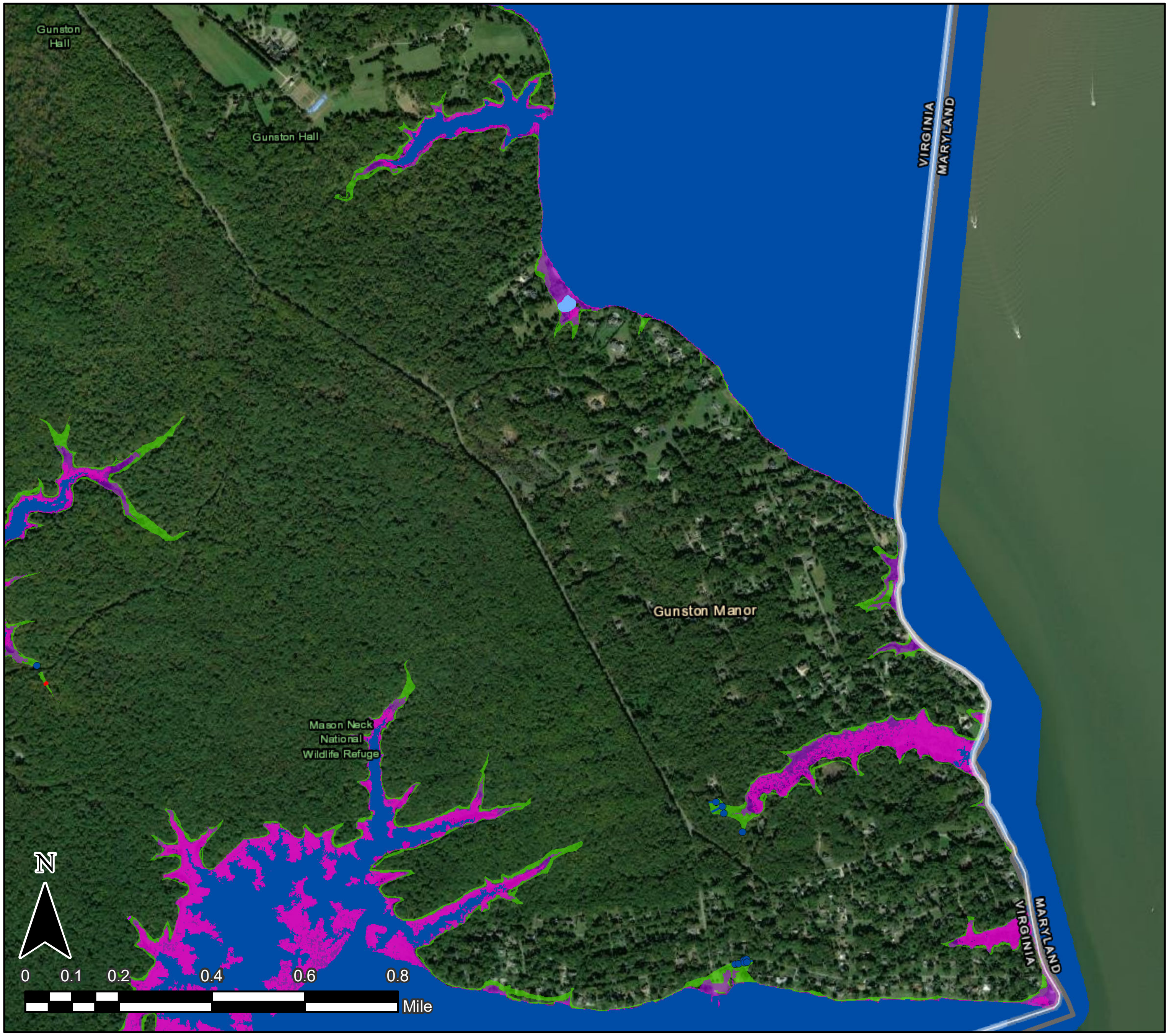
This map shows infrastructure features that may be affected by coastal flooding in the future.

Coastal Flooding Effects on Infrastructure - Yacht Haven Area



This map shows infrastructure features that may be affected by coastal flooding in the future.

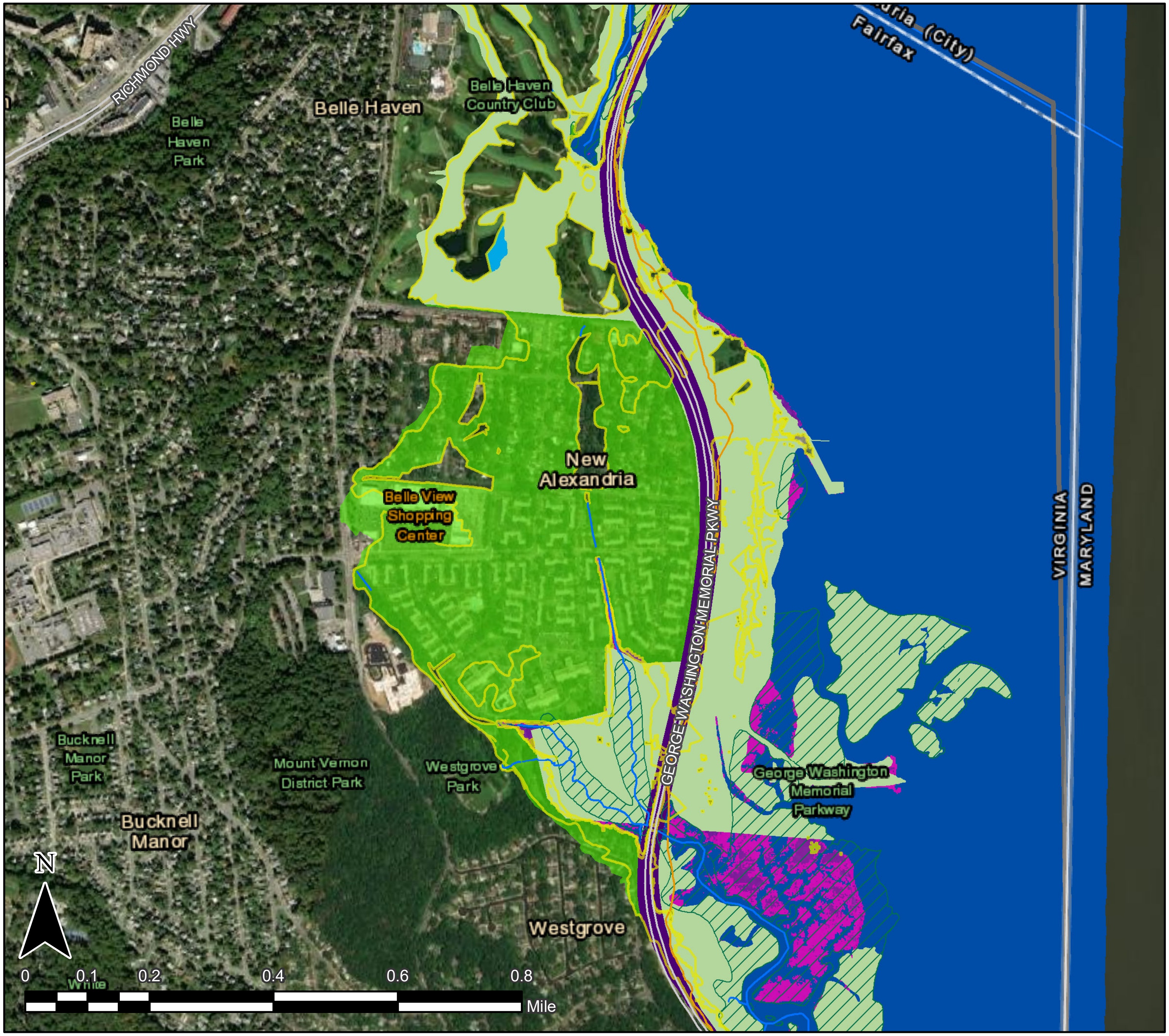
Coastal Flooding Effects on Infrastructure - Gunston Cove Area



Fairfax County Border
Pump Station
Metro Bus Stop
Stormwater Node
Stormwater Arc
Sewerline
Encasement
Bike Route
Bike Trail
Metro Bus Line
Transit Ridership Line
Stormwater Facility
Bridge or Overpass
SLR 0ft
SLR 1ft
SLR 3ft
CAT 2 Storm Surge

This map shows infrastructure features that may be affected by coastal flooding in the future.

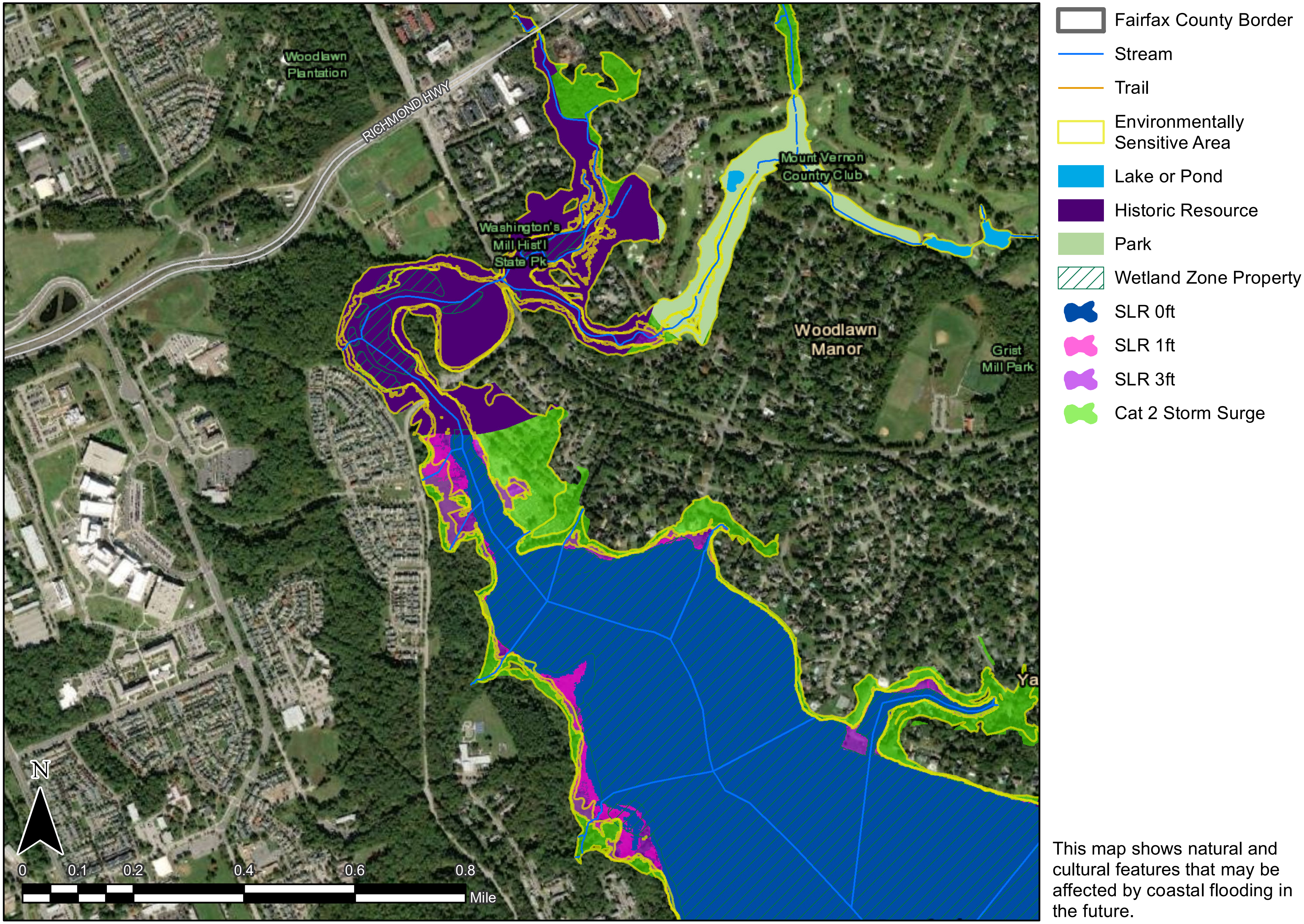
Coastal Flooding Effects on Natural and Cultural Features - Belle Haven/New Alexandria Area



Fairfax County Border
Stream
Trail
Environmentally Sensitive Area
Lake or Pond
Historic Resource
Park
Wetland Zone Property
SLR 0ft
SLR 1ft
SLR 3ft
Cat 2 Storm Surge

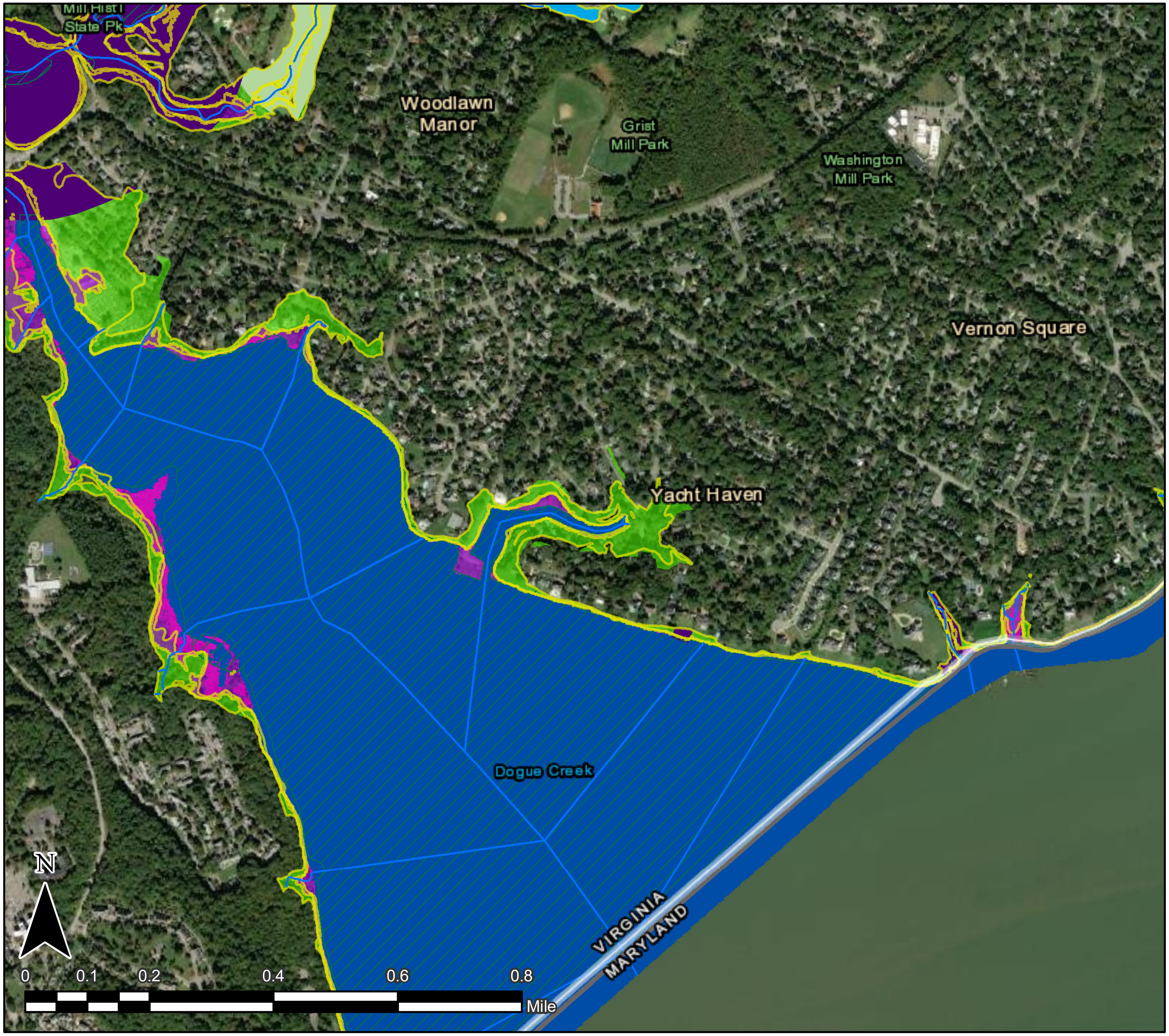
This map shows natural and cultural features that may be affected by coastal flooding in the future.

Coastal Flooding Effects on Natural and Cultural Features - Woodlawn Area



This map shows natural and cultural features that may be affected by coastal flooding in the future.

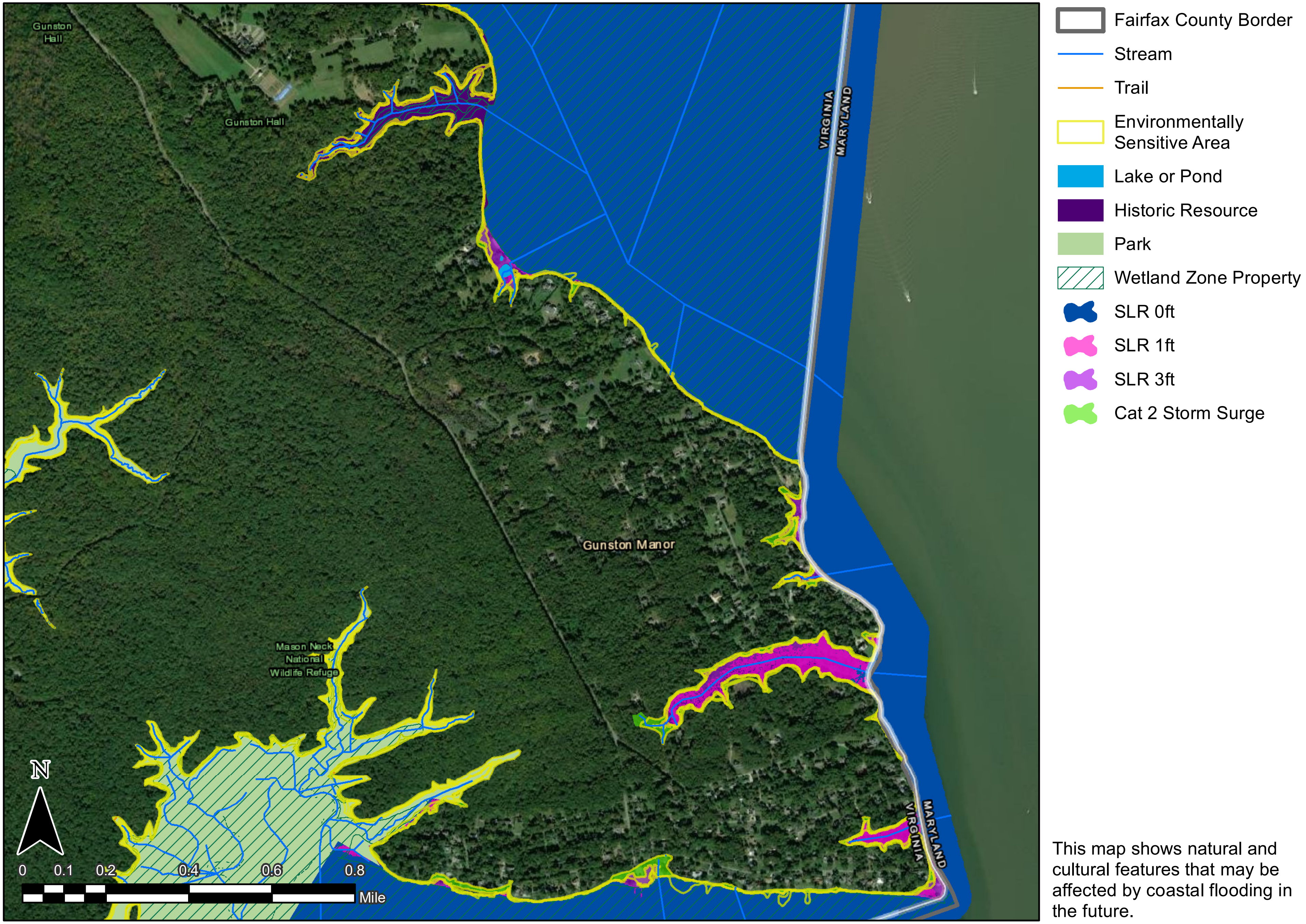
Coastal Flooding Effects on Natural and Cultural Features - Yacht Haven Area



Fairfax County Border
Stream
Trail
Environmentally Sensitive Area
Lake or Pond
Historic Resource
Park
Wetland Zone Property
SLR 0ft
SLR 1ft
SLR 3ft
Cat 2 Storm Surge

This map shows natural and cultural features that may be affected by coastal flooding in the future.

Coastal Flooding Effects on Natural and Cultural Features - Gunston Cove Area



This map shows natural and cultural features that may be affected by coastal flooding in the future.

APPENDIX 3- TABLES

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	**Unit of Analysis**	**Asset Total**	**FEMA 100-yr Flood-plain**	**FEMA 500-yr Flood-plain**	**County Recorded Flood-plain**	**Flood Score >= 2**	**Flood Score >= 4**	**Flood Score >= 6**	**High UHI**	**LST Above 100F Avg**	**"Coastal" Assets (w/n 1 mile of shore)**	**Storm Surge Cat 1, 2 with SLR**	**Tidal Flooding SLR 0 Feet**	**Sea Level Rise 1 foot +MHHW**	**Sea Level Rise 3 feet +MHHW**
Populations																
1	**General Population, by Census Tract**	Individuals	1144124	109449	117733	95187	N/A	N/A	N/A	788346	N/A	NA	39748	28717	31278	33778
		% of total		**9.57%**	**10.29%**	**8.32%**	**N/A**	**N/A**	**N/A**	**68.90%**	**N/A**	**N/A**	**3.47%**	**2.51%**	**2.73%**	**2.95%**
2	**General Population, by Household**	Households	415133.48	20692.08	22959.89	34903.09	295737.59	58316.03	3586.04	305680.02	141099.22	50609.98	3689.91	0.00	1539.09	1717.33
		Population Estimate *(2.8 per HH)*	1162373.74	57937.81	64287.70	97728.64	828065.24	163284.88	10040.91	855904.04	395077.81	141707.94	10331.74	0.00	4309.45	4808.51
		% of total		**4.98%**	**5.53%**	**8.41%**	**71.24%**	**14.05%**	**0.86%**	**73.63%**	**33.99%**	**12.19%**	**0.89%**	**0.00%**	**0.37%**	**0.41%**
		% of coastal										100.00%	7.29%	0.00%	3.04%	3.39%
3	**Vulnerable Population, by Census Tract**	Individuals	345,055	6575	7389	7271	N/A	N/A	N/A	274238	N/A	NA	601	100	335	565
		% of total		**1.91%**	**2.14%**	**2.11%**	**N/A**	**N/A**	**N/A**	**79.48%**	**N/A**	**N/A**	**0.17%**	**0.03%**	**0.10%**	**0.16%**
4	**Vulnerable Population, by Household**	Households	118,670	7202	8043	9908	77355	12435	888	108345	43603	21317	85	0	13	33
		Population Estimate *(2.8 per HH)*	332,276	20165	22521	27743	216594	34819	2486	303366	122087	59687	238	0	36	93
		% of total		**6.07%**	**6.78%**	**8.35%**	**65.19%**	**10.48%**	**0.75%**	**91.30%**	**36.74%**	**17.96%**	**0.07%**	**0.00%**	**0.01%**	**0.03%**
		% of coastal										100.00%	0.40%	0.00%	0.06%	0.16%
Public Services																
Health & Community Services																
5	Community Centers	Polygons (counts)	51	1	1	1	23	5	0	50	30	10	0	0	0	0
		% of total		**1.96%**	**1.96%**	**1.96%**	**45.10%**	**9.80%**	**0%**	**98.04%**	**58.82%**	**19.61%**	**0%**	**0%**	**0%**	**0%**
6	Hospitals & Urgent Care	Polygons (counts)	46	0	0	0	29	2	0	46	40	5	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**63.04%**	**4.35%**	**0%**	**100.00%**	**86.96%**	**10.87%**	**0%**	**0%**	**0%**	**0%**
7	Libraries	Polygons (counts)	23	0	0	1	2	1	0	23	8	4	0	0	0	0
		% of total		**0%**	**0%**	**4.35%**	**8.70%**	**4.35%**	**0%**	**100%**	**34.78%**	**17.39%**	**0%**	**0%**	**0%**	**0%**

				Inland Flooding						Urban Heat Island		Coastal Flooding				
Asset		Unit of Analysis	Asset Total	FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
8	HHS Facilities	Points (Counts)	95	1	1	0	55	1	0	93	55	29	0	0	0	0
		% of total points		**1.05%**	**1.05%**	**0.00%**	**57.89%**	**1.05%**	**0.00%**	**97.89%**	**57.89%**	**30.53%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
		Polygons (Counts)	56	1	1	0	23	1	0	55	31	9	0	0	0	0
		% of total polygons		**1.79%**	**1.79%**	**0.00%**	**41.07%**	**1.79%**	**0.00%**	**98.21%**	**55.36%**	**16.07%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
Emergency Operations																
9	Police Stations	Polygons (counts)	19	0	0	0	1	1	0	19	13	1	0	0	0	0
		% of total	-	**0%**	**0%**	**0%**	**5.26%**	**5.26%**	**0%**	**100%**	**68.42%**	**5.26%**	**0%**	**0%**	**0%**	**0%**
10	Fire Stations	Polygons (counts)	43	0	1	1	6	4	0%	43	22	8	0%	0%	0%	0%
		% of total	-	**0%**	**2.33%**	**2.33%**	**13.95%**	**9.30%**	**0%**	**100%**	**51.16%**	**18.60%**	**0%**	**0%**	**0%**	**0%**
11	Emergency Management	Polygons (Counts)	4	0	0	0	N/A	N/A	N/A	4	4	0	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**N/A**	**N/A**	**N/A**	**100%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**
Parks and Recreation																
12	County Trails	Line (miles)	334.70	91.50	103.67	107.35	N/A	N/A	N/A	79.12	5.67	32.27	3.89	0	0	0.12
		% of total		**27.34%**	**30.97%**	**32.07%**	**N/A**	**N/A**	**N/A**	**23.64%**	**1.69%**	**9.64%**	**1.16%**	**0%**	**0%**	**0.04%**
		% of coastal					-					**100%**	**12.07%**	**0%**	**0%**	**0.38%**
13	Non-County Trails	Line (miles)	304.06	29.92	33.20	41.97	N/A	N/A	N/A	132.44	16.21	73.97	8.91	0	0.47	1.55
		% of total		**9.84%**	**10.92%**	**13.80%**	**N/A**	**N/A**	**N/A**	**43.56%**	**5.33%**	**24.33%**	**2.93%**	**0%**	**0.15%**	**0.51%**
		% of coastal					-					**100%**	**12.05%**	**0%**	**0.63%**	**2.09%**
14	County Parks	Polygons (sq miles)	37.21	10.08	10.93	11.08	N/A	N/A	N/A	5.15	0.20	4.78	0.44	0	0.08	0.13
		% of total		**27.08%**	**29.37%**	**29.76%**	**N/A**	**N/A**	**N/A**	**13.84%**	**0.54%**	**12.84%**	**1.19%**	**0%**	**0.23%**	**0.34%**
		% of coastal										**100%**	**9.28%**	**0%**	**1.77%**	**2.63%**

				Inland Flooding						Urban Heat Island		Coastal Flooding				
Asset		Unit of Analysis	Asset Total	FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
15	Non-County Parks	Polygons (sq miles)	30.84	5.50	5.80	5.49	N/A	N/A	N/A	2.86	0.24	17.50	4.36	0.01	1.25	1.68
		% of total		**17.83%**	**18.81%**	**17.80%**	**N/A**	**N/A**	**N/A**	**9.27%**	**0.78%**	**56.74%**	**14.15%**	**0.03%**	**4.06%**	**5.45%**
		% of coastal										**100%**	**24.94%**	**0.06%**	**7.15%**	**9.60%**
Waste Management																
16	Landfills	Polygons (Sq miles)	1.77	0.03	0.04	0.05	N/A	N/A	N/A	1.34	0.24	1.09	0.00			
		% of total		**2%**	**2%**	**3%**	**N/A**	**N/A**	**N/A**	**76%**	**14%**	**62%**	**0%**	**0%**	**0%**	**0%**
Buildings																
17	**All Buildings**	**Polygons (counts)**	**259440**	**2063**	**2781**	**2077**	**131256**	**17141**	**814**	**174733**	**23848**	**40248**	**699**	**0**	**24**	**122**
		% of total		**0.80%**	**1.07%**	**0.80%**	**50.59%**	**6.61%**	**0.31%**	**67.35%**	**9.19%**	**15.51%**	**0.27%**	**0.00%**	**0.01%**	**0.05%**
		% of coastal										**100.00%**	**1.74%**	**0.00%**	**0.06%**	**0.30%**
18	Residential Buildings (SFR, MFR, MH)	Polygons (counts)	243872	1696	2306	1666	122726	14060	670	161025	15860	36151	576	0	22	105
		% of total		**0.70%**	**0.95%**	**0.68%**	**50.32%**	**5.77%**	**0.27%**	**66.03%**	**6.50%**	**14.82%**	**0.24%**	**0.00%**	**0.01%**	**0.04%**
		% of coastal										100.00%	1.59%	0.00%	0.06%	0.29%
19	Industrial Buildings (I)	Polygons (counts)	1841	50	90	51	781	88	3	1763	1139	260	0	0	0	0
		% of total		**2.72%**	**4.89%**	**2.77%**	**42.42%**	**4.78%**	**0.16%**	**95.76%**	**61.87%**	**14.12%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**
		% of coastal										100.00%	0.00%	0.00%	0.00%	0.00%
20	Commercial Buildings (C)	Polygons (counts)	4855	94	118	115	1884	175	26	4731	3750	549	29	0	0	3
		% of total		**1.94%**	**2.43%**	**2.37%**	**38.81%**	**3.60%**	**0.54%**	**97.45%**	**77.24%**	**11.31%**	**0.60%**	**0%**	**0%**	**0.06%**
		% of coastal										100%	5.28%	0%	0%	0.55%
21	Mixed-Use Buildings (MU)	Polygons (counts)	34	0	0	0	14	0	0	34	34	1	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**41.18%**	**0%**	**0%**	**100%**	**100%**	**2.94%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										100%	0%	0%	0%	0%

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	Unit of Analysis	Asset Total	FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
22	Parking Garage Buildings (MG)	Polygons (counts)	302	3	3	2	160	10	0	295	255	8	0	0	0	0
		% of total		**0.99%**	**0.99%**	**0.66%**	**52.98%**	**3.31%**	**0%**	**97.68%**	**84.44%**	**2.65%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										100%	0%	0%	0%	0%
23	***Public Buildings (P) (total)***	Polygons (counts)	***4907***	***155***	***191***	***177***	***3556***	***2202***	***89***	***3956***	1618	***2489***	***73***	***0***	***2***	***11***
		% of total		***3.16%***	***3.89%***	***3.61%***	***72.47%***	***44.87%***	***1.81%***	***80.62%***	***32.97%***	***50.72%***	***1.49%***	***0%***	***0.04%***	***0.22%***
		% of coastal										***100%***	***2.93%***	***0%***	***0.08%***	***0.44%***
24	*P:General*	Polygons (counts)	550	8	12	12	276	56	15	424	134	74	4	0	1	4
		% of total		**1.45%**	**2.18%**	**2.18%**	**50.18%**	**10.18%**	**2.73%**	**77.09%**	**24.36%**	**13.45%**	**0.73%**	**0%**	**0.18%**	**0.73%**
		% of coastal										100%	5.41%	0%	1.35%	5.41%
25	*P: Community / Rec Center*	Polygons (counts)	384	27	30	35	185	71	14	203	25	104	4	0	1	4
		% of total		**7.03%**	**7.81%**	**9.11%**	**48.18%**	**18.49%**	**3.65%**	**52.86%**	**6.51%**	**27.08%**	**1.04%**	**0%**	**0.26%**	**1.04%**
		% of coastal										100%	3.85%	0%	0.96%	3.85%
26	*P: Education Facility*	Polygons (counts)	1186	0	0	0	874	73	1	1085	498	178	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**73.69%**	**6.16%**	**0.08%**	**91.48%**	**41.99%**	**15.01%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										100%	0%	0%	0%	0%
27	*P: Government or Military*	Polygons (counts)	2304	65	90	77	1993	1893	1	2034	892	1994	56	0	0	2
		% of total		**2.82%**	**3.91%**	**3.34%**	**86.50%**	**82.16%**	**0.04%**	**88.28%**	**38.72%**	**86.55%**	**2.43%**	**0%**	**0%**	**0.09%**
		% of coastal										100%	2.81%	0%	0%	0.10%
28	*P: Health or Medical Facility*	Polygons (counts)	26	0	0	1	13	2	0	23	21	3	0	0	0	0
		% of total		**0%**	**0%**	**3.85%**	**50.00%**	**7.69%**	**0%**	**88.46%**	**80.77%**	**11.54%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										100%	0%	0%	0%	0%
29	*P: Historic Site / Point of Interest*	Polygons (counts)	428	54	58	51	203	107	58	159	29	134	9	0	0	1
		% of total		**12.62%**	**13.55%**	**11.92%**	**47.43%**	**25.00%**	**13.55%**	**37.15%**	**6.78%**	**31.31%**	**2.10%**	**0%**	**0%**	**0.23%**
		% of coastal										100%	6.72%	0%	0%	0.75%

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	**Unit of Analysis**	**Asset Total**	**FEMA 100-yr Flood-plain**	**FEMA 500-yr Flood-plain**	**County Recorded Flood-plain**	**Flood Score >= 2**	**Flood Score >= 4**	**Flood Score >= 6**	**High UHI**	**LST Above 100F Avg**	**"Coastal" Assets (w/n 1 mile of shore)**	**Storm Surge Cat 1, 2 with SLR**	**Tidal Flooding SLR 0 Feet**	**Sea Level Rise 1 foot +MHHW**	**Sea Level Rise 3 feet +MHHW**
30	*P: Transportation Facility*	Polygons (counts)	29	1	1	1	12	0	0	28	19	2	0	0	0	0
		% of total		**3.45%**	**3.45%**	**3.45%**	**41.38%**	**0%**	**0%**	**96.55%**	**65.52%**	**6.90%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										100%	0%	0%	0%	0%
31	Other Buildings	Polygons (counts)	3,629	65	73	66	2135	606	26	2929	1192	790	21	0	0	3
		% of total		**1.79%**	**2.01%**	**1.82%**	**58.83%**	**16.70%**	**0.72%**	**80.71%**	**32.85%**	**21.77%**	**0.58%**	**0%**	**0%**	**0.08%**
		% of coastal										100%	2.66%	0%	0%	0.38%
32	Buildings on County Property (BOS, FCPA, FCPS)	Polygons (counts)	2,974	84	119	117	N/A	N/A	N/A	2454	909	600	14	0	0	0
		% of total		**2.82%**	**4.00%**	**3.93%**	**N/A**	**N/A**	**N/A**	**82.52%**	**30.56%**	**20.17%**	**0.47%**	**0%**	**0%**	**0%**
		% of coastal										100%	2.33%	0%	0%	0%
Water																
Drinking Water Infrastructure																
33	Griffith Water Treatment Plant	Polygons (Count)	7	0	0	0	7	0	0	7	0	7	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**100%**	**0%**	**0%**	**100%**	**0%**	**100%**	**0%**	**0%**	**0%**	**0%**
34	James J Corbalis Jr Water Treatment	Polygons (Count)	17	0	0	0	0	0	0	17	0	0	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
35	Fairfax Water Headquarters	Polygons (Count)	1	0	0	0	0	0	0	1	1	0	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**100%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**
36	Fairfax Water Other Buildings	Polygons (Count)	16	0	0	0	16	0	0	16	0	16	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**100%**	**0%**	**0%**	**100%**	**0%**	**100%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										**100%**	**0%**	**0%**	**0%**	**0%**
37	Drinking Water Lines	Lines (Miles)	4081.60	50.17	64.08	65.36	630.51	64.10	3.41	N/A	N/A	517.32	18.46	0	0.17	0.83
				1.23%	**1.57%**	**1.60%**	**15.45%**	**1.57%**	**0.08%**	**N/A**	**N/A**	**12.67%**	**0.45%**	**0%**	**0.00%**	**0.02%**
												100.00%	**3.57%**	**0%**	**0.03%**	**0.16%**

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	Unit of Analysis	Asset Total	FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
Stormwater Infrastructure																
38	Stormwater Management Facilities	Polygon (Counts)	9077	238	296	499	N/A	N/A	N/A	7417	2718	1034	32	1	8	17
		% of total		**2.62%**	**3.26%**	**5.50%**	**N/A**	**N/A**	**N/A**	**81.71%**	**29.94%**	**11.39%**	**0.35%**	**0.01%**	**0.09%**	**0.19%**
		% of coastal										**100.00%**	**3.09%**	**0.10%**	**0.77%**	**1.64%**
39	Stormwater Arcs	line (miles)	3,680.46	139.38	161.67	212.01	N/A	N/A	N/A	N/A	N/A	460.53	15.77	0.09	1.68	4.57
		% of total		**3.79%**	**4.39%**	**5.76%**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**12.51%**	**0.43%**	**0.00%**	**0.05%**	**0.12%**
		% of coastal										**100%**	**3.42%**	**0.02%**	**0.36%**	**0.99%**
40	Stormwater Nodes	Point (Count)	209,212	7803	9158	12701	N/A	N/A	N/A	161018	48226	25,811	979	4	109	289
		% of total		**3.73%**	**4.38%**	**6.07%**	**N/A**	**N/A**	**N/A**	**76.96%**	**23.05%**	**12.34%**	**0.47%**	**0.00%**	**0.05%**	**0.14%**
		% of coastal										**100%**	**3.79%**	**0.02%**	**0.42%**	**1.12%**
41	Service Requests	Point (Count)	57954	1668	1882	1890	39066	11850	1491	N/A	N/A	9948	626	0	N/A	N/A
		% of total		**2.88%**	**3.25%**	**3.26%**	**67.41%**	**20.45%**	**2.57%**	**N/A**	**N/A**	**17.17%**	**1.08%**	**0.00%**	**N/A**	**N/A**
Wastewater Infrastructure																
42	Noman Cole Wastewater Treatment Plant	Polygon (Count)	1	1	1	1	N/A	N/A	N/A	1	1	1	0	0	0	0
		% of total		**100%**	**100%**	**100%**	**N/A**	**N/A**	**N/A**	**100%**	**100%**	**100%**	**0%**	**0%**	**0%**	**0%**
43	Upper Occoquan Sewage Treatment Plant	Polygon (Count)	1	1	1	1	N/A	N/A	N/A	1	1	0	0	0	0	0
		% of total		**100%**	**100%**	**100%**	**N/A**	**N/A**	**N/A**	**100%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**
44	Sewer Structures	Points (Count)	107,179	4664	5394	6496	24,535	3329	229	76,014	15069	12,925	386	0	8	52
		% of total		**4.35%**	**5.03%**	**6.06%**	**22.89%**	**3.11%**	**0.21%**	**70.92%**	**14.06%**	**12.06%**	**0.36%**	**0.00%**	**0.01%**	**0.05%**
		% of coastal										100%	3%	0%	0%	0%
45	Sewer Lines	Line (Miles)	3,449.96	257.20	286.80	334.40	826.13	136.79	9.30	NA	N/A	471.36	35.90	0.00	1.14	3.59
		% of total		**7.46%**	**8.31%**	**9.69%**	**23.95%**	**3.97%**	**0.27%**	**N/A**	**N/A**	**13.66%**	**1.04%**	**0.00%**	**0.03%**	**0.10%**
		% of coastal										**100%**	**7.62%**	**0.00%**	**0.24%**	**0.76%**
46	Wastewater Pump Stations	Points (Count)	59	13	16	17	19	5	0	26	3	27	5	0	0	0
		% of total		**22.03%**	**27.12%**	**28.81%**	**32.20%**	**8.47%**	**0.00%**	**44.07%**	**5.08%**	**45.76%**	**8.47%**	**0%**	**0%**	**0%**
		% of coastal										**100.00%**	**18.52%**	**0%**	**0%**	**0%**

	Asset	Unit of Analysis	Asset Total	Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	**Unit of Analysis**	**Asset Total**	**FEMA 100-yr Flood-plain**	**FEMA 500-yr Flood-plain**	**County Recorded Flood-plain**	**Flood Score >= 2**	**Flood Score >= 4**	**Flood Score >= 6**	**High UHI**	**LST Above 100F Avg**	**"Coastal" Assets (w/n 1 mile of shore)**	**Storm Surge Cat 1, 2 with SLR**	**Tidal Flooding SLR 0 Feet**	**Sea Level Rise 1 foot +MHHW**	**Sea Level Rise 3 feet +MHHW**
47	Wastewater Encasements	line (miles)	49.65	9.64	10.37	11.69	13.98	3.39	0.28	N/A	N/A	5.44	0.59	0.00	0.24	0.34
		% of total		**19.42%**	**20.89%**	**23.55%**	**28.16%**	**6.83%**	**0.56%**	**N/A**	**N/A**	**10.96%**	**1.20%**	**0.00%**	**0.48%**	**0.68%**
		% of coastal										**100%**	**10.93%**	**0.00%**	**4.39%**	**6.23%**
Energy & Comms																
48	Electric: Major Utility Lines	Line (miles)	107.16	10.40	11.60	12.80	40.47	4.09	0.07	55.78	10.60	17.93	0.96	0.0	0.13	0.16
		% of total		**9.71%**	**10.83%**	**11.95%**	**37.77%**	**3.82%**	**0.06%**	**52.05%**	**9.89%**	**16.73%**	**0.90%**	**0%**	**0.12%**	**0.15%**
		% of coastal										**100%**	**5.35%**	**0%**	**0.74%**	**0.89%**
49	Electric Utility Owned Assets	Polygons (Count)	75	10	10	15	26	1	0	65	26	14	0	0	0	0
		% of total		**13.33%**	**13.33%**	**20.00%**	**34.67%**	**1.33%**	**0%**	**86.67%**	**34.67%**	**18.67%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										**100%**	**0%**	**0%**	**0%**	**0%**
50	Gas: Major Utility Lines	Line (miles)	129.63	5.91	6.80	8.70	51.65	4.24	0.34	62.51	8.40	15.78	0.23	0	0.07	0.11
		% of total		**4.56%**	**5.25%**	**6.71%**	**39.84%**	**3.27%**	**0.26%**	**48.22%**	**6.48%**	**12.17%**	**0.18%**	**0%**	**0.05%**	**0.09%**
		% of coastal										**100%**	**1.46%**	**0%**	**0.43%**	**0.73%**
51	Gas Utility Owned Assets	Polygons (Count)	23	3	3	3	11	0	0	18	6	1	0	0	0	0
		% of total		**13.04%**	**13.04%**	**13.04%**	**47.83%**	**0%**	**0%**	**78.26%**	**26.09%**	**4.35%**	**0%**	**0%**	**0%**	**0%**
52	Telephone: Major Utility Lines	Line (miles)	14.12	1.07	1.17	1.37	4.59	0.53	0.01	6.74	0.21	2.41	0	0	0	0
		% of total		**7.57%**	**8.28%**	**9.72%**	**32.51%**	**3.75%**	**0.10%**	**47.73%**	**1.49%**	**17.07%**	**0%**	**0%**	**0%**	**0%**
53	Communications Utility Owned Properties	Polygon (Counts)	33	1	1	5	28	4	0	30	13	5	0	0	0	0
		% of total		**3.03%**	**3.03%**	**15.15%**	**84.85%**	**12.12%**	**0.00%**	**90.91%**	**39.39%**	**15.15%**	**0%**	**0%**	**0%**	**0%**
54	Communications Towers	Polygon (Counts)	69	0	0	0	32	8	0	48	10	13	0	0	0	0
		% of total		**0.00%**	**0.00%**	**0.00%**	**46.38%**	**11.59%**	**0.00%**	**69.57%**	**14.49%**	**18.84%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	**Unit of Analysis**	**Asset Total**	**FEMA 100-yr Flood-plain**	**FEMA 500-yr Flood-plain**	**County Recorded Flood-plain**	**Flood Score >= 2**	**Flood Score >= 4**	**Flood Score >= 6**	**High UHI**	**LST Above 100F Avg**	**"Coastal" Assets (w/n 1 mile of shore)**	**Storm Surge Cat 1, 2 with SLR**	**Tidal Flooding SLR 0 Feet**	**Sea Level Rise 1 foot +MHHW**	**Sea Level Rise 3 feet +MHHW**
Transportation																
Roadway																
55	Electric Vehicle Charging Stations	Points (Count)	46	0	0	0	23	2	0	45	32	1	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**50%**	**4%**	**0%**	**98%**	**70%**	**2%**	**0%**	**0%**	**0%**	**0%**
		% of coastal										**100%**	**0%**	**0%**	**0%**	**0%**
56	Bridge Segments	Polygon (Count)	3422	701	730	820	N/A	N/A	N/A	2082	659	296	130	0	53	73
		% of total		**20.49%**	**21.33%**	**23.96%**	**N/A**	**N/A**	**N/A**	**60.84%**	**19.26%**	**8.65%**	**3.80%**	**0.00%**	**1.55%**	**2.13%**
		% of coastal					-					**100%**	**43.92%**	**0.00%**	**17.91%**	**24.66%**
57	Roadway Centerlines	Line (Miles)	4,948.87	70.878	89.13	83.13	N/A	N/A	N/A	3601.2	854.38	757.89	42.71	0	0.94	1.85
		% of total		**1.43%**	**1.80%**	**1.68%**	**N/A**	**N/A**	**N/A**	**72.77%**	**17.26%**	**15.31%**	**0.86%**	**0%**	**0.02%**	**0.04%**
		% of coastal					-					**100%**	**5.64%**	**0%**	**0.12%**	**0.24%**
Transit and Rail																
58	Metrorail	Line (Miles)	21.92	0.25	0.27	0.20	N/A	N/A	N/A	21.39	4.88	0.68	0.28	0	0.03	0.03
		% of total		**1.13%**	**1.24%**	**0.92%**	**N/A**	**N/A**	**N/A**	**97.56%**	**22.24%**	**3.09%**	**1.26%**	**0%**	**0.13%**	**0.14%**
		% of coastal					-					**100%**	**40.92%**	**0%**	**4.28%**	**4.58%**
59	Metrorail Stations	Polygon (Counts)	10	1	1	1	4	1	0	10	8	1	0	0	0	0
		% of total		**10%**	**10%**	**10%**	**40%**	**10%**	**0%**	**100%**	**80%**	**10%**	**0%**	**0%**	**0%**	**0%**
60	Metro Bus Lines	Line (miles)	463.27	7.69	11.06	9.84	N/A	N/A	N/A	425.48	193.74	54.90	3.44	0.00	0.14	0.23
		% of total		**1.66%**	**2.39%**	**2.12%**	**N/A**	**N/A**	**N/A**	**91.84%**	**41.82%**	**11.9%**	**0.74%**	**0.00%**	**0.03%**	**0.05%**
		% of coastal					-					**100%**	**6.26%**	**0.00%**	**0.26%**	**0.41%**
61	Metro Bus Stops	Points (Count)	1509	12	17	23	208	46	0	1282	458	116	4	0	0	0
				0.80%	**1.13%**	**1.52%**	**13.78%**	**3.05%**	**0.00%**	**84.96%**	**30.35%**	**7.69%**	**0.27%**	**0.00%**	**0.00%**	**0.00%**
												100%	**3%**	**0%**	**0%**	**0%**
62	Fairfax Connector Bus Stops	Points (Count)	3,078	27	34	52	360	65	0	2679	1019	487	10	0	0	0
				0.88%	**1.10%**	**1.69%**	**11.70%**	**2.11%**	**0.00%**	**87.04%**	**33.11%**	**15.82%**	**0.32%**	**0.00%**	**0.00%**	**0.00%**
												100%	**2%**	**0%**	**0%**	**0%**

				Inland Flooding						Urban Heat Island		Coastal Flooding				
	Asset	Unit of Analysis	Asset Total	FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
63	Private Railroads	Line (miles)	80.83	0.67	5.51	3.87	55.06	10.34	0.00	52.92	10.75	11.26	0	0	0	0
		% of total		**0.82%**	**6.81%**	**4.79%**	**68.12%**	**12.79%**	**0.00%**	**65.47%**	**13.30%**	**13.93%**	**0%**	**0%**	**0%**	**0%**
64	Virginia Railway Express Stations	Points (Count)	5	0	0	0	4	1	0	5	0	0	0	0	0	0
		% of total		**0%**	**0%**	**0%**	**80%**	**20%**	**0%**	**100%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**
Bike & Ped																
65	Bicycle Routes	Line (Miles)	1,577.26	21.15	28.18	32.61	N/A	N/A	N/A	1115.22	242.81	221.39	8.02	0.00	0.14	0.36
		% of total	100%	**1.34%**	**1.79%**	**2.07%**	**N/A**	**N/A**	**N/A**	**70.71%**	**15.39%**	**14.04%**	**0.51%**	**0.00%**	**0.01%**	**0.02%**
		% of coastal							-			**100%**	**3.62%**	**0.00%**	**0.06%**	**0.16%**
66	Bicycle Trails	Line (Miles)	949.89	118.59	135.73	156.60	N/A	N/A	N/A	486.88	110.01	136.30	11.70	0.00	0.55	1.69
		% of total		**12.48%**	**14.29%**	**16.49%**	**N/A**	**N/A**	**N/A**	**51.26%**	**11.58%**	**14.35%**	**1.23%**	**0.00%**	**0.06%**	**0.18%**
		% of coastal							-			**100.00%**	**8.59%**	**0.00%**	**0.40%**	**1.24%**
67	Walkways	Line (Miles)	4106.30	63.85	75.09	96.22	1097.17	160.93	9.91	3412.29	760.01	498.99	39.21	0.14	0.52	1.86
		% of total	100%	**1.55%**	**1.83%**	**2.34%**	**26.72%**	**3.92%**	**0.24%**	**83.10%**	**18.51%**	**12.15%**	**0.95%**	**0.00%**	**0.01%**	**0.05%**
		% of coastal										**100%**	**7.86%**	**0.03%**	**0.10%**	**0.37%**
68	Capital Bike Share	Points (Counts)	54	0	0	0	9	0	0	52	22	0	0	0	0	0
		% of total	100%	**0%**	**0%**	**0%**	**16.67%**	**0%**	**0%**	**96.30%**	**40.74%**	**0%**	**0%**	**0%**	**0%**	**0%**
Natural and Cultural																
Water Bodies, Wetlands, ESAs																
69	Water Bodies: Lakes, Ponds, Rivers, Streams, Swamps	Polygon (sq miles)	17.12	15.09	15.13	5.49	N/A	N/A	N/A	0.96	0.06	12.34	11.14	0.00	10.82	11.09
		% of total		**88.14%**	**88.38%**	**32.07%**	**N/A**	**N/A**	**N/A**	**5.61%**	**0.37%**	**72.08%**	**65.08%**	**0.00%**	**63.20%**	**64.75%**
		% of coastal										**100%**	**90.29%**	**0.01%**	**87.68%**	**89.83%**
70	Wetlands USFWS	Polygon (Sq miles)	28.66	22.59	22.79	13.21	9.16	2.94	0.18	1.77	0.14	15.59	12.15	0.00	11.25	11.76
		% of total		**78.82%**	**79.52%**	**46.09%**	**31.97%**	**10.26%**	**0.61%**	**6.16%**	**0.48%**	**54.39%**	**42.39%**	**0.01%**	**39.27%**	**41.05%**
		% of coastal										**100.00%**	**77.94%**	**0.01%**	**72.20%**	**75.47%**

		Unit of Analysis	Asset Total	Inland Flooding						Urban Heat Island		Coastal Flooding				
Asset				FEMA 100-yr Flood-plain	FEMA 500-yr Flood-plain	County Recorded Flood-plain	Flood Score >= 2	Flood Score >= 4	Flood Score >= 6	High UHI	LST Above 100F Avg	"Coastal" Assets (w/n 1 mile of shore)	Storm Surge Cat 1, 2 with SLR	Tidal Flooding SLR 0 Feet	Sea Level Rise 1 foot +MHHW	Sea Level Rise 3 feet +MHHW
71	Environmentally Sensitive Areas	Polygon (Sq miles)	180.99	76.20	80.36	81.87	N/A	N/A	N/A	25.27	0.84	52.73	38.08	0.02	13.84	15.60
		% of total		**42.10%**	**44.40%**	**45.23%**	**N/A**	**N/A**	**N/A**	**13.96%**	**0.46%**	**29.13%**	**21.04%**	**0.01%**	**7.65%**	**8.62%**
		% of coastal										**100.00%**	**72.22%**	**0.04%**	**26.24%**	**29.59%**
Trees																
72	Tree Cover 2015	Polygon (Sq miles)	223.255	21.61	23.56	25.29	109.27	19.49	0.99	63.70	5.71	49.46	4.08	0.00	0.61	1.12
		% of total		**9.68%**	**10.55%**	**11.33%**	**48.94%**	**8.73%**	**0.44%**	**28.53%**	**2.56%**	**22.15%**	**1.83%**	**0.00%**	**0.27%**	**0.50%**
		% of coastal										**100.00%**	**8.24%**	**0.01%**	**1.23%**	**2.26%**
Agriculture																
73	Agricultural and Forestal Districts	Polygon (Sq miles)	4.78	0.33	0.37	0.34	1.99	0.07	0.00	0.27	0.00	0.81	0.14	0.00	0.01	0.03
		% of total		**6.98%**	**7.69%**	**7.08%**	**41.63%**	**1.42%**	**0.00%**	**5.57%**	**0.00%**	**16.88%**	**3.02%**	**0.00%**	**0.28%**	**0.70%**
		% of coastal										**100.00%**	**17.87%**	**0.00%**	**1.67%**	**4.13%**
74	Potential Agricultural Use Parcels	Polygon (Sq miles)	129.29	6.04	6.70	8.41	62.11	4.96	0.46	23.91	1.45	18.01	0.55	0.00	0.24	0.33
		% of total		**4.67%**	**5.18%**	**6.50%**	**48.04%**	**3.84%**	**0.36%**	**18.49%**	**1.12%**	**13.93%**	**0.43%**	**0.00%**	**0.18%**	**0.26%**
		% of coastal										**100.00%**	**3.05%**	**0.00%**	**1.31%**	**1.83%**
Cultural and Historic Resources																
75	Inventory of Historic Sites	Polygon (Counts)	365	67	70	84	259	80	9	132	77	62	21	0	18	19
		% of total		**18.36%**	**19.18%**	**23.01%**	**70.96%**	**21.92%**	**2.47%**	**36.16%**	**21.10%**	**16.99%**	**5.75%**	**0%**	**4.93%**	**5.21%**
		% of coastal										**100.00%**	**33.87%**	**0%**	**29.03%**	**30.65%**
76	*Public Bldgs: Historic Site / Point of Interest*	Polygons (counts)	428	54	58	51	203	107	58	159	29	134	9	0	0	1
		% of total		**12.62%**	**13.55%**	**11.92%**	**47.43%**	**25.00%**	**13.55%**	**37.15%**	**6.78%**	**31.31%**	**2.10%**	**0%**	**0%**	**0.23%**
		% of coastal										**100.00%**	**6.72%**	**0%**	**0%**	**0.75%**

ENDNOTES

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