

CHAPTER 4

THREAT & HAZARD IDENTIFICATION AND RISK ASSESSMENT

THREAT & HAZARD IDENTIFICATION AND RISK ASSESSMENT

Title 44 Code of Federal Regulations (CFR) § 201.6 requires local jurisdictions to have an HMP with data derived from a risk assessment. The 2020 Central Shenandoah Hazard Mitigation Plan includes a Hazard Identification and Risk Assessment (HIRA) that measures the region's vulnerability to 12 specific hazards. For this update, the CSPDC broadened the scope of the risk assessment to include a profile on man-made, non-natural threats. Thus, this chapter of the plan will be referred to as the Threat and Hazard Identification and Risk Assessment (THIRA).

Analyzing hazard data through a risk assessment allows communities to better determine and understand most likely and worst-case impacts of those hazards to the people, infrastructure, environment, and economy. The THIRA thereby supports informed decision-making on mitigation priorities to lessen the impacts and to acquire disaster related grants in the aftermath of a disaster.

In sum, the purpose of the THIRA is to:

- Identify hazards that have affected and/or could affect the region,
- profile hazard events and determine what areas and community assets are the most vulnerable to damage from these hazards,
- and estimate losses and prioritze the potential risks.

THREAT AND HAZARD PROFILES

Flooding	Tropical Storm / Hurricane	High Winds	Wildfire
Drought	Sinkholes	Extreme Temperatures	Severe Winter Weather
Infectious Disease Outbreak	Hazardous Materials Release	Critical Infrastructure Failure	Active Assailant

METHODS

The CSPDC followed a standardized five-step process to identify relevant threats and hazards and to assess the risks posed to the region.

1. **Identify the Hazards:** the planning district's Steering Committee voted on the top threats and hazards of highest concern that occur within the geographic area; these are the hazards that received further analysis as part of the THIRA process.

2. **Describe the Hazards:** the final list of threats and hazards were researched for the planning region, (annotating probability, magnitude, secondary effects, estimated losses, etc.) using available tools and resources.

3. **Identify Critical Facilities:** the CSPDC's existing dataset of community-identified critical facilities was updated to incorporate any changes in the last 5 years (e.g., new critical construction, decommissioning of old infrastructure, etc.).

4. **Calculate Risk:** the hazards were analyzed using information gathered during steps 1-3 and then quantified using a simplified risk formula:

   Risk = Probability x Impact

5. **Summarize Vulnerability:** each hazard was ranked as either "low," "medium," or "high" based on the risk results from step 4, presenting the planning region with a clear way to prioritize and implement long-term mitigation measures to reduce impacts.

Each step of the process, along with the data limitations and planning assumptions that shaped the risk assessment methodology, is described in more detail in the following sections.

LIMITATIONS & ASSUMPTIONS

FEMA guidelines emphasize using "best available" data for hazard mitigation planning. However, this plan's risk assessment faced several data limitations. Many hazards lack standardized damage estimate criteria or localized datasets at the jurisdictional level, which affects the precision of vulnerability assessments in specific hazard profiles. Additionally, comprehensive region-wide datasets on local critical infrastructure and structural values were not available for advanced risk analysis tools such as HAZUS for flooding scenarios. As a result, the risk assessment relies on generalized baseline analysis methods that may not fully capture the nuances of local development patterns and infrastructure vulnerabilities.

LOCALITY-SPECIFIC VULNERABILITY SUMMARIES

The THIRA is regional in scope and is intended to provide a broad assessment of threats and hazards across the planning area. Because vulnerability can vary significantly between jurisdictions based on geography, infrastructure, and local conditions, jurisdiction-specific summaries have been developed to complement the regional analysis. For detailed information on each locality's or special district's vulnerability to the hazards identified in this plan, refer to Appendix H – Locality Vulnerability Summaries.

STEP 1: THREAT AND HAZARD IDENTIFICATION

The first step of the THIRA involved identifying the threats and hazards that impact the region and will be included in the analysis. FEMA identifies three types of hazards for planning consideration:

- **Natural Hazards** – environmental or other naturally occurring phenomena that has the potential to impact people, property, and/or the environment.
- **Technological Hazards** – accidental/unintentional incident, failure, or loss that is caused by the application of mechanical, industrial, or technological sciences.
- **Malevolent Man-made Threats** – intentional incidents to inflict damage, fear, injury, or death.

At the June 2024 Steering Committee Meeting, members were provided with a list of 31 hazards, from which they voted on 15 that most impact their communities and the region for further analysis. A summary of this exercise can be found in Appendix C. The top 15 were:

1. Flooding
2. Drought
3. Wildfire
4. High Winds
5. Extreme Temperatures
6. Snow & Blizzard
7. Tropical Storm & Hurricane
8. Infectious Disease Outbreak
9. Transportation Incident
10. Utility Outage
11. Telecom. & Network Outage
12. Critical Infrastructure Failure
13. Hazardous Materials Release
14. Cyber-Attack Against Infrastructure
15. Active Assailant

Following a preliminary review of the 15 threats and hazards voted for by the Steering Committee, the CSPDC consolidated them into the final 12 hazard profiles included in this THIRA. This involved combining utility outage, telecommunication/network outage, and critical infrastructure failure into a single category. A Transportation Incident hazard profile was deemed beyond the scope of this update given staff and capacity limitation. Its incorporation should be considered in subsequent updates.

STEP 2: DESCRIBE THE HAZARDS

Once the hazards and threats were identified, the CSPDC conducted a comprehensive evaluation of each hazard utilizing a standardized evaluation framework, which incorporated the following components:

- **Historical Hazard Review** – thorough review of documented hazard events within the region to understand how frequently events occur and how severe the impacts can be.
- **Spatial Risk Assessment** – Identification and mapping of areas that are especially vulnerability to each hazard based on topographic, geologic, hydrologic, and built environment characteristics.
- **Loss Estimation** – assessing potential losses associated with a hazard event (when sufficient data was available).
- **Probability Assessment** – estimating the probability of future occurrences based on historical occurrence data.

The findings of this hazard assessment were documented in the hazard profiles represented in the following sections of this chapter. Each hazard profile provides a definition of the hazard; a description of the type, location, and extent of the hazard; the probability of future events; and a summary of the region's vulnerability, given the available data.

STEP 3: IDENTIFY CRITICAL FACILITIES

Identifying critical community assets is an essential part of developing a THIRA. These assets provide a targeted framework for mitigation activities to address the most critical potential impacts from hazards. In identifying at-risk assets, jurisdictions can develop a list of mitigation strategies and projects that will reduce vulnerabilities to the hazards within the community.

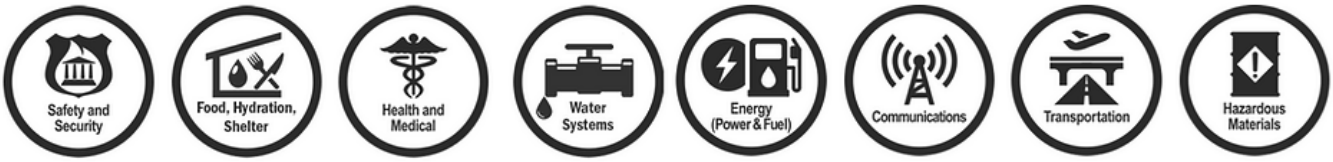
For citizens, visitors, businesses, and the environment, critical community assets are those that, either private or public, provide essential products and services and are necessary to preserve the welfare and quality of life in the local jurisdiction, or fulfill important public safety, emergency response, and/or disaster recovery functions. FEMA defines four categories of assets: population, economic, natural environment, and built environment/lifelines. This section focuses on the last category, as the first three are discussed in Chapter 3: Community Profile.

Table 4.0.4. FEMA Asset Categories

Population	Economic	Natural Environment	Built Environment and Lifelines
• General demographics • Population density • Functional and access needs • Projected growth considerations	• Major employers • Commercial centers • Primary economic sectors (e.g., agriculture)	• Natural resources (clean air and water) • Recreation areas • Critical habitats	• Infrastructure • Critical facilities • Cultural resources • Future development

COMMUNITY LIFELINES FRAMEWORK

Lifelines, a subcategory of the Built Environment Asset Category, highlight priority areas, interdependencies, and other functions critical to community operations. FEMA defines eight broad lifeline categories that provide a useful way of classifying critical facilities:



The previous version of this plan identified critical facilities based upon data provided to CSPDC and/or researched via the Environmental Systems Research Institute (ESRI) and the Virginia Tech Center for Geospatial Information Technology (CGIT). During this update, the CSPDC requested that each of the 21 jurisdictions review and edit the existing inventory of critical facilities given FEMA's updated guidance.

At the October 2024 Steering Committee meeting, the CSPDC presented FEMA's guidance for identifying critical facilities, noting the eight lifeline categories. The steering committee representatives reviewed and updated their respective lists by January 2025. The CSPDC categorized the updated data according to Table 4.0.5. and spatialized the dataset.

Table 4.0.5. CSPDC Critical Facilities Categories	
Emergency & Medical	**Transportation**
This category includes emergency response, fire and rescue stations, police departments, medical facilities, and hospitals.	This category includes major railroad stations and airports.
Public Service	**Major Employers**
This category includes local and state government offices, libraries, and schools.	This category is a single dataset: Shenandoah Valley Partnership's *Leading Employers* webpage. Data was only at the county/city level.
Water Systems	**Historic Places**
This category includes public works, water and wastewater treatment plants, water pump stations, water tanks, and publicly-owned wells.	This category is a single dataset: the National Register of Historic Places. Data was only at the county/city level.
Utility	**Social Centers**
This category includes solar/power stations, fuel stations, cell towers, and emergency generators.	This category includes community centers, child daycare, social service agencies, and churches.
Industrial	**Special Populations**
This category includes industrial sites, public waste disposal sites, quarries, and lumber yards.	This category includes senior/assisted living, correctional facilities, and subsidized housing.

FINAL CRITICAL FACILITIES INVENTORY

In this update, our communities identified a total of **1,719 critical facilities**, representing an increase of over 500 facilities from the 2020 plan's inventory of 1,153 facilities. For security purposes and to prevent potential targeting of critical infrastructure, the CSPDC does not include a comprehensive map showing all facility locations. Alternatively, Table 4.0.6. summarizes the data by locality and facility type.

When feasible, the CSPDC performed additional spatial analysis with this dataset and relevant hazard data to identify facilities at elevated risk. These analyses are presented in the individual hazard profiles in the following sections of this chapter.

Table 4.0.6. Inventory of Community-Identified Critical Facilities												
			Emergency + Medical	Public Service	Water Systems	Utility	Industrial	Transportation	Major Employers	Historic Places	Social Centers	Special Populations
Sub-Area	Harrisonburg-Rockingham	City of Harrisonburg	12	33	12	6	20	0	11	13	0	10
		Rockingham County	11	12	6	0	6	2	19	44	0	3
		Town of Bridgewater	4	5	3	0	0	0	-	-	7	3
		Town of Broadway	4	4	3	0	0	0	-	-	0	0
		Town of Dayton	2	4	8	1	1	0	-	-	4	0
		Town of Elkton	3	3	5	0	1	0	-	-	14	2
		Town of Grottoes	4	2	3	4	4	0	-	-	12	0
		Town of Mt. Crawford	0	1	0	2	0	0	-	-	2	0
		Town of Timberville	3	1	7	0	0	0	-	-	4	2
	Staunton-Augusta-Waynesboro	City of Staunton	6	12	2	43	13	3	4	39	43	9
		City of Waynesboro	4	17	5	33	17	0	4	11	53	5
		Augusta County	42	76	77	111	100	1	19	57	133	19
		Town of Craigsville	0	3	0	9	2	0	-	-	12	1
	Rockbridge-Lexington-Buena Vista	City of Buena Vista	4	8	3	0	6	0	2	5	16	2
		City of Lexington	10	14	3	0	0	0	-	17	18	6
		Rockbridge County	9	14	12	2	9	0	3	54	33	6
		Town of Glasgow	3	1	2	0	1	0	-	-	2	0
		Town of Goshen	2	0	0	0	1	0	-	-	3	0
	Bath-Highland	Bath County	7	6	2	3	3	1	2	25	21	3
		Highland County	6	4	2	0	0	0	-	7	17	0
		Town of Monterey	0	0	0	0	0	0	-	-	0	0
CSPDC Total			138	220	155	214	184	7	64	272	394	71

STEP 4: CALCULATE RISK

To compare the risk of different hazards and prioritize mitigation strategies, a scoring system is needed to standardize the units of analysis. Since not all hazards assessed in this plan have precisely quantifiable probability or impact data, this plan uses a scoring system based on multi-criteria decision analysis methodology to rank the hazards. This approach prioritizes hazard risk by combining factors from available data, including historical records, local knowledge, public surveys, and spatial data.

The risk results were quantified using the following overarching formula:

Risk = Probability x Impact

PROBABILITY

Probability is the estimation of the likelihood or frequency at which a hazard may occur, taking into consideration factors such as historical data and geographic location to make informed predictions about future occurrences. Other considerations include, but are not limited to, evolving threat environments, technology capabilities, and climate change.

Hazard probability is determined through the following research:

- Exposure/GIS analysis: hazards with geographic areas of known risk
- Historical analysis: hazards with a repository of historical data
- Scenario analysis: hazards with no defined pattern, geography, or historical record
- Combination analysis using two or more methods above

Probability for each of the 12 hazards were ranked on a scale of 0 to 3 based on the following criteria:

Table 4.0.7. Probability Rankings

Ranking		Level	Criteria
	0	Unlikely	Recurrence interval of less than 1 event per year
	1	Occasional	Recurrence interval of 1-3 events per year
	2	Likely	Recurrence interval of 4-6 events per year
	3	Highly Likely	Recurrence interval over more than 6 events per year

IMPACT

Once probabilities were ranked, Steering Committee members were asked to rank impacts stemming from each hazard across three categories as it directly relates to their jurisdictions: health, property, and businesses. For many hazards, predicting impact can be challenging. Typically, historical data is examined to evaluate quantified damages, fatalities, and injuries associated with specific events of varying intensities. The ranking structures for each of the three categories are outlined below.

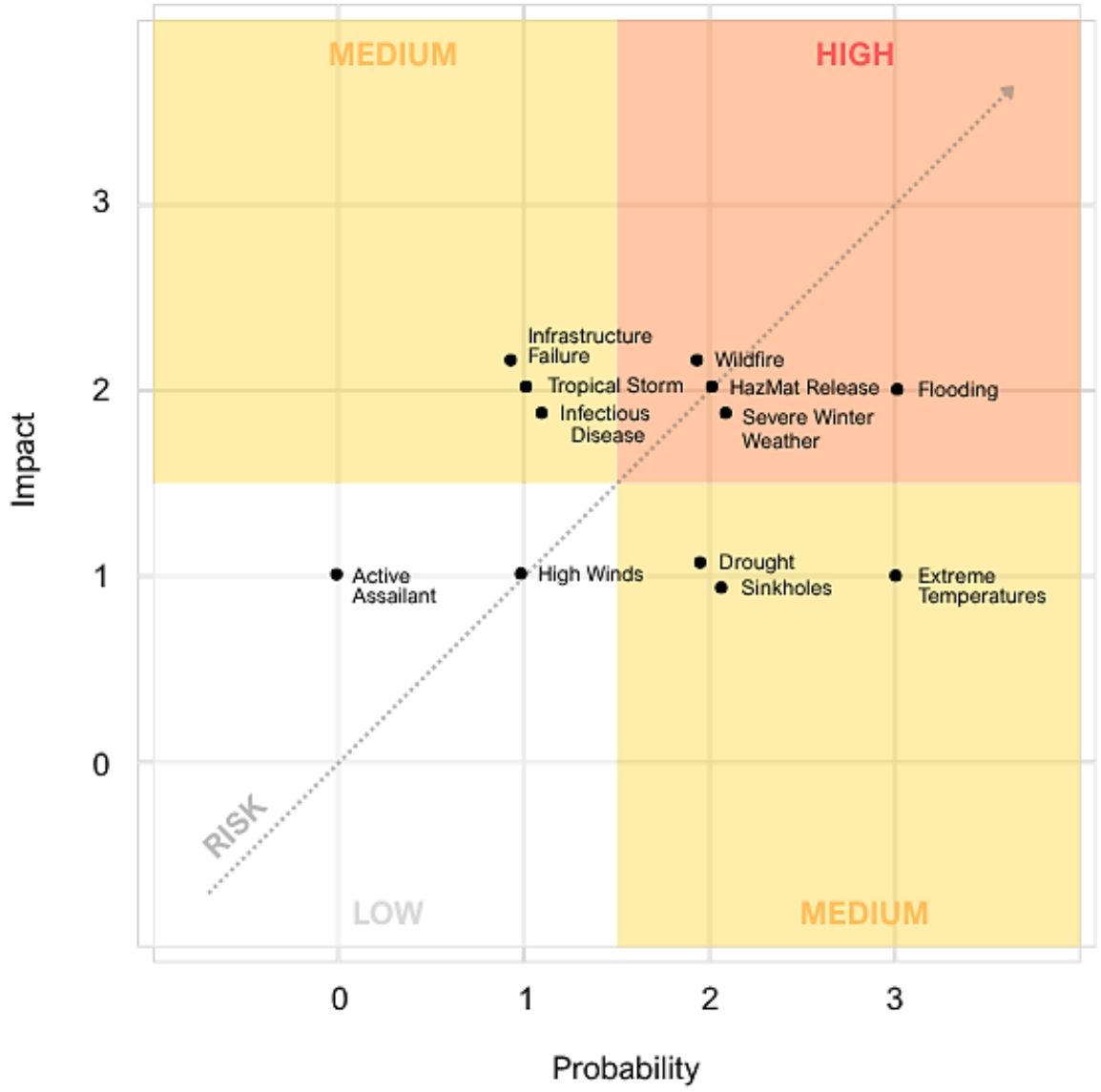
Table 4.0.8. Impact Rankings	
Ranking	**Criteria**
Health Impacts	
0	Deaths are very unlikely, injuries are unlikely
1	Deaths are unlikely, injuries are minimal
2	Deaths are possible, injuries may be substantial
3	Deaths are probable, injuries will be substantial
Property Impacts	
0	Damage is minimal (e.g., homes are still inhabitable, very few critical facilities affected)
1	Damage is low (e.g., less than 10 homes are uninhabitable, some critical facilities affected)
2	Damage is moderate (e.g., less than 40 homes are uninhabitable, many critical facilities affected)
3	Damage is severe (e.g., whole neighborhoods are uninhabitable, several critical facilities affected)
Business Impacts	
0	Interruptions are less than 6 hours
1	Interruptions are less than 24 hours
2	Interruptions are expected to last between 24 to 48 hours
3	Interruptions are expected to last more than 48 hours

STEP 5: SUMMARIZE VULNERABILITY

The average scores for the probability and impact of a given threat or hazard were averaged and multiplied, giving an ultimate risk score. Figure 4.0.1. shows the average probability score plotted against the average impact score for each hazard. Hazards fell into one of three categories: Low, Medium, High.

Table 4.0.8. Risk Scores		
Low Risk	Medium Risk	High Risk
• Active Assailant • High Winds	• Infrastructure Failure • Hurricanes • Infectious Disease Outbreak • Drought • Sinkholes • Extreme Temperatures	• Flooding • Wildfire • Hazardous Material Release • Severe Winter Weather

Figure 4.0.1. Risk Score Comparison



CASCADING EFFECTS

Hazards are often interconnected, meaning one event can trigger or intensify another, creating cascading effects that amplify overall damage. For example, an earthquake can cause landslides, tsunamis, or dam failures, each leading to further destruction. Similarly, wildfires can increase the risk of flash floods and mudslides in affected areas by stripping the land of vegetation. These chains of events highlight how a single hazard can set off a series of related disasters, making it essential to understand their interconnections when planning for risk reduction and emergency response.



HAZARD PROFILE 1

FLOODING

DEFINITION

An overflow of water onto normally dry land caused by rising water in an existing waterway, such as a river, stream, or ditch. A flash flood is a sudden, severe flood, typically caused by heavy rainfall in a short period, often within six hours, characterized by rapidly rising water levels and strong currents.

BACKGROUND

A flood is a natural event for rivers and streams. Excess water from snowmelt, rainfall, or storm surge accumulates and overflows onto the banks and adjacent floodplains. Floodplains are lowlands, adjacent to rivers, lakes, and oceans that are subject to recurring floods. Under natural conditions, a flood causes little or no damage. Flood problems only exist when the built environment is damaged by nature's water or when property and lives are jeopardized. Floods in the region are almost always associated with hurricanes, tropical storms, and tropical depressions. However, some of the Region's flooding is caused by sustained heavy rains, severe thunderstorms, and even rapid snowmelts.

The Central Shenandoah Region experiences both riverine flooding and urban flooding. Riverine flooding is when streams and rivers exceed the capacity of their natural or constructed channels to accommodate water flow and water overflows the banks, spilling out into adjacent low-lying, dry land. Most riverine flooding occurs from the Shenandoah River, James River, or their tributaries that are found throughout the Central Shenandoah Region. Urban flooding refers to the rapid rise of floodwater in urban areas due to impervious surfaces limiting infiltration and heavy rainfall events. The region's cities and towns experience flash flooding from stormwater runoff, but much of their flooding is riverine due to their historic development along the tributary creeks and streams of the major river systems.

ASSOCIATED EFFECTS

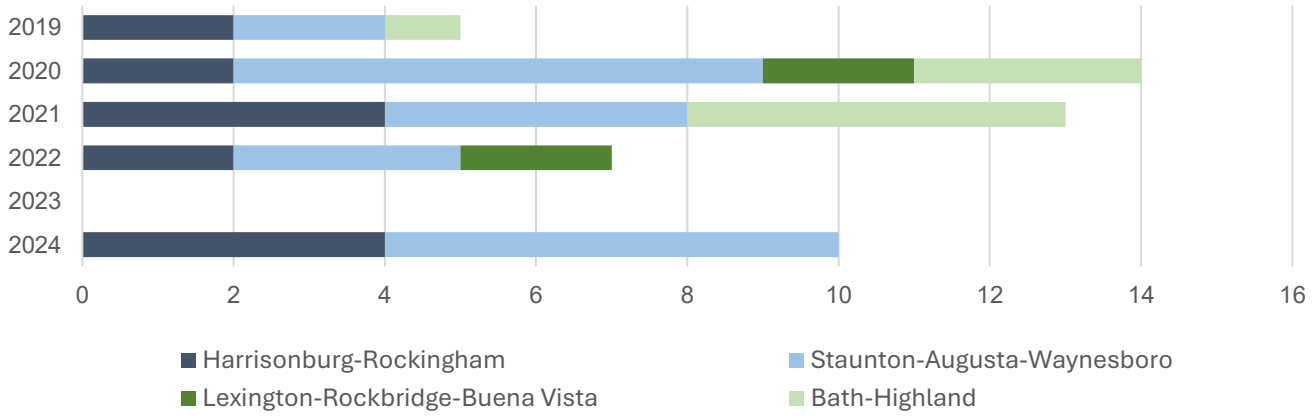
Significant secondary impacts associated with flooding include mud and rockslides, infrastructure, and utility failure, and impacts to roadways, water service, and wastewater treatment. These impacts can affect not only the immediate vicinity of the flood, but also the entire region, making the area vulnerable to limited emergency services. Additionally, floodwater contaminated with chemicals and sewage can pose a threat to the health of the population and can increase the risk of contracting waterborne diseases.

SIGNIFICANT HISTORICAL EVENTS

While the Region experiences nearly all types of natural disasters, including snowstorms, ice storms, wildfires, and tornadoes, flooding is perhaps the most common and devastating type of disaster. It is also the most common hazard in the United States with hundreds of floods occurring every year causing an average of 150 deaths annually. Flooding has occurred in the region at least once per year since 2003 (Storm Events Database, 2024). Multiple events within a year occur often, such as in 2021 when flooding occurred in several areas on 11 separate dates. Flooding that is severe enough to cause property damage has occurred in every 5-year period since 2003.

Appendix E – Detailed Hazard Histories includes a complete list of floods in the CSPDC over the last 20 years. During this period, 417 separate flooding events were recorded, with 15 of the 21 localities affected. One fatality and 1 injury occurred, and 23 events caused property damage. Recent flood events by year and area are summarized below in Chart 4.1.1. and detailed in Table 4.1.1.

Chart 4.1.1. Number of Recorded Flooding Events by Subarea, 2019-2024



DISASTER DECLARATIONS

Numerous disaster declarations associated with flooding have been declared in the CSPDC region. A full list of flood-related disaster declarations can be found in the appendices. The following is a summary:

- **Total declarations:** since 1969, the CSPDC has received 15 Major Disaster Declarations due to flooding. Individual localities in the Region have been included in the Major Disaster Declarations a combined total of 81 times. Floods in 1969, 1972, 1985, 1992, 1994, 1995, 1996, 2001, 2003, 2006, and 2018 have had severe and long-term effects on property owners, businesses, industry, and the region's economy.
- **Agricultural declarations**: flooding has also impacted agriculture in the region, with 1 Secretarial Disaster Declaration since 2012 and 3 Presidential Major Disaster and Presidential Emergency Declarations since 2017. The Secretarial Disaster Declaration included 3 localities, and the Presidential Major Disaster and Presidential Emergency Declarations included 10 localities.

Table 4.1.1. Flooding Events Between 2019-2024		
Date	**City or County**	**Type of Flood Event**
07/05/2019	Augusta	Flood
07/11/2019	Rockingham	Flood
07/15/2019	Bath	Flash Flood
08/20/2019	Rockingham	Flood
08/31/2019	Augusta	Flood
04/13/2020	Rockbridge	Flash Flood
04/30/2020	Augusta, Rockingham	Flood
05/16/2020	Bath	Flash Flood
05/16/2020	Bath	Flash Flood
06/05/2020	Rockingham	Flood
06/18/2020	Highland	Flood
08/06/2020	Augusta, Staunton	Flood, Flash Flood
08/08/2020	Augusta	Flash Flood
08/22/2020	Staunton, Augusta, Rockbridge	Flood, Flash Flood
10/29/2020	Augusta	Flood
02/28/2021	Bath	Flash Flood
03/01/2021	Highland	Flood
03/01/2021	Highland	Flood
05/04/2021	Rockingham	Flood
06/13/2021	Augusta, Bath, Highland	Flood
07/27/2021	Augusta	Flood, Flash Flood
08/08/2021	Rockingham	Flash Flood
08/16/2021	Harrisonburg	Flood
08/25/2021	Augusta	Flood
09/01/2021	Rockingham	Flood
10/06/2021	Augusta	Flood
02/04/2022	Rockingham, Augusta	Flood
07/01/2022	Rockingham	Flash Flood
08/10/2022	Augusta, Rockbridge	Flood
08/21/2022	Rockbridge, Augusta	Flood, Flash Flood
05/06/2024	Rockingham	Flood, Flash Flood
08/09/2024	Rockingham	Flood
09/26/2024	Augusta	Flood
09/27/2024	Augusta, Waynesboro	Flood
09/28/2024	Augusta, Rockingham	Flood
09/30/2024	Augusta, Waynesboro, Rockingham	Flood

Data Source(s): NOAA Storm Events Database, 2019-2024; Note: Data was only available on the City/County scale.

AREAS OF IMPACT

The Central Shenandoah Region experiences both riverine and rainfall-driven flooding. Most riverine flooding occurs from either the Shenandoah River, James River, or their tributaries. The region's cities and towns experience flash flooding, usually due to a combination of stormwater runoff and riverine flooding from tributary creeks. The speed and volume of stormwater runoff can increase with the amount of impervious surfaces in each community. Table 4.1.2. shows the estimated acres of impervious surfaces in each City and County in the region. It also provides the percent of each community's total land area that is designated as impervious, according to the Chesapeake Bay Land Use/Land Cover (LULC) Database.

Table 4.1.2. Estimated Impervious Land Cover Area by City/County (Acres)					
Augusta County	20,238.1	3.3%	City of Buena Vista	848.0	20.6%
Bath County	2,730.1	0.8%	City of Harrisonburg	4,883.0	44.1%
Highland County	2,149.2	0.8%	City of Lexington	522.7	32.6%
Rockbridge County	9,367.1	2.5%	City of Staunton	3,134.0	24.6%
Rockingham County	23,054.8	4.2%	City of Waynesboro	2,687.8	28.0%

Data Source(s): Chesapeake Bay Land Use/Land Cover (LULC) Database, 2024
Note: Data was only available on the City/County scale.

NATIONAL FLOOD HAZARD LAYER (NFHL)

The National Flood Hazard Layer (NFHL) is a geospatial database that contains current effective flood hazard data. FEMA provides this data to support the National Flood Insurance Program (NFIP). The NFHL is made from effective Flood Insurance Rate Maps (FIRMs) and Letters of Map Change (LOMCs) in each community. A regional map of flood hazard areas is shown in Map 4.1.1. and is provided only for reference. To use the NFHL for official purposes, maps are required to meet additional accuracy standards established by FEMA. Appendix # includes information on accessing FIRMs for each locality.

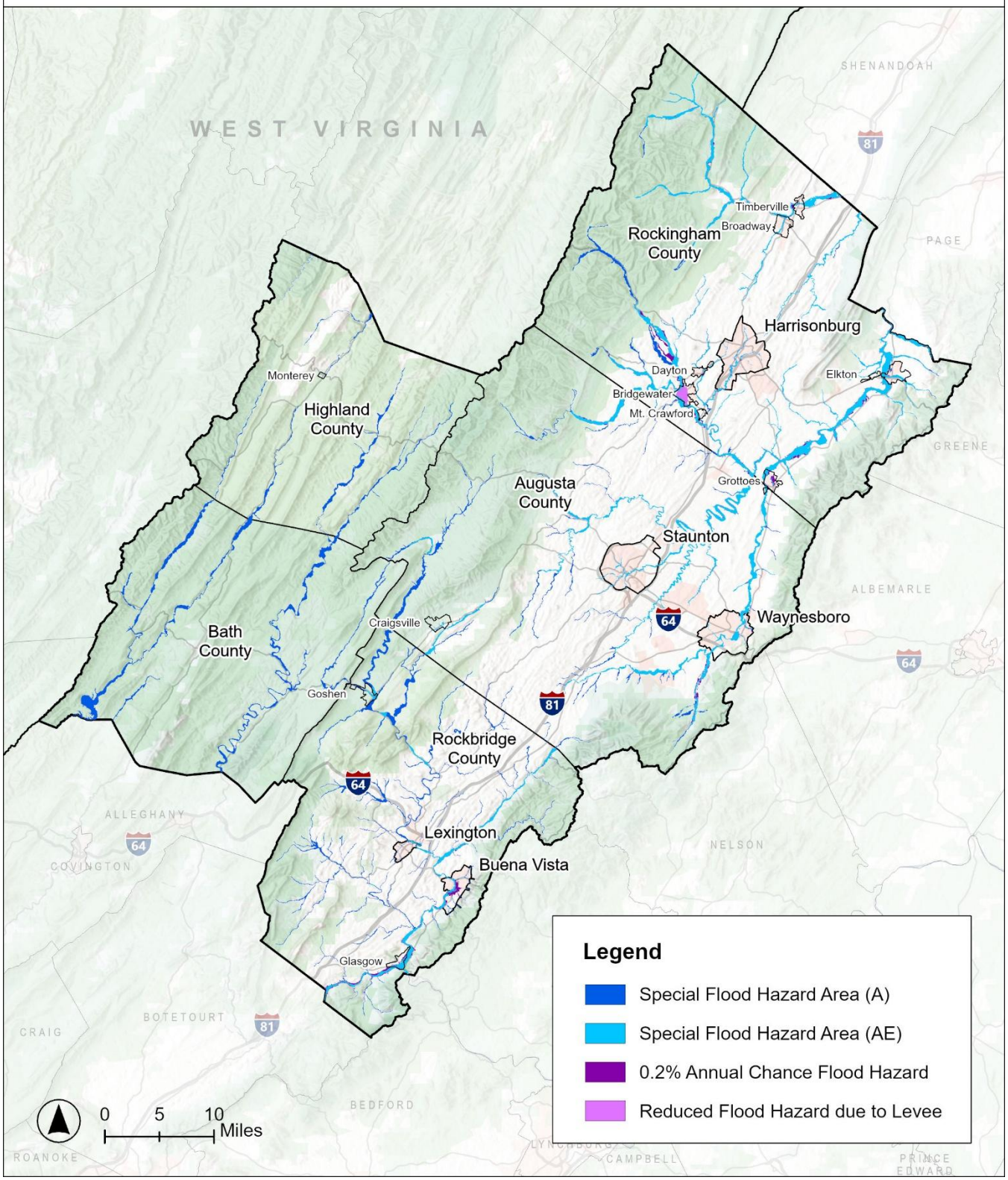
SPECIAL FLOOD HAZARD AREAS

Special Flood Hazard Areas in the region are identified as flood zones A/AE. They are areas that will be inundated by a flood event having a 1% chance of being equaled or exceeded in any given year. The 1% annual flood chance is also referred to as the "100-year flood."

MODERATE FLOOD HAZARD AREAS

While the 1% annual chance flood is useful for insurance, regulations, and general planning, it is crucial to remember that significant flooding occurs outside of these zones. On average, 40% of flood insurance claims occur outside of these mapped areas. Additionally, the mapped areas do not reflect rainfall-driven flooding, which can be significant in many areas. Another area to consider for planning purposes is the 0.2% annual chance storm or "500-year flood."

Map 4.1.1. Flood Hazard Areas



Data Source(s): FEMA National Flood Hazard Layer, 2024

Table 4.1.3. Percent of Land Area in Flood Hazard Areas by Locality				
		Total Land Area	% Land in 100-Year Flood Zone	% Land in 500-Year Flood Zone
Harrisonburg-Rockingham	City of Harrisonburg	17.34 mi^2	6.08%	7.29%
	Rockingham County	840.60 mi^2	4.76%	5.31%
	Town of Bridgewater[1]	2.52 mi^2	11.90%	12.27%
	Town of Broadway	2.40 mi^2	12.73%	13.59%
	Town of Dayton	1.03 mi^2	10.97%	15.14%
	Town of Elkton	3.42 mi^2	18.13%	19.16%
	Town of Grottoes	2.07 mi^2	18.87%	32.88%
	Town of Mount Crawford	0.51 mi^2	14.12%	15.88%
	Town of Timberville	1.35 mi^2	8.10%	10.54%
Staunton-Augusta-Waynesboro	City of Staunton	19.98 mi^2	3.84%	4.11%
	City of Waynesboro	15.11 mi^2	9.90%	10.49%
	Augusta County	968.68 mi^2	3.77%	3.97%
	Town of Craigsville	2.07 mi^2	7.82%	8.56%
Lexington-Rockbridge-Buena Vista	City of Buena Vista	6.52 mi^2	11.44%	20.98%
	City of Lexington	2.53 mi^2	6.71%	7.45%
	Rockbridge County	596.65 mi^2	4.61%	4.87%
	Town of Glasgow	1.53 mi^2	35.16%	46.40%
	Town of Goshen	1.77 mi^2	24.73%	25.29%
Bath-Highland	Bath County	534.62 mi^2	3.72%	3.72%
	Highland County	415.58 mi^2	1.91%	1.91%
	Town of Monterey	0.27 mi^2	4.44%	4.44%
	CSPDC Total	3,436.55 mi^2	1.65%	2.20%

Notes: (1) 43.7% of the Town of Bridgewater is in an "area with reduced flood risk due to levee."
(2) 500-Year Flood Zone includes 100-Year Flood Zone.

ESTIMATED LOSSES

Historical flood losses in the CSPDC region have run into millions of dollars. For twenty years (2004-2024), documented losses from floods and flash floods totaled approximately $8 million. Based on the National Oceanic and Atmospheric Administration (NOAA) Storm Center data, in the last 5 years, two flash floods have resulted in property damage totaling $50,000. Both occurred in 2020 and were in Augusta and Rockbridge counties. Importantly, information on the historic cost of flooding is limited in availability and often does not capture all associated costs. Consequently, researchers have modeled annual average flood loss estimates for every county across the nation (Wing et al., 2022). As shown in Table 4.1.4, the region is estimated to have nearly $50 million in annual average flood loss combined.

Table 4.1.4. Modeled Current Annual Average Flood Loss (2020 US Dollars)

Augusta County	$11.0 million	City of Buena Vista	$4.3 million
Bath County	$10.5 million	City of Harrisonburg	$0.2 million
Highland County	$2.8 million	City of Lexington	$0.1 million
Rockbridge County	$10.0 million	City of Staunton	$2.1 million
Rockingham County	$7.1 million	City of Waynesboro	$1.6 million

Source: Wing, O.E.J., Lehman, W., Bates, P.D. et al. (2022).
Note: Data was only available on the City/County scale.

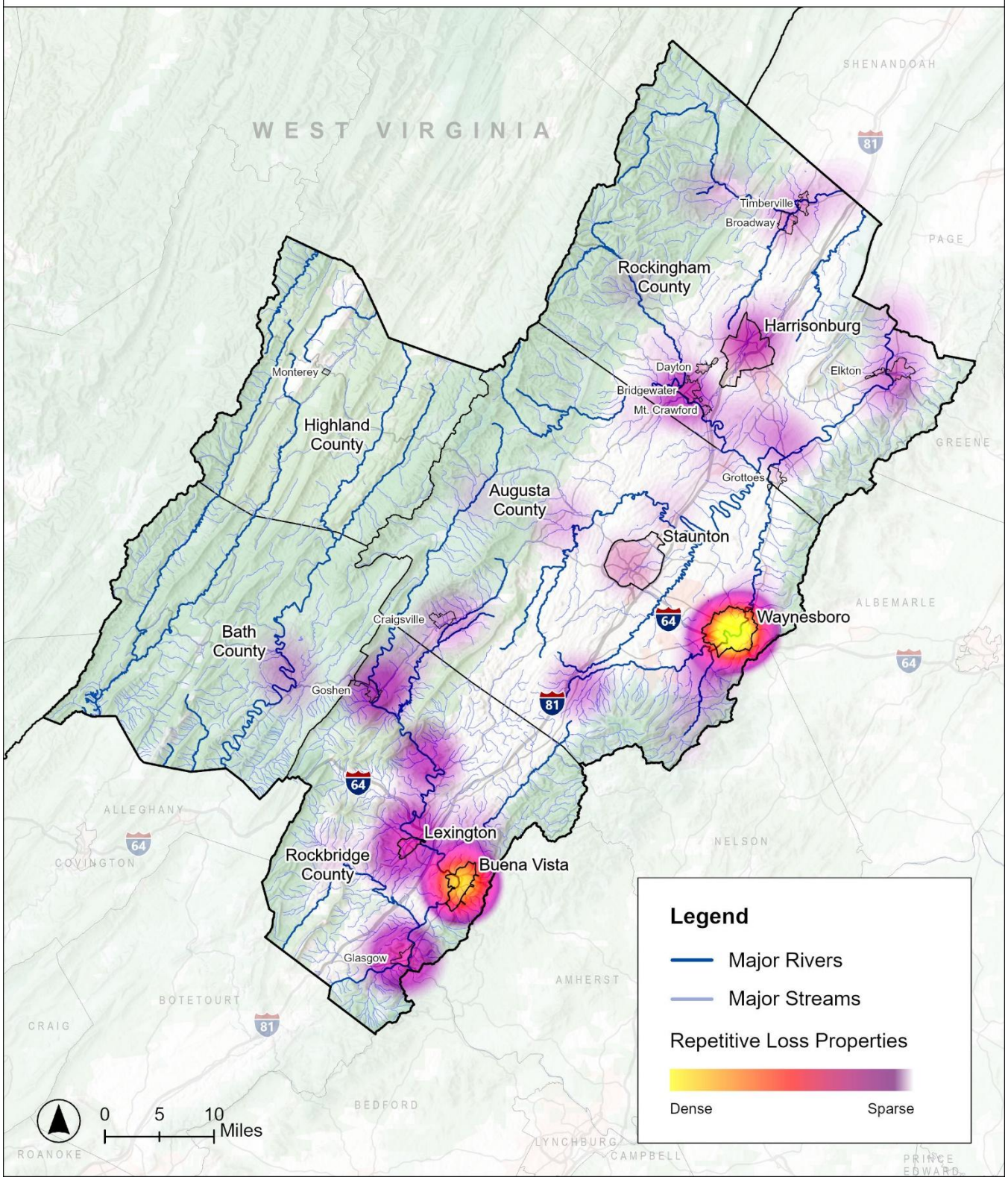
REPETITIVE LOSS AND SEVERE REPETITIVE LOSS STRUCTURES

Flood-prone areas tend to contain structures that are repeatedly impacted by floods over many years. These structures, termed repetitive loss (RL) and severe repetitive loss (SRL) structures, may be eligible for additional federal funding. An RL structure is defined as a National Flood Insurance Program (NFIP)-insured structure with at least 2 paid flood losses of more than $1,000 each in any 10-year period since 1978. An SRL structure is defined as an NFIP-insured structure that:

- has at least 4 NFIP claim payments, including building and contents, over $5,000 each and the cumulative amount of such claim payments exceeds $20,000, or
- for which at least 2 separate claims payments have been made with the cumulative amount of the building portion of these claims exceeding the market value of the building. At least 2 of these claims must have occurred within any 10-year period and must be greater than 10 days apart.

Map 4.1.2 shows hot spots of repetitive and severe repetitive loss properties in the region; the CSPDC obtained this data from FEMA and removed all personally identifiable information. Table 4.1.5 shows the number of NFIP Repetitive Loss and Severe Repetitive Loss properties in the CSPDC region by locality. The Staunton-Augusta-Waynesboro and Lexington-Rockbridge-Buena Vista sub areas have the highest recorded number of repetitive loss properties. NFIP-participating communities should request this information from FEMA to consider the properties for elevation, relocation, acquisition, or demolition.

Map 4.1.2. Hot Spots of Repetitive Loss (RL) and Severe Repetitive Loss (SRL) Properties



Data Source(s): FEMA, 2025

Table 4.1.5. Repetitive Loss and Severe Repetitive Loss Structures Inventory						
		# RL	# SRL	# Mitigated	# Insured	# Paid Losses > $1,000
Harrisonburg-Rockingham	City of Harrisonburg	4	0	0	2	13
	Rockingham County	12	1	1	2	36
	Town of Bridgewater	1	0	1	0	5
	Town of Broadway	2	0	0	1	5
	Town of Dayton	0	0	0	0	0
	Town of Elkton	1	0	0	1	3
	Town of Grottoes	0	0	0	0	0
	Town of Mt. Crawford	0	0	0	0	0
	Town of Timberville	0	0	0	0	0
Staunton-Augusta-Waynesboro	City of Staunton	2	0	0	2	5
	City of Waynesboro	39	12	4	8	181
	Augusta County	12	1	1	1	36
	Town of Craigsville	0	1	0	0	5
Lexington-Rockbridge-Buena Vista	City of Buena Vista	30	3	10	4	117
	City of Lexington	3	1	0	0	17
	Rockbridge County	14	7	0	1	58
	Town of Glasgow	12	0	0	0	26
	Town of Goshen	2	1	0	0	9
Bath-Highland	Bath County	2	0	0	0	5
	Highland County	0	0	0	0	0
	Town of Monterey	0	0	0	0	0

Data Source(s): FEMA, 2025

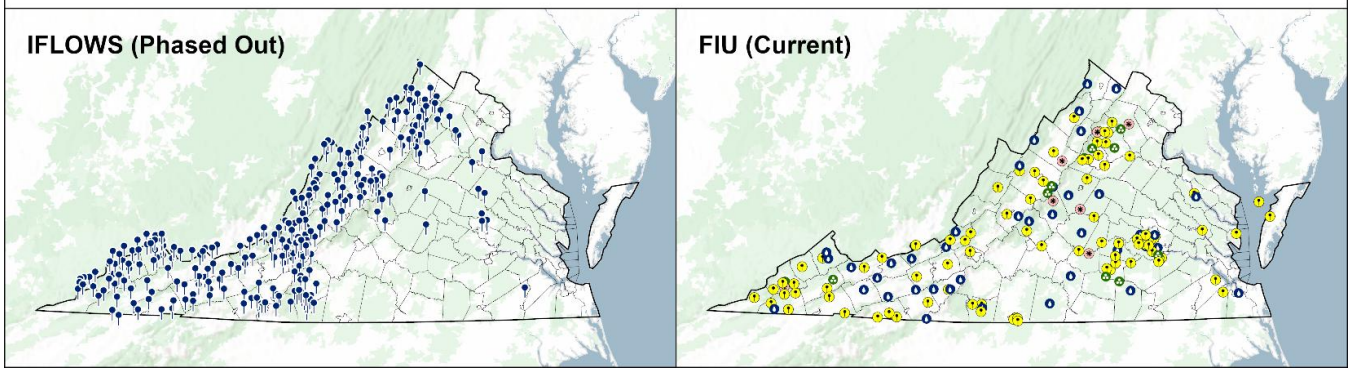
FLOOD MONITORING

For several decades, the Virginia Department of Emergency Management (VDEM) has operated a flood monitoring system to supplement local gauge networks and provide critical information to localities. Since the last update in 2020, VDEM undertook an effort to modernize the system. Consequently, the flood monitoring capabilities of local emergency managers have changed significantly.

INTEGRATED FLOOD OBSERVING AND WARNING SYSTEM (IFLOWS)

In the late 1970s and early 1980s, the National Weather Service (NWS) created the Integrated Flood Observing and Warning System (IFLOWS) in several Appalachian states after a series of devastating flood events (Campbell Scientific, 2020). The CSPDC region has 145 IFLOWS gauges, with at least one located in 6 of the 10 cities and counties. The cities of Harrisonburg, Staunton, Buena Vista, and Lexington do not have IFLOWS gauges. Since the phasing-out of IFLOWS, the gauges remain in place, but the system no longer alerts localities with critical water-level information.

Map 4.1.3. Change in State-Operated Flood Monitoring Systems



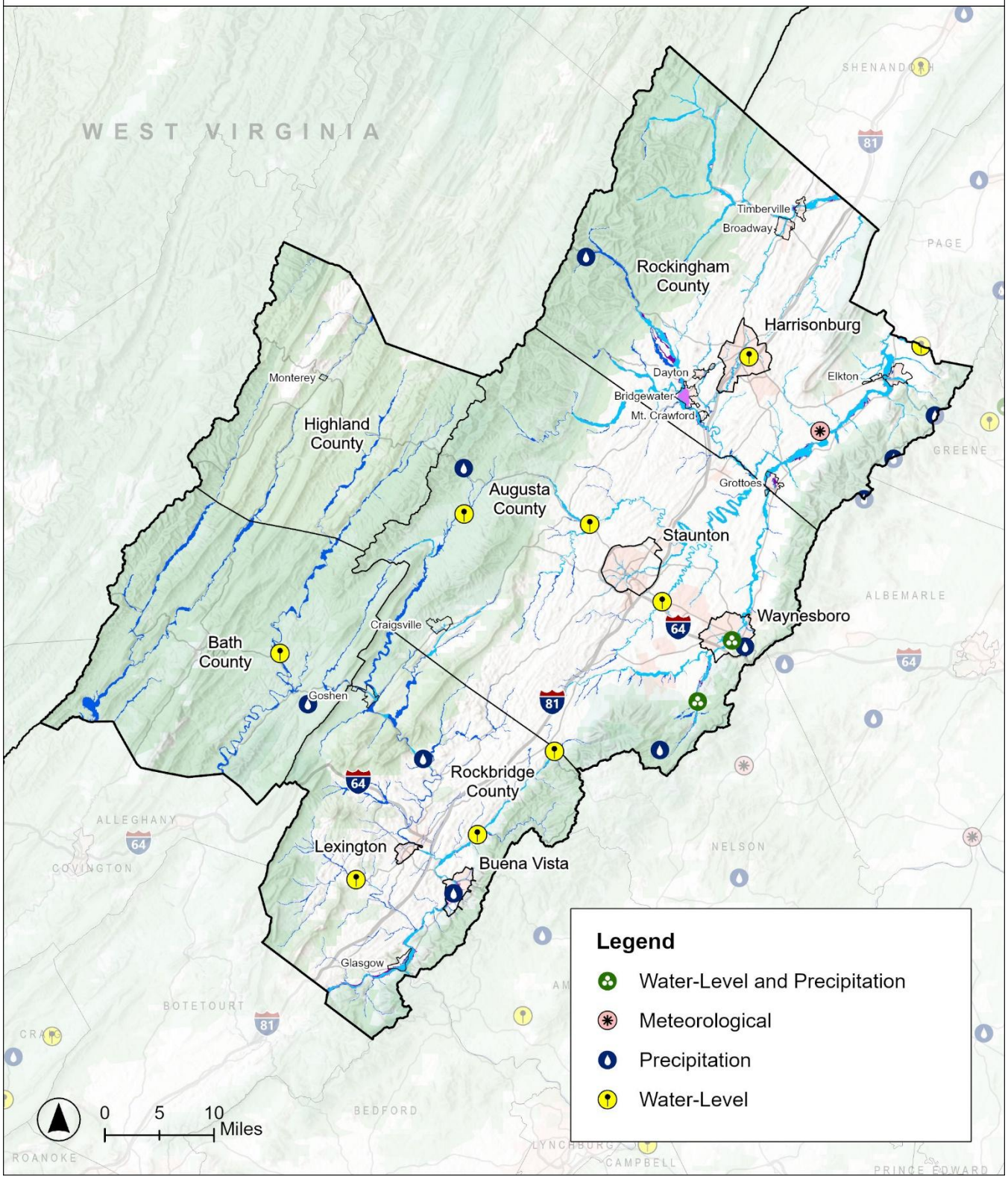
Data Source(s): Virginia IFLOWS (public), 2021; VDEM FIU Gauge Sites Public View, 2025

VIRGINIA FLOOD MONITORING SYSTEM (VFMS)

In 2022, VDEM created the Flood Intelligence Unit (FIU). The FIU operates a modernized flood monitoring network, the Virginia Flood Monitoring System (VFMS), which is comprised of water-level gauges, rain gauges, and meteorological stations across the state. The network is intended to complement existing gauge networks operated by local government agencies, the National Weather Service (NWS), and the United States Geological Society (USGS) (VDEM, n.d.).

As shown on Map 4.1.4, there are 19 gauges in the region through the modernized system. 9 are water-level gauges, 7 are precipitation gauges, and 2 are both water-level and precipitation gauges. There is 1 meteorological gauge in Rockingham. Highland is the only county in the region without a gauge.

Map 4.1.4. Virginia Flood Monitoring System (VFMS) Gauges in CSPDC Region



Data Source(s): VDEM FIU Gauge Sites Public View, 2025

PROBABILITY OF FUTURE OCCURRENCES

Map 4.1.5. shows the annualized frequency of riverine flooding by census tract according to FEMA's National Risk Index (NRI) dataset. According to this data, Augusta County experiences the most riverine flooding events compared to the rest of the region. Importantly, FEMA's database does not include the annual frequency of non-riverine flooding, which may be higher in the more developed areas of the region given greater amounts of impervious surfaces. Additionally, the likelihood of future flood events is dependent on several factors, such as new development near rivers and floodplains, increased impervious surfaces, and a warming climate.

DEVELOPMENT PATTERNS

As localities grow, it is important to avoid unnecessary development in floodplains because they serve an important function of absorbing excess water. Most federal and state laws allow construction in floodplains if buildings are raised above the base flood elevation. To meet these requirements, many contractors use the "fill and build" method of filling the low-elevation land with dirt and then building on top. However, this method can lead to pockets of land at higher elevations and create runoff that floods lower-elevation properties (Aon Edge Insurance Agency, n.d.).

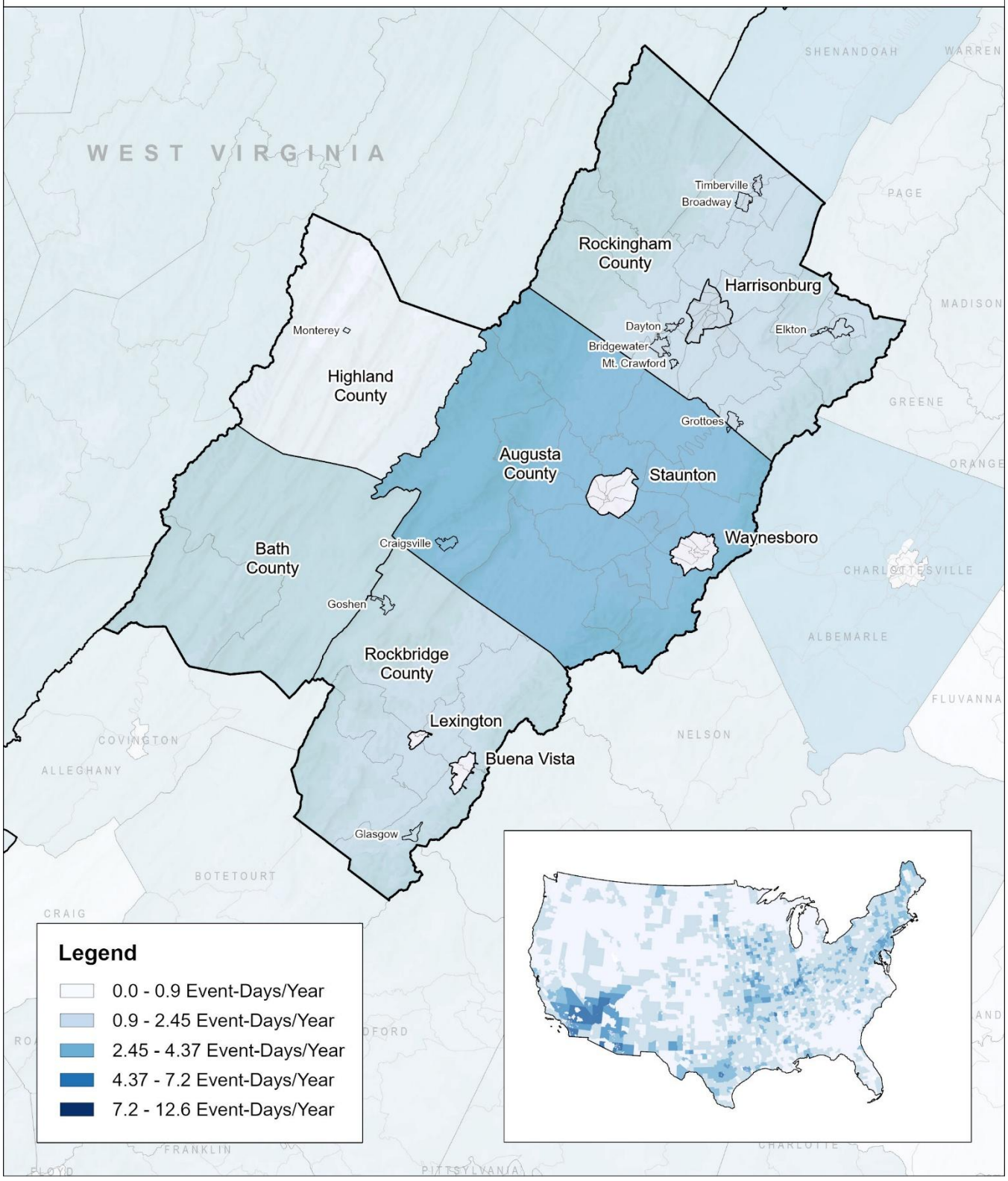
New development outside of floodplains is important, too. Increasing impervious surfaces increases stormwater runoff, as excess water is no longer re-entering the ground under new pavement. This may lead to more flash flooding and related impacts, particularly in the region's cities.

Since all the localities in the region participate in the National Flood Insurance Program (NFIP), they are required to have flood control ordinances. The Department of Conservation and Recreation provides a model floodplain ordinance which incorporates minimum NFIP requirements and suggests higher standards. Communities have the flexibility to adopt additional standards or draft their own ordinance.

CLIMATE CHANGE CONSIDERATIONS

Key drivers of inland flooding include precipitation accumulating over several days; intense precipitation over a short period of time; rapid melting of snow; accumulation of debris in rivers; and dam or levee failure. Research suggests that climate change affects the first three of these key drivers. Warmer air holds more moisture, bringing heavier rainfall extremes. Increased heat also extends drought periods. During intense downpours, dry and hardened soils can lead to more runoff and flash flooding. And finally, earlier snowmelt and more precipitation falling as rain than as snow can lead to more intense floods in colder regions (Climate Central, 2024).

Map 4.1.5. Annualized Frequency of Riverine Flooding by Census Tract



Data Source(s): FEMA National Risk Index (NRI), 2023

VULNERABILITY

Localities with high percentages of land in Special Flood Hazard Areas, as identified by FEMA, could be considered more vulnerable to flooding. For example, Table 4.1.3 shows that the towns of Glasgow, Grottoes, and Goshen have 46.4%, 32.88%, and 25.3% of their land area in flood zones, respectively. It is important to note that flooding occurs outside of the hazardous areas identified by FEMA. With less consideration of areas beyond the 100-year and 500-year flood zones, citizens in those areas may be less prepared for a hazardous flood. Furthermore, people living in manufactured homes are particularly vulnerable during major flood events, especially if the structures are not anchored. Table 4.1.6 shows the estimated number of manufactured homes by City/County, according to American Community Survey estimates.

Table 4.1.6. Estimated Number of Manufactured Homes by City/County, 2023			
Augusta County	2,946	City of Buena Vista	133
Bath County	392	City of Harrisonburg	218
Highland County	295	City of Lexington	0
Rockbridge County	1,183	City of Staunton	49
Rockingham County	3,120	City of Waynesboro	60

Data Source(s): U.S. Census, American Community Survey, 5-Year Estimates, Tables B25024 & B25032, 2023

PROXIMITY TO MAJOR RIVERS

Several of the localities in the CSPDC region are located along prominent rivers. The South River, which connects to the Shenandoah River, runs through the eastern parts of Rockingham and Augusta counties, running through the towns of Elkton and Grottoes and the City of Waynesboro. The Maury River, which connects to the James River, is entirely contained within Rockbridge County, touching the towns of Goshen and Glasgow and the cities of Lexington and Buena Vista. Similarly, the Cowpasture River, a tributary of the James River, runs through Bath and Highland counties.

CRITICAL FACILITIES

The following tables (Table 4.1.7 – 4.1.8) show the number of critical facilities identified by the steering committee in 100-year flood areas and 500-year flood areas. For security purposes the facilities are not directly identified. Across the planning region, 96 critical facilities fall within the 100-year flood zone, with an additional 48 located outside the 100-year flood zone but within the 500-year flood zone. These vulnerable facilities were reviewed with local staff and stakeholders throughout the planning process and were considered in the development of final mitigation actions, as presented in Chapter 6.

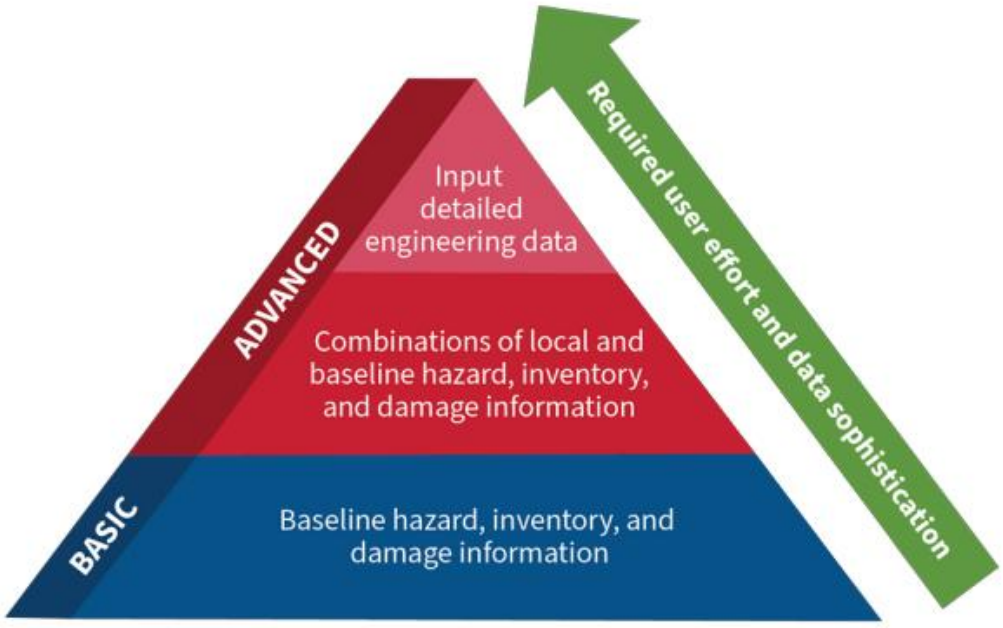
Table 4.1.7. Number of Critical Facilities in 100-Year Flood Areas												
			Emergency + Medical	Public Service	Water Systems	Utility	Industrial	Transportation	Major Employers	Historic Places	Social Centers	Special Populations
Sub-Area	Harrisonburg-Rockingham	City of Harrisonburg	1	2	1	2	0	0	1	1	0	1
		Rockingham County	1	0	2	0	1	0	0	2	0	0
		Town of Bridgewater	0	0	0	0	0	0	-	-	0	0
		Town of Broadway	0	0	1	0	0	0	-	-	0	0
		Town of Dayton	0	0	2	0	0	0	-	-	0	0
		Town of Elkton	0	0	1	0	1	0	-	-	1	0
		Town of Grottoes	0	0	0	0	0	0	-	-	0	0
		Town of Mt. Crawford	0	0	0	0	0	0	-	-	0	0
		Town of Timberville	0	0	0	0	0	0	-	-	0	0
	Staunton-Augusta-Waynesboro	City of Staunton	1	0	0	3	0	1	0	1	1	0
		City of Waynesboro	1	0	2	4	2	0	2	0	1	0
		Augusta County	2	1	7	4	6	0	0	5	6	1
		Town of Craigsville	0	1	0	0	1	0	-	-	5	0
	Rockbridge-Lexington-Buena Vista	City of Buena Vista	0	0	0	0	0	0	0	0	0	0
		City of Lexington	0	0	0	0	0	0	0	2	0	0
		Rockbridge County	2	1	1	1	0	0	0	3	2	0
		Town of Glasgow	0	0	1	0	0	0	-	-	0	0
		Town of Goshen	0	0	0	0	1	0	-	-	0	0
	Bath-Highland	Bath County	0	0	1	1	0	0	0	0	0	0
		Highland County	0	0	0	0	0	0	0	0	3	0
		Town of Monterey	0	0	0	0	0	0	-	-	0	0
CSPDC Total			8	5	18	15	12	1	3	14	18	2

Table 4.1.8. Number of Critical Facilities in 500-Year Flood Areas												
			Emergency + Medical	Public Service	Water Systems	Utility	Industrial	Transportation	Major Employers	Historic Places	Social Centers	Special Populations
Sub-Area	Harrisonburg-Rockingham	City of Harrisonburg	0	2	0	1	0	0	0	0	0	0
		Rockingham County	0	0	0	0	0	0	1	3	0	0
		Town of Bridgewater	0	0	0	0	0	0	-	-	0	0
		Town of Broadway	0	0	0	0	0	0	-	-	0	0
		Town of Dayton	0	0	0	0	1	0	-	-	0	0
		Town of Elkton	0	0	1	0	0	0	-	-	1	0
		Town of Grottoes	0	0	1	0	1	0	-	-	0	0
		Town of Mt. Crawford	0	0	0	0	0	0	-	-	0	0
		Town of Timberville	0	0	1	0	0	0	-	-	0	0
	Staunton-Augusta-Waynesboro	City of Staunton	0	0	0	0	0	0	0	0	1	0
		City of Waynesboro	0	0	0	0	0	0	0	1	0	0
		Augusta County	2	0	0	0	1	0	0	0	3	0
		Town of Craigsville	0	0	0	1	1	0	-	-	1	0
	Rockbridge-Lexington-Buena Vista	City of Buena Vista	2	2	2	0	4	0	1	2	5	1
		City of Lexington	0	0	0	0	0	0	0	1	0	0
		Rockbridge County	0	1	0	0	0	0	1	0	0	0
		Town of Glasgow	1	0	0	0	1	0	-	-	0	0
		Town of Goshen	0	0	0	0	0	0	-	-	0	0
	Bath-Highland	Bath County	0	0	0	0	0	0	0	0	0	0
		Highland County	0	0	0	0	0	0	0	0	0	0
		Town of Monterey	0	0	0	0	0	0	-	-	0	0
CSPDC Total			5	5	5	2	9	0	3	7	11	1

RISK

This plan uses FEMA's Hazus 7.0 software to estimate the potential economic loss to the region given a 100-year flood event. Hazus is a standardized risk modeling tool that can be used to estimate potential damages, economic losses, and social impacts from flood and hurricane events. Hazus risk analyses are categorized as Basic or Advanced given the type of data used.

Chart 4.1.2. Levels of Hazus Analysis

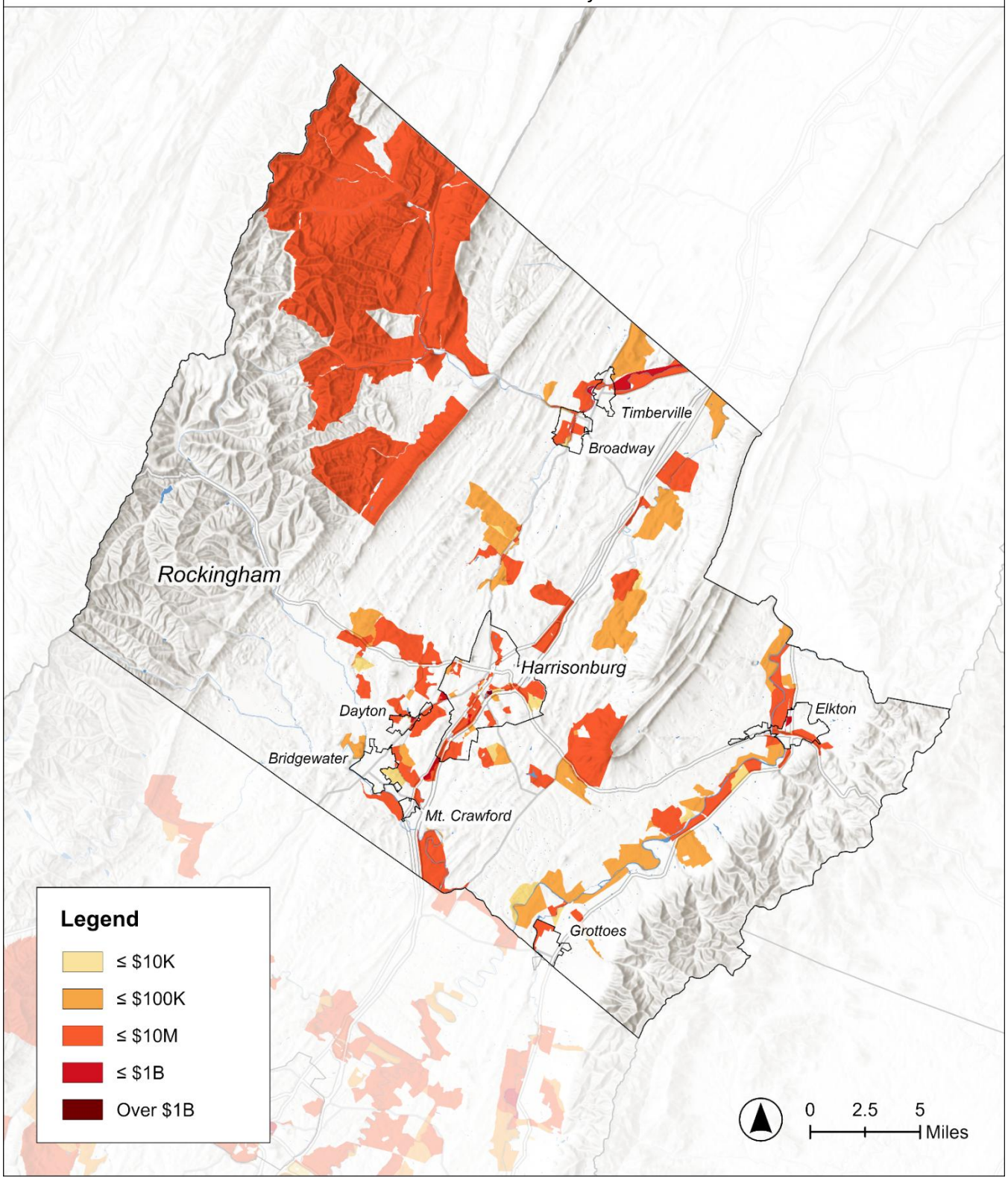


Due to capacity limitations, only a basic analysis was generated for this plan. A basic analysis uses baseline data from nationwide or generic datasets and may not be the most accurate data to represent the region's population characteristics, geography, essential facilities inventory, or built environment.

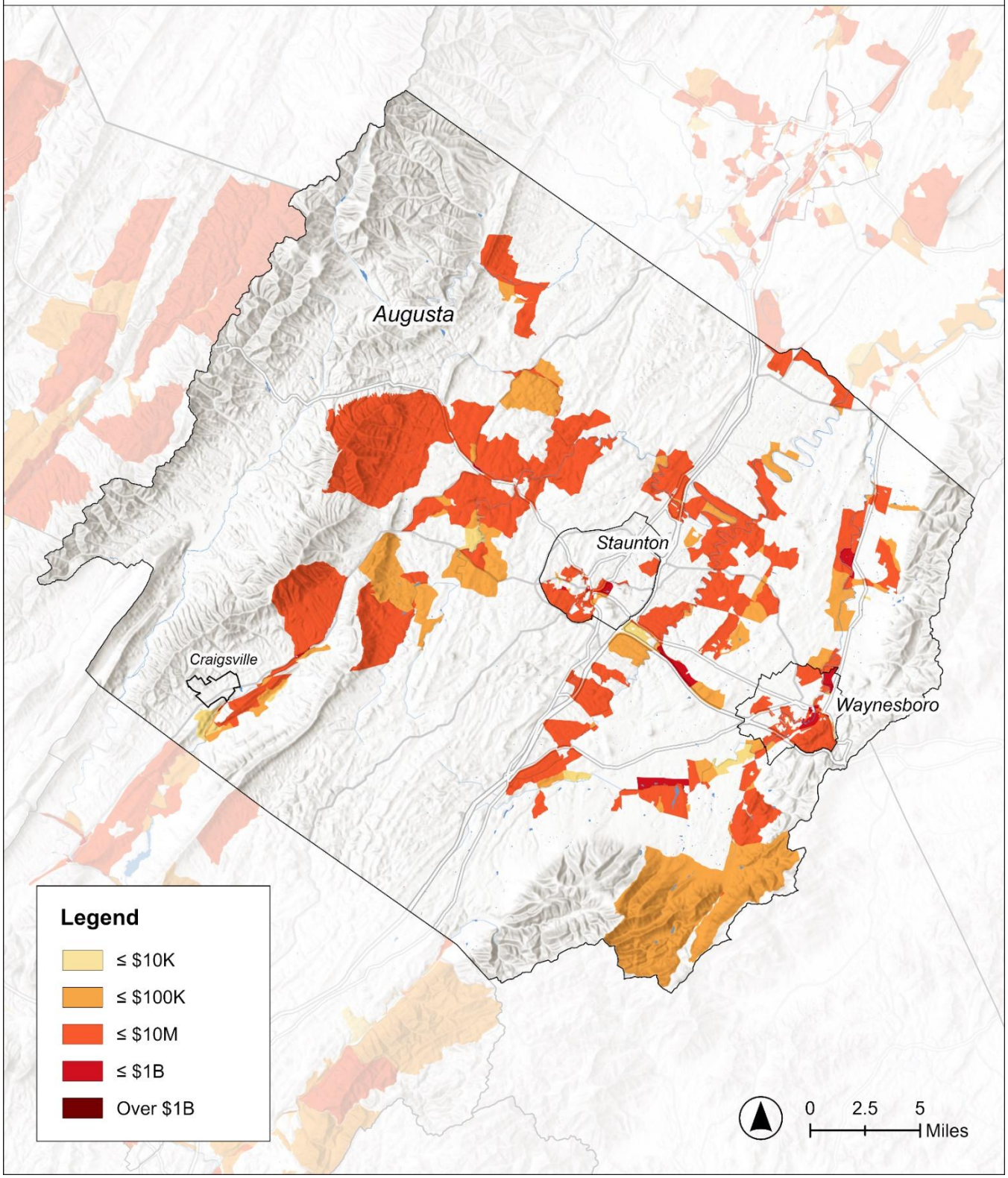
To perform this analysis, the CSPDC used ESRI's ArcGIS Pro software to construct a depth grid from FEMA's National Flood Hazard Layer (NFHL) and USGS's 1-meter Digital Elevation Models (DEM). Flood depth grids illustrate the flood depth, in this case in meters, above the ground surface. After importing the depth grid into Hazus, the CSPDC ran a flood scenario for a 100-year flood event.

The following sub-area maps (Maps 4.1.6 – 4.1.9) show the estimated total economic loss by census block given a one percent-chance annual flood event. According to this scenario, all localities except for the towns of Bridgewater, Mount Crawford, and Craigsville appear to have at least one census block with significant economic loss given a 100-year flood event. This scenario, however, comes with several data limitations as described later.

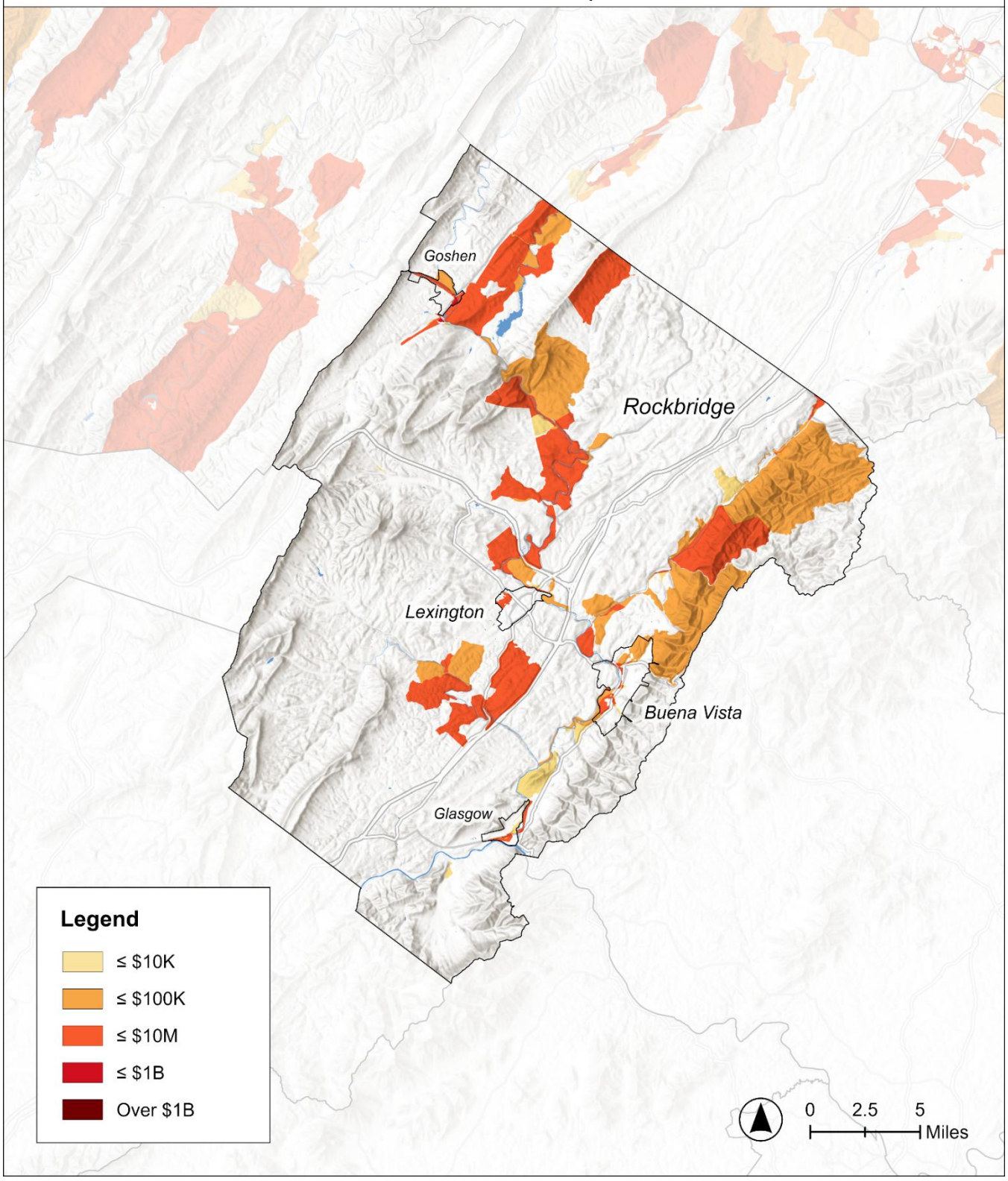
Map 4.1.6. Harrisonburg-Rockingham Hazus Analysis
Estimated Total Economic Loss by Census Block



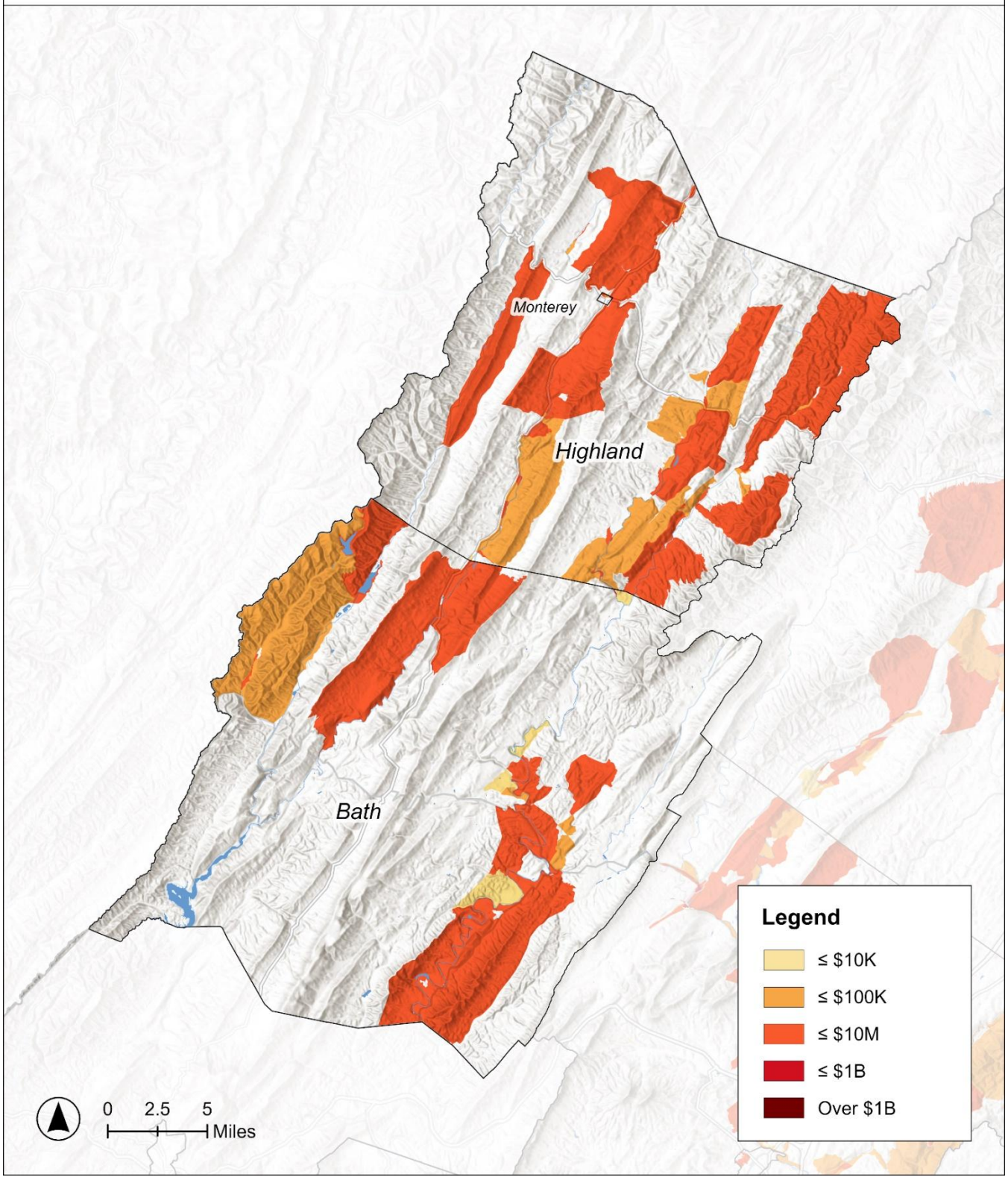
Map 4.1.7. Staunton-Augusta-Waynesboro Hazus Analysis
Estimated Total Economic Loss by Census Block



Map 4.1.8. Lexington-Rockbridge-Buena Vista Hazus Analysis
Estimated Total Economic Loss by Census Block



Map 4.1.9. Bath-Highland Hazus Analysis
Estimated Total Economic Loss by Census Block



HAZUS DATA LIMITATION: REGIONAL BUILDING INVENTORY DATA

Hazus helps estimate the economic loss given a disaster event. To do this, the input building stock information ideally includes information such as the type of structure, building materials, and/or assessment value. The CSPDC does not have a dataset with this information for the region.

HAZUS DATA LIMITATION: AVAILABLE FLOOD RISK DATA

The accuracy of the depth grid created for Hazus is dependent on the best available data. Table 4.1.9 shows the data available to the region at the time of this plan update. The ideal data is a premade depth grid from FEMA, which can be downloaded and imported directly to Hazus. However, this information has only been created for the Staunton-Augusta-Waynesboro subarea.

Alternatively, a depth grid can be built in ESRI's ArcGIS software using the National Flood Hazard Layer flood zones and elevation data. Importantly, the difference between flood zones A and AE is that AE zones include base flood elevations (BFE), which are the heights to which floodwaters are expected to rise during a 100-year flood. BFEs are key measurements for modeling depth grids. Flood zones A do not include this information and, therefore, result in more uncertainty. As shown in Table 4.1.9, the Bath-Highland subarea has the least amount of data with base flood elevation.

Finally, it is important to note the effective dates on local FIRMs, as these maps delineate the boundaries of the flood zones. FEMA provides local jurisdictions with FIRMs based on a grid system; all localities in the region except for the Town of Monterey have at least two FIRMs. The counties have several dozens, given their large geographic size. Notably, most of the region's FIRMs have effective dates from the early 2000s. The Lexington-Rockbridge-Buena Vista subarea has the oldest effective dates. Maintaining updated information on flood zone boundaries is important, especially as population growth and development alter the shape of floodplains over time.

Table 4.1.9. Available Flood Risk Data					
		Pre-Made Depth Grid	100-Year Flood Zone Data		FIRM Effective Date(s)
			% AE (Has BFE)	% A (No BFE)	
Harrisonburg-Rockingham	City of Harrisonburg	-	100.0%	0.0%	2008
	Rockingham County	-	87.5%	12.5%	2008 (most) 2014 (some)
	Town of Bridgewater	-	100.0%	0.0%	2014
	Town of Broadway	-	100.0%	0.0%	2008
	Town of Dayton	-	100.0%	0.0%	2008
	Town of Elkton	-	91.5%	8.5%	2008
	Town of Grottoes	-	99.0%	1.0%	2008
	Town of Mt. Crawford	-	41.6%	58.4%	2014
	Town of Timberville	-	100.0%	0.0%	2008
Staunton-Augusta-Waynesboro	City of Staunton	✓	99.9%	0.1%	2007
	City of Waynesboro	✓	100.0%	0.0%	2007 (most) 2015 (one)
	Augusta County	✓	65.1%	34.9%	2007 (most) 2015 (some)
	Town of Craigsville	✓	100.0%	0.0%	2007
Lexington-Rockbridge-Buena Vista	City of Buena Vista	-	71.9%	28.1%	2000
	City of Lexington	-	57.9%	42.1%	2000
	Rockbridge County	-	26.2%	73.8%	2000
	Town of Glasgow	-	100.0%	0.0%	2000
	Town of Goshen	-	56.4%	43.6%	2000
Bath-Highland	Bath County	-	0.0%	100.0%	2009
	Highland County	-	0.1%	99.9%	2009
	Town of Monterey	-	100.0%	0.0%	2009

Data Source(s): FEMA Flood Map Service Center, 2025



HAZARD PROFILE 2

TROPICAL STORM/HURRICANE

DEFINITION

A tropical cyclone with a sustained surface wind of at least 39 mph. This hazard profile includes both tropical storms (windspeeds 39-73 mph) and hurricanes (windspeeds of 74 mph and greater) based on the Saffer-Simpson scale.

Table 4.2.1. Saffer-Simpson Hurricane Wind Scale

Category	Sustained Winds	Types of Damage
1	74-95 mph	Very dangerous winds will produce some damage
2	96-110 mph	Extremely dangerous winds will cause extensive damage
3 (major)	111-129 mph	Devastating damage will occur
4 (major)	130-156 mph	Catastrophic damage will occur
5 (major)	157 mph or higher	Catastrophic damage will occur

Data Source(s): NOAA

BACKGROUND

Depending on strength, these storms are classified as tropical depressions, tropical storms, or hurricanes. Tropical cyclones involve both atmospheric and hydrologic characteristics, such as severe windstorms, surge flooding, high waves, coastal erosion, extreme rainfall, thunderstorms, lightning, and, in some cases, tornadoes. Storm surge flooding can push inland, and riverine flooding associated with heavy inland rains can be extensive. High winds are associated with hurricanes, with two significant effects: widespread debris and power outages. Widespread debris is due to damaged and downed trees and damaged buildings. Additionally, hurricanes that do not have a historical storm system track through the Region have still resulted in catastrophic impacts, such as Hurricane Camille.

ASSOCIATED EFFECTS

The primary damaging forces associated with these storms in inland areas are high-level sustained winds, heavy precipitation, and tornados. Secondary and associated effects can include flash and sustained flooding, large-scale utility outages, mass casualties, inundated critical community services, transportation accidents and/or access issues, widespread evacuation and/or displaced communities.

SIGNIFICANT HISTORICAL EVENTS

Higher-category hurricanes generally reduce to tropical storms or depressions by the time they reach inland areas of the state. While the planning district is relatively untouched by direct hurricane tracks, the region still experiences their effects. The following list details storms from the past 60 years that notably affected the region (Urbanowicz, 2018):

- **October 2024: Hurricane Helene** was a deadly hurricane, causing severe damage to communities in North Carolina and Southwest Virginia. In Waynesboro, the South River rose to 12.4 feet, nearly three feet above flood stage. High winds from the storm caused significant tree damage and power outages for thousands of residents (Graham, 2024).
- **September 2018: Hurricane Florence** reportedly caused widespread flooding in Staunton, Augusta County, and Waynesboro; the Shenandoah National Park closed due to severe weather.
- **September 2004: Hurricane Jeanne** brought widespread flooding to the state with the heaviest rainfall spreading from the New River Valley to the Southern Shenandoah Valley; rainfall in this region ranged from 3 inches to 7 inches, with high amounts falling in Rockbridge County, among other western Virginia counties.
- **September 2003: Hurricane Isabel** caused an estimated $29 million in damages to the Shenandoah Valley and was not just known for the heavy rain and flash flooding, but also the damaging winds that caused millions of power outages and down trees.
- **September 1999: Hurricanes Dennis and Floyd** made landfall in North Carolina and spread heavy rain and wind across Virginia; 4 to 7 inches of rain fell across the region with peaks of 9.5 inches at Mill Creek Dam in Augusta County and 8.5 inches at Monterey in Highland County.
- **September 1996: Hurricane Fran** caused the Shenandoah National Park to close for 2 weeks due to wind and flood damage; Rockingham County reported 40 homes destroyed and 105 homes with major damage.
- **November 1985: Hurricane Juan** led to $8 million in road damage in Augusta County, and another $7 million in damage to homes, businesses, and public facilities.
- **June 1972: Hurricane Agnes** caused the South River to rise over its banks, submerging downtown Waynesboro under 5 feet of water; similarly, Buena Vista and the Town of Glasgow in Rockbridge County were heavily flooded.
- **August 1969: Hurricane Camille** is known as one of Virginia's deadliest hurricanes, causing the deaths of 23 people Rockbridge County; Buena Vista was deluged under 6 feet of water, while

Glasgow was under 14 feet of water; 150 head of cattle were lost, crops were destroyed, and fertile topsoil was washed away, impacting agriculture for years. Damages in Rockbridge County alone exceeded $30 million.

DISASTER DECLARATIONS

Since 1996, FEMA has recognized the following Major Disaster Declarations related to tropical storms/hurricanes in the state:

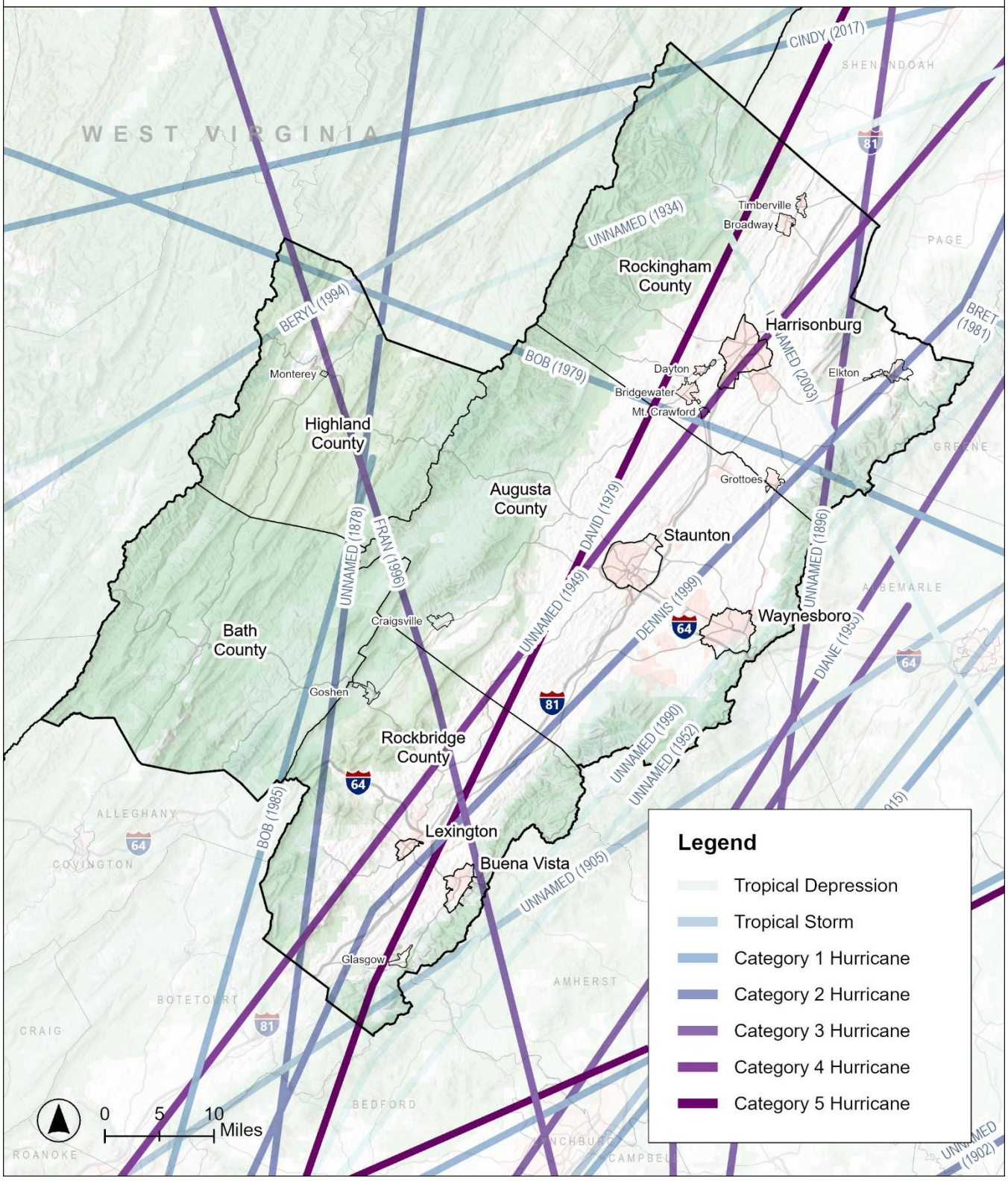
- October 1, 2024: Tropical Storm Helene (DR-4831-VA)
- September 29, 2024: Post-Tropical Cyclone Helene (EM-3621-VA)
- December 18, 2018: Tropical Storm Michael (DR-4411-VA)
- October 15, 2018: Hurricane Florence (DR-4401-VA)
- November 2, 2016: Hurricane Matthew (DR-4291-VA)
- November 26, 2012: Hurricane Sandy (DR-4092-VA)
- November 17, 2011: Remnants of Tropical Storm Lee (DR-4045-VA)
- September 3, 2011: Hurricane Irene (DR-4024-VA)
- December 9, 2009: Tropical Depression Ida and Nor'easter (DR-1862-VA)
- September 22, 2006: Tropical Depression Ernesto (DR-1661-VA)
- September 12, 2005: Hurricane Katrina Evacuation (EM-3240-VA)
- October 18, 2004: Hurricane Jeanne (DR-1570-VA)
- September 3, 2004: Tropical Depression Gaston (DR-1544-VA)
- September 18, 2003: Hurricane Isabel (DR-1491-VA)
- September 18, 1999: Hurricane Floyd (DR-1293-VA)
- September 16, 1999: Hurricane Floyd (EM-3147-VA)
- September 6, 1999: Tropical Storm Dennis and Tornadoes (DR-1290-VA)
- September 4, 1998: Hurricane Bonnie (DR-1242-VA)
- September 6, 1996: Hurricane Fran (DR-1135-VA)

AREAS OF IMPACT

Map 4.2.1. shows the historical storm system tracks for tropical depressions, tropical storms, and hurricanes that have passed through the region from 1950 to present. Often, these storms reduced in intensity by the time they traveled through the region.

Hurricane-force and tropical storm-force winds pose significant risks to the Central Shenandoah region despite its inland location. Wind impacts typically include widespread tree damage and failure, particularly affecting the region's heavily forested areas and tree-lined residential streets. Fallen trees and branches create hazards by blocking roadways, damaging structures, and bringing down power lines. Power outages represent one of the most widespread impacts, with recent events like Hurricane Helene (2024) and Hurricane Isabel (2003) resulting in outages affecting thousands of residents across multiple jurisdictions for several days. The region's topography, with ridges and valleys that can channel and amplify wind speeds, may intensify localized wind damage in certain areas. Flood-related impacts due to Tropical Storms are noted in Appendix D – Detailed Hazard Histories.

Map 4.2.1. Hurricane Tracks, 1950-2025



Data Source(s): NOAA's International Best Track Archive for Climate Stewardship (IBTrACS), 2025

ESTIMATED LOSSES

Data from the National Oceanic and Atmospheric Administration (NOAA) shows that there have been 21 tropical cyclone events with damages reaching $1 billion or more in Virginia since 1980.

Table 4.2.2. Virginia's $1 Billion Hurricane Events

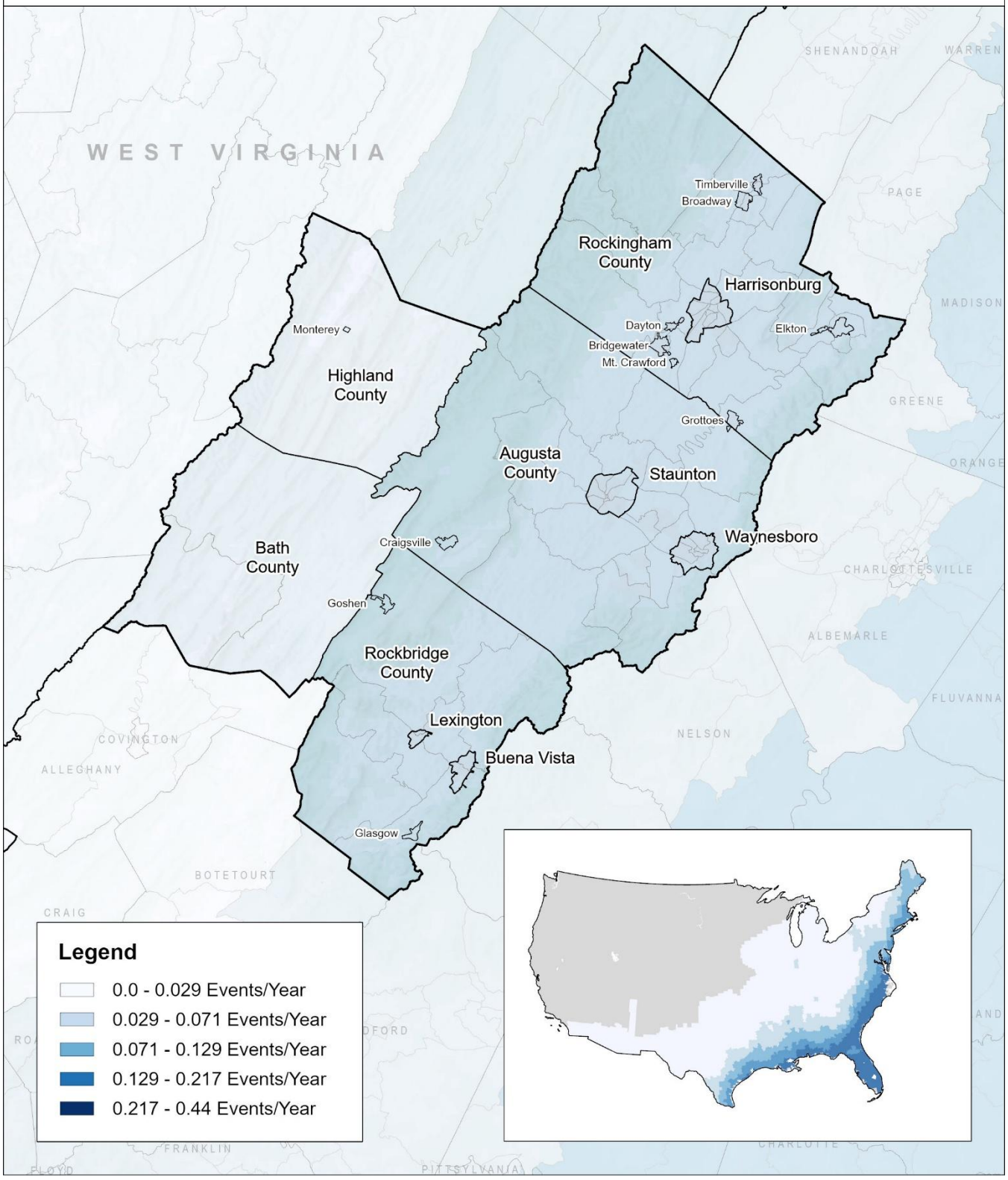
Date	Event	Estimated Cost	Reported Deaths	Affected the Region?
Sept. 2022	Hurricane Ian	$118.5 billion	152	-
Aug. 2021	Hurricane Ida	$84.6 billion	96	-
Aug. 2021	Tropical Storm Fred	$1.5 billion	7	-
July 2021	Tropical Storm Elsa	$1.4 billion	1	-
Nov. 2020	Tropical Storm Eta	$1.8 billion	12	-
Aug. 2020	Hurricane Isaias	$5.8 billion	16	-
Sept. 2019	Hurricane Dorian	$2.0 billion	10	-
Oct. 2018	Hurricane Michael	$31.0 billion	49	-
Sept. 2018	Hurricane Florence	$29.8 billion	53	Yes
Oct. 2016	Hurricane Matthew	$13.0 billion	49	-
Oct. 2012	Hurricane Sandy	$88.5 billion	159	-
Sept. 2011	Tropical Storm Lee	$3.5 billion	21	-
Aug. 2011	Hurricane Irene	$18.8 billion	45	-
Sept. 2004	Hurricane Jeanne	$12.4 billion	28	Yes
Sept. 2004	Hurricane Ivan	$33.4 billion	57	-
Sept. 2003	Hurricane Isabel	$9.3 billion	55	Yes
Sept. 1999	Hurricane Floyd	$12.1 billion	77	Yes
Aug. 1998	Hurricane Bonnie	$1.9 billion	3	-
Sept. 1996	Hurricane Fran	$10 billion	37	Yes
Sept. 1989	Hurricane Hugo	$22.6 billion	86	-
Sept. 1985	Hurricane Gloria	$2.5 billion	11	-

Data Source(s): National Oceanic and Atmospheric Administration (NOAA), 2024

PROBABILITY OF FUTURE OCCURRENCES

The probability of future hurricanes directly affecting the Shenandoah Valley in Virginia is relatively low, but not zero. This is because hurricanes primarily impact coastal regions, and the Shenandoah Valley is located inland. Map 4.2.2. illustrates the annualized frequency of hurricanes, calculated by FEMA's National Risk Index. The data suggests the region may experience between 0 to 0.07 events per year, compared to nearly three times that along the eastern coast. However, hurricanes and tropical storms can still have indirect effects on the region.

Map 4.2.2. Annualized Frequency of Tropical Storms/Hurricanes



Data Source(s): FEMA National Risk Index Annualized Frequency Hurricane, 2023

CLIMATE CHANGE CONSIDERATIONS

According to the Geophysical Fluid Dynamics Laboratory, several studies indicate that global warming may not affect the *frequency* of future tropical events. However, global warming will likely increase the *intensity* of storms due to greater water vapor in the atmosphere. In the Central Shenandoah Valley region, this could mean more severe secondary effects such as flash flooding, mudslides, and winds.

VULNERABILITY

The Commonwealth of Virginia 2023 Hazard Mitigation Plan estimates the region's vulnerability to hurricanes using a Hazus model for a 1-percent-annual-chance return period. The plan reports the results by VDEM's regions; the CSPDC is partially in both VDEM region 3 and region 6. Because the CSPDC's footprint does not align exactly with either VDEM region, the damage estimates from the model are difficult to reconcile. However, Table 4.2.3. shows the loss estimates reported by locality. The average loss estimate across the state was $77,649, with Northern Virginia and the Eastern Shore showing the greatest loss. Combining the estimates for the localities in the CSPDCs footprint, it is estimated that the region would be at risk of losing approximately $323,500 given a 1-percent annual chance hurricane. Rockingham County, Augusta County, and the City of Harrisonburg rank the highest in terms of potential loss.

Table 4.2.3. Hazus Hurricane Wind Annualized Loss

VDEM Region	Jurisdiction	Loss Estimate
VDEM Region 3	Augusta	$77,929
	Staunton	$30,691
	Waynesboro	$26,145
	Rockingham	$81,727
	Harrisonburg	$51,506
VDEM Region 6	Bath	$8,585
	Highland	$3,836
	Rockbridge	$26,044
	Buena Vista	$7,352
	Lexington	$9,729

Data Source(s): Commonwealth of Virginia 2023 Hazard Mitigation Plan (Table 3-70)



HAZARD PROFILE 3

HIGH WINDS

DEFINITION

Sustained winds greater than 40 miles per hour (mph) or gusts of 58 mph or greater; not associated with a tropical storm or hurricane.

Tornadoes represent the most extreme form of high wind events and are classified using the Enhanced Fujita Scale (EF Scale), which ranges from EF0 to EF5 based on damage severity (see Table 4.3.1). The Enhanced Fujita Scale, implemented in 2007, replaced the original Fujita Scale after research demonstrated that the original scale overestimated the wind speeds necessary to produce specific types of damage.

Table 4.3.1. Tornado Classification

Rating	F Scale (1971-2007)	EF Scale (2007-Present)	Damage Level
0	F0: 40-72 mph	EF0: 65-85 mph	Light Damage – peeled surface from roof, gutter or siding damage.
1	F1: 73-112 mph	EF1: 86-110 mph	Moderate Damage – stripped roof, mobile homes overturned, loss of exterior doors or windows.
2	F2: 113-157 mph	EF2: 111-135 mph	Considerable Damage – roof torn off structure, foundation shifted, mobile homes destroyed.
3	F3: 158-206 mph	EF3: 136-165 mph	Severe Damage – entire building stories destroyed, severe damage to large buildings (e.g., mall / school).
4	F4: 207-260 mph	EF4: 166-200 mph	Devastating Damage – well-constructed houses and whole-frame homes completely leveled.
5	F5: 261-318 mph	EF5: >200 mph	Incredible Damage – houses leveled, foundations swept away, high-rise buildings deformed.

Data Source(s): National Weather Service, National Oceanic and Atmospheric Administration

BACKGROUND

This analysis reviewed tornadoes and straight-line wind events, such as derechos and downburst events. Straight-line winds are associated with thunderstorm winds which have no rotation. These winds are often called damaging winds to differentiate the damage caused by a tornado and are classified as those which exceed 50-60 mph. A derecho is a windstorm that is widespread and long-lived that produces damaging straight-line winds. It is associated with rapidly moving thunderstorms that are curved in shape. An event is classified as a derecho if wind damage extends more than 250 miles, several wind gusts of 75 mph or greater, and has wind gusts of at least 58 mph along most of the length of the storm's path.

ASSOCIATED EFFECTS

High wind events can lead to several secondary hazards such as property damage, transportation access issues, power outages, and telecommunication outages. Due to the rapid movement and short notice of straight-line wind events, activities outdoors, especially vehicles on roads, are most vulnerable and at risk. These events could have significant impact on power and cause loss of life.

SIGNIFICANT HISTORICAL EVENTS

From 1991-2010, Virginia averaged 18 tornadoes each year (NOAA, n.d.). During that same period, the CSPDC region only had 5 recorded tornadoes—this number could be higher since tornadoes are generally recorded when people are affected or structures are damaged. Table 4.3.2. summarizes the tornadoes in the region since 1950. Appendix E includes a more detailed history of tornadoes and strong wind events in the region, dating back to the 1800s.

Table 4.3.2. Recorded Tornadoes and Impact Since 1950

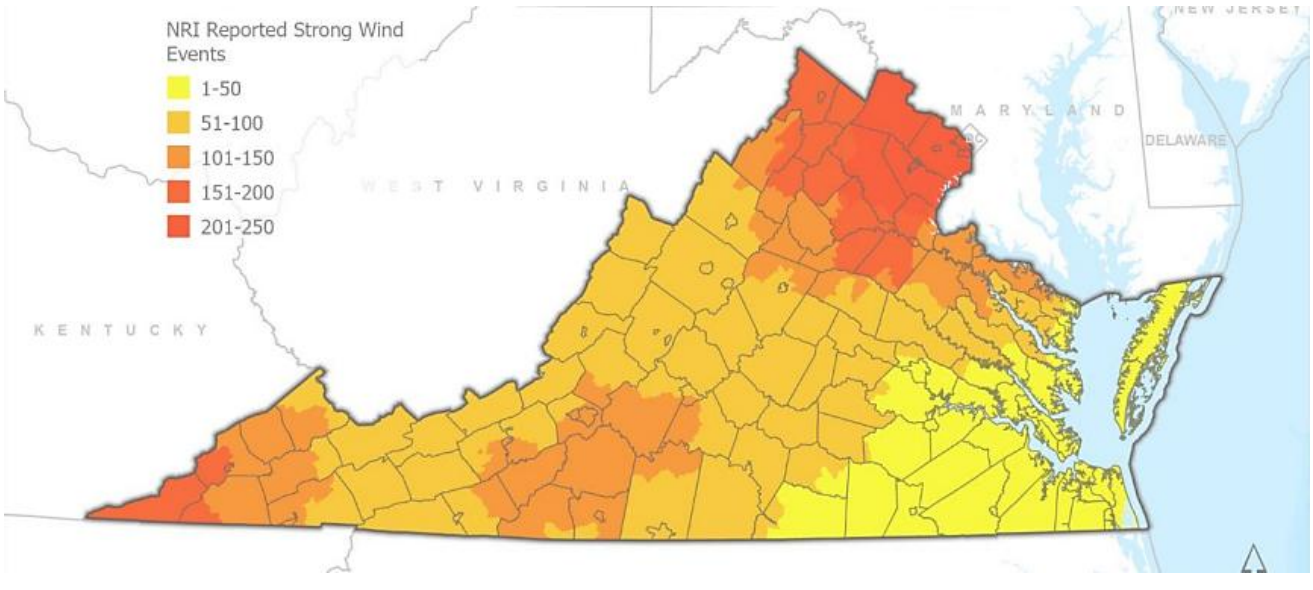
Date	Intensity	Locality(s)	Impact
May 6, 2022	EF0	Rockbridge	Property Damage $8K
April 26, 2022	EF1	Augusta, Waynesboro	Property Damage: $200K
August 6, 2020	EF0	Augusta	Property Damage: $150K Crop Damage: $200K
October 31, 2019	EF0	Rockingham	Property Damage: $30K
April 28, 2011	EF1	Augusta, Rockingham	Property Damage: $425K
April 16, 2011	EF0	Augusta, Rockbridge	Property Damage: $2.2M
August 2, 2008	EF0	Rockingham	N/A
May 9, 2003	F0	Augusta	N/A
July 31, 1999	F1	Augusta	Property Damage: $15K
June 24, 1996	F1	Rockingham	Property Damage: $40K

Date	Intensity	Locality(s)	Impact
June 10, 1995	F1	Augusta, Waynesboro	Property Damage: $2M
May 4, 1990	F2	Augusta	Fatalities: 2; Injuries: 10 Property Damage: $2.5M
October 2, 1979	F1	Rockingham	Property Damage: $25K
August 15, 1975	F1	Rockingham	Property Damage: $25K
June 5, 1975	F0	Augusta, Rockbridge	N/A
April 4, 1974	F1	Augusta	Property Damage: $2.5M
November 29, 1963	F2	Augusta	Property Damage: $25K
August 6, 1960	F2	Rockingham	Property Damage: $25K
July 1, 1959	F1	Augusta	Property Damage: $25K
April 28, 1959	N/A	Highland	Property Damage: $2.5K
April 5, 1952	F2	Augusta, Rockingham	Injuries: 2 Property Damage: $275K

Data Source(s): Tornado Path, 2025. Note: Data was only available at the County level.

While tornadoes are relatively uncommon in the region, the region has experienced other high wind events. Map 4.3.1. shows the number of occurrences for non-tornadic events using National Risk Index (NRI) reported events for counties in Virginia. Most of the communities in the CSPDC region have 51-100 events reported. The easternmost part of Rockingham County has slightly more, 101-150 events reported.

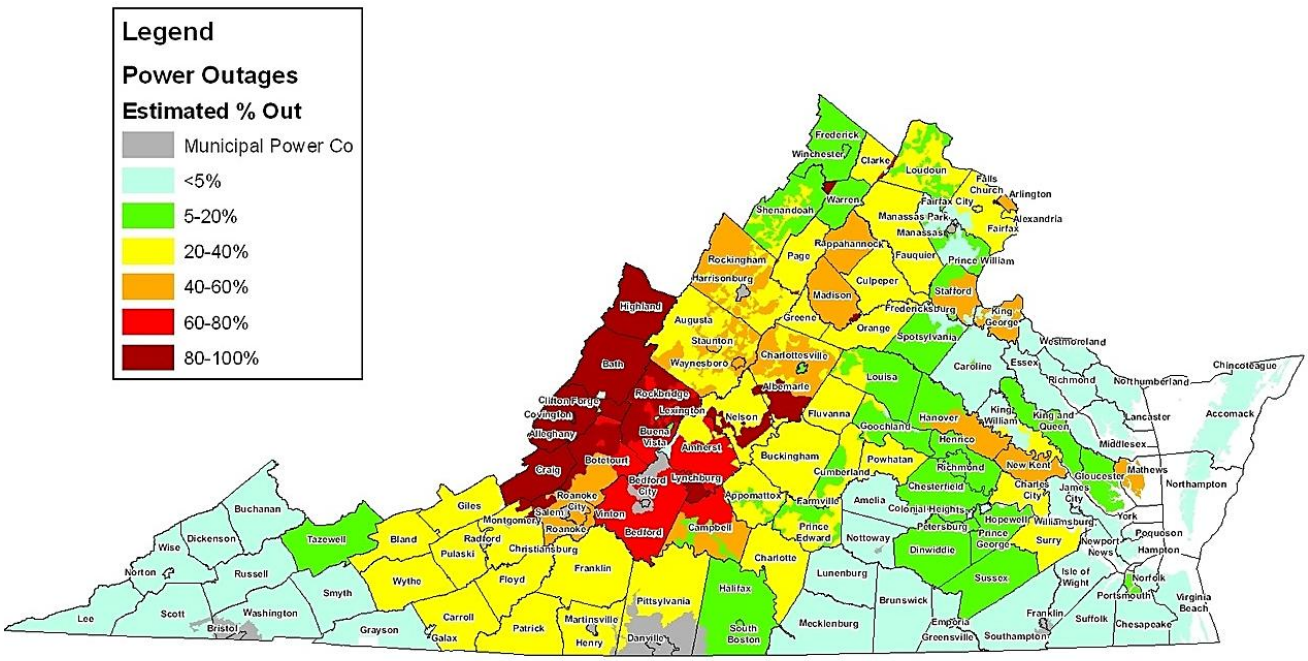
Map 4.3.1. Reported Number of Historic Strong Wind Events



Source: Commonwealth of Virginia 2023 Hazard Mitigation Plan (Figure 3-129).

High winds and damaging winds associated with straight-line winds have been known to impact this region. However, derechos are rare. It has been over a decade since the last major derecho, which affected several Midwest and Mid-Atlantic states at the end of June 2012. The storm complex was fueled by hot and humid air. The system produced 70-90 mph straight-line winds and caused over a million residents to lose power during the subsequent heat wave (Sublette, 2013). Map 4.3.2. shows the percent of people without power on July 1, 2012, as estimated by the Commonwealth. In the region, Highland, Bath, and Rockbridge counties and the cities of Lexington and Buena Vista were most affected.

Map 4.3.2. Percent of Population that Experienced a Power Outage (July 1, 2012)



Source: Commonwealth of Virginia, 2012

DISASTER DECLARATIONS

Since 2000, FEMA has recognized one Major Disaster Declaration related to high winds in the state:

- July 17, 2012: Severe Storms and Straight-Line Winds (FEMA-4072-DR)

Immediately following the 2012 derecho, the Governor requested a declaration for Public Assistance for 47 counties and 15 independent cities and Hazard Mitigation Grant Program assistance for the entire commonwealth. The counties of Augusta, Bath, Highland, Rockbridge, and Rockingham and the cities of Lexington and Staunton were included in the nearly $21 million public assistance request (FEMA, 2012). The calculated county/city-wide per capita impact for each is shown in Table 4.3.3.

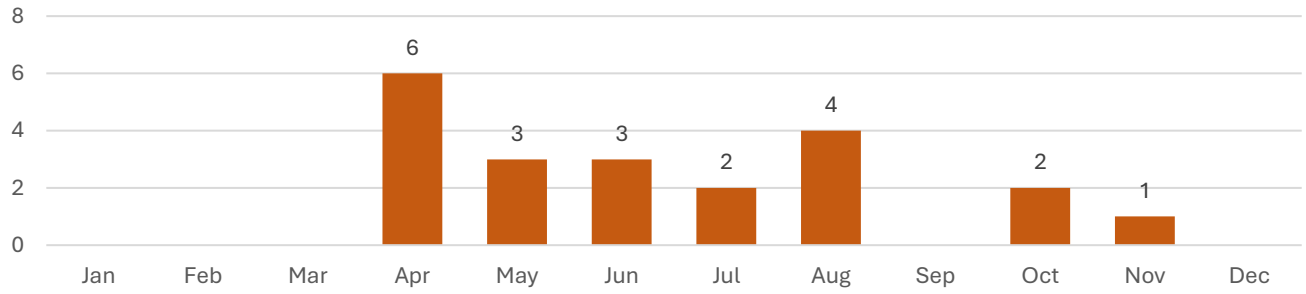
Table 4.3.3. Estimated Per Capita Impact, 2012			
Augusta County	$13.02	Rockbridge County	$16.81
City of Staunton	$4.18	City of Lexington	$27.36
Bath County	$248.86	Rockingham County	$12.23
Highland County	$77.13	Statewide	$3.44

Data Source(s): FEMA, 2012

AREAS OF IMPACT

The entire region's population and infrastructure are vulnerable to high winds based on historical occurrences. Chart 4.3.1. shows the number of tornado instances by month. In the region, tornadoes are more common in the spring and summer months, likely because they can be caused by thunderstorms.

Chart 4.3.1. Number of Recorded Tornadoes Since 1950 by Month

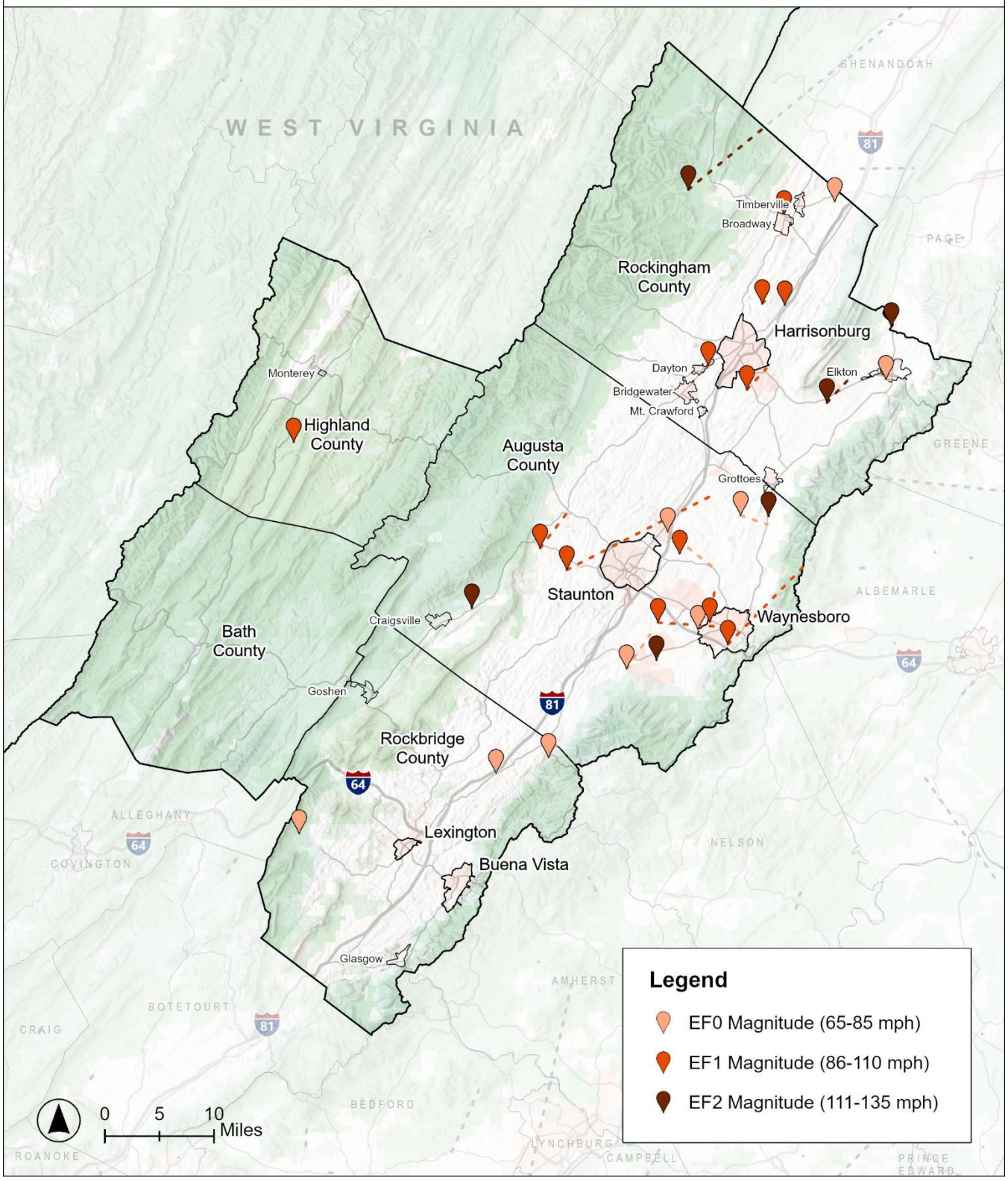


Data Source(s): Tornado Path, 2025

Map 4.3.3. shows the tornado touchdowns and tracks in the region since 1950, according to the National Oceanic and Atmospheric Administration's database. Over the past 75 years, around 20 tornadoes have affected Rockingham and Augusta counties alone. It is important to note, however, that records of tornado instances require reporting on populations affected and property damage; in less populated areas, such as Highland and Bath counties, tornado instances may be underrepresented.

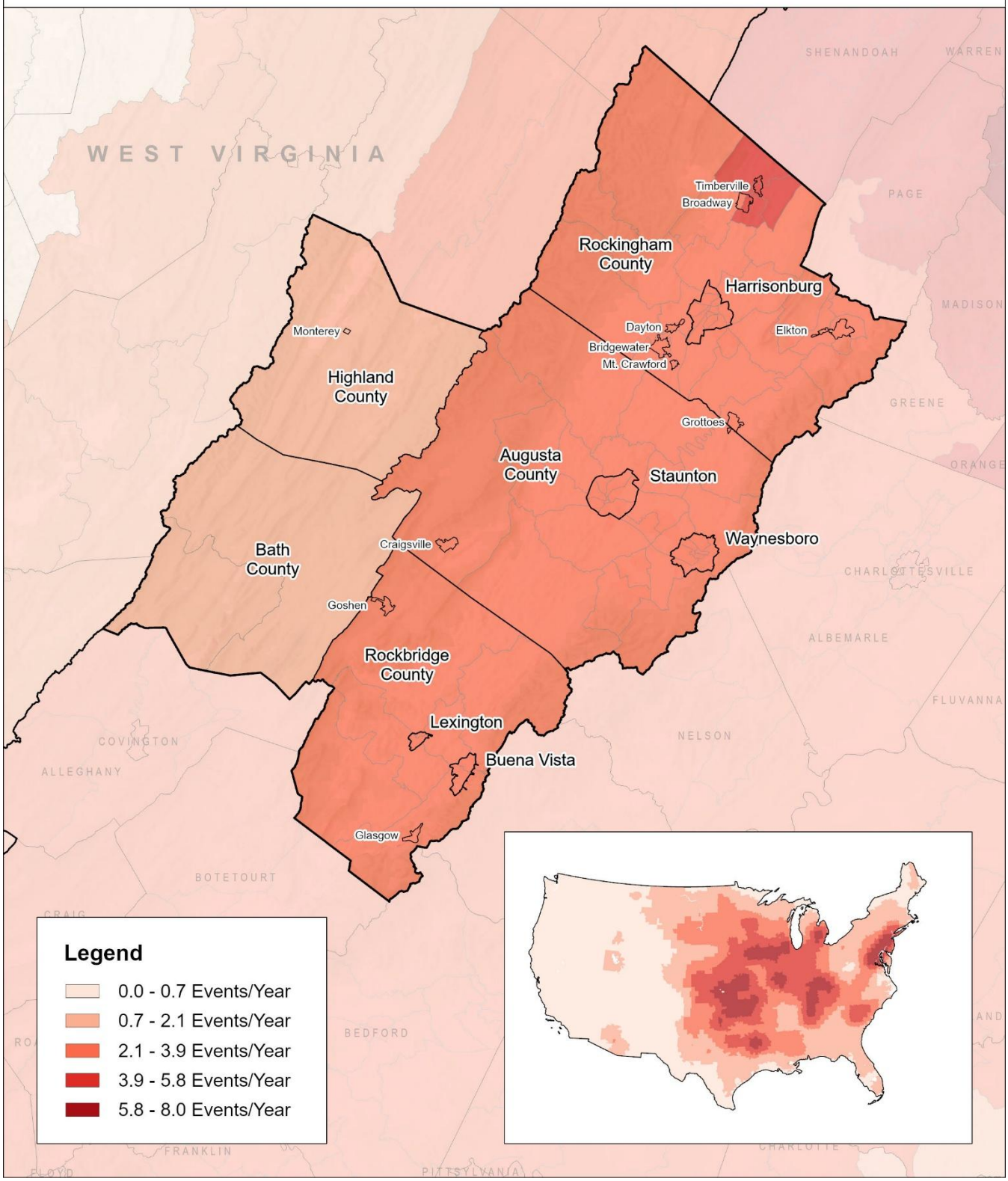
In terms of straight-line wind events, the National Risk Index (NRI) includes a dataset for the estimated frequency of strong wind events per year by census tract at the county/city level. While not as accurate as local data, this was the best available data to the region at the time of the plan update. Map 4.3.4. shows the census tract-level data in the context of the region. According to this dataset, Bath and Highland counties experience about 0.7 to 2.1 events per year, while the rest of the region is estimated to have between 2.1 and 3.9 events per year.

Map 4.3.3. Tornado Touchdowns and Tracks since 1950



Data Source(s): FEMA Geospatial Resource Center, National Oceanic and Atmospheric Administration, 2024

Map 4.3.4. Annualized Frequency of Strong Wind Events by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Strong Wind, 2023

ESTIMATED LOSSES

As listed earlier in Table 4.3.2., NOAA's dataset indicates that the region has lost about $1.5 million in property damage due to tornado events since 1950. Two tornado events, one in 1952 and the other in 1990, led to personal injury. The latter event also resulted in two fatalities. In terms of straight wind events, it is harder to estimate the losses to the region over time due to historic data limitations. Additionally, cascading effects can exacerbate recovery costs. For example, the June 2012 derecho that travelled 600 miles between Indiana to Virginia cost a collective $2.9 billion in damages across 3 states.

PROBABILITY OF FUTURE OCCURRENCES

High wind events are expected to occur regularly within the region, primarily in association with thunderstorm activity. Based on National Risk Index data, most of the region experiences approximately 2.1 to 3.9 strong wind events per year, while more mountainous areas such as Bath and Highland counties experience 0.7 to 2.1 events annually. This suggests a high annual probability that at least one damaging wind event will occur in any given year.

While tornadoes are less frequent, historical records indicate that they occur intermittently, with roughly 20 recorded events in Augusta and Rockingham counties since 1950, indicating a low to moderate annual probability but a persistent long-term risk.

CLIMATE CHANGE CONSIDERATIONS

Research on how climate change affects high wind events remains limited compared to other hazards. However, some studies suggest that a warming climate may increase the intensity of thunderstorm wind gusts. This is thought to result from greater temperature differences within storms, which can strengthen downdrafts and produce stronger surface winds. Due to the localized nature of thunderstorms, these relationships are less well understood than for larger-scale storm systems (Owen, 2023).

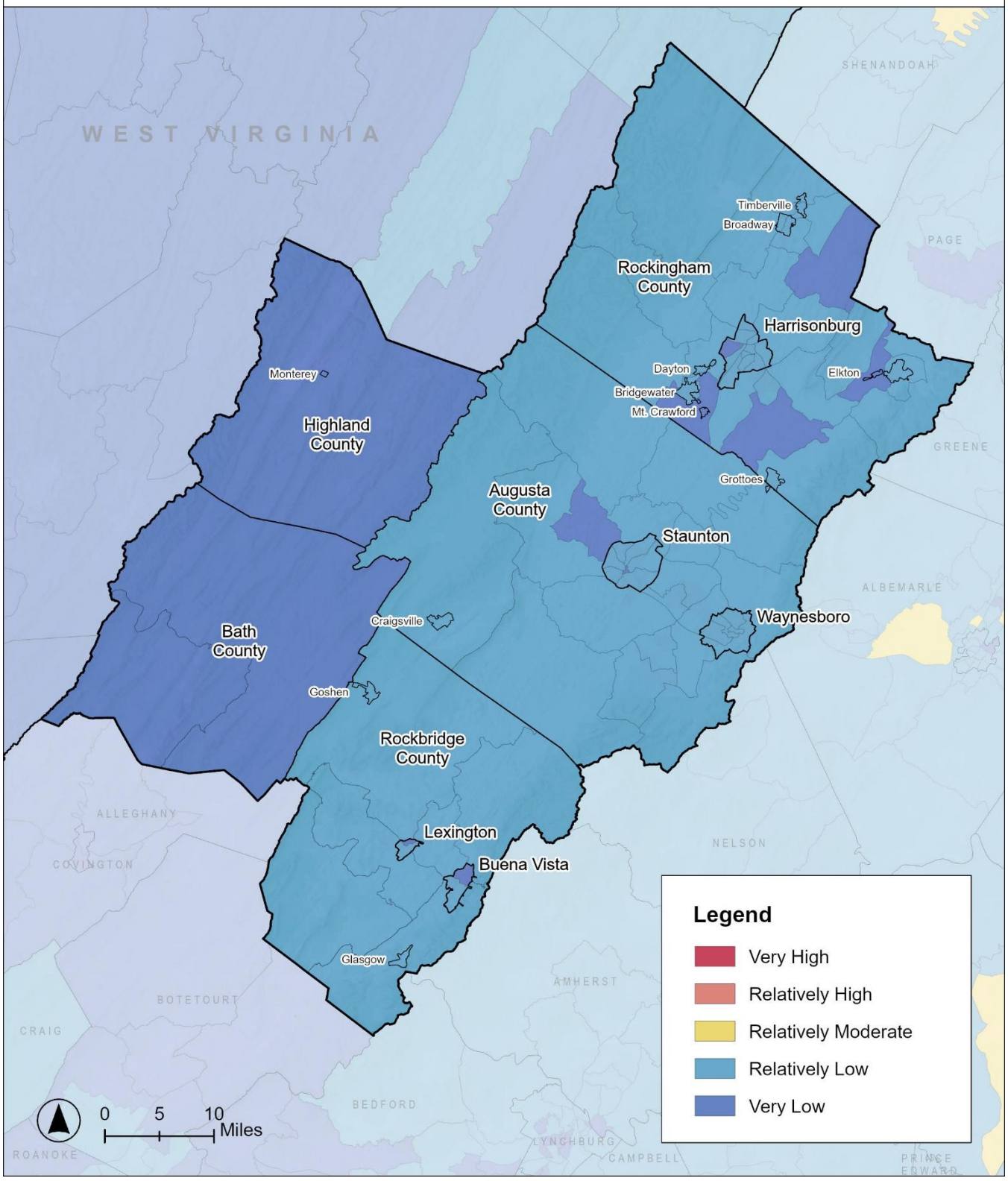
VULNERABILITY

The FEMA National Risk Index (NRI) is a tool developed by the Federal Emergency Management Agency (FEMA) to assess and communicate the relative risk of natural hazards across the United States. The tool provides a risk rating score for each of the 18 natural hazards included in the database. Each hazard's risk rating is a composite score that incorporates the:

- Frequency of the hazard.
- Severity or intensity of the event.
- Vulnerability of the area (e.g., population density, building construction).
- Resilience of the area (e.g., preparedness, mitigation measures).

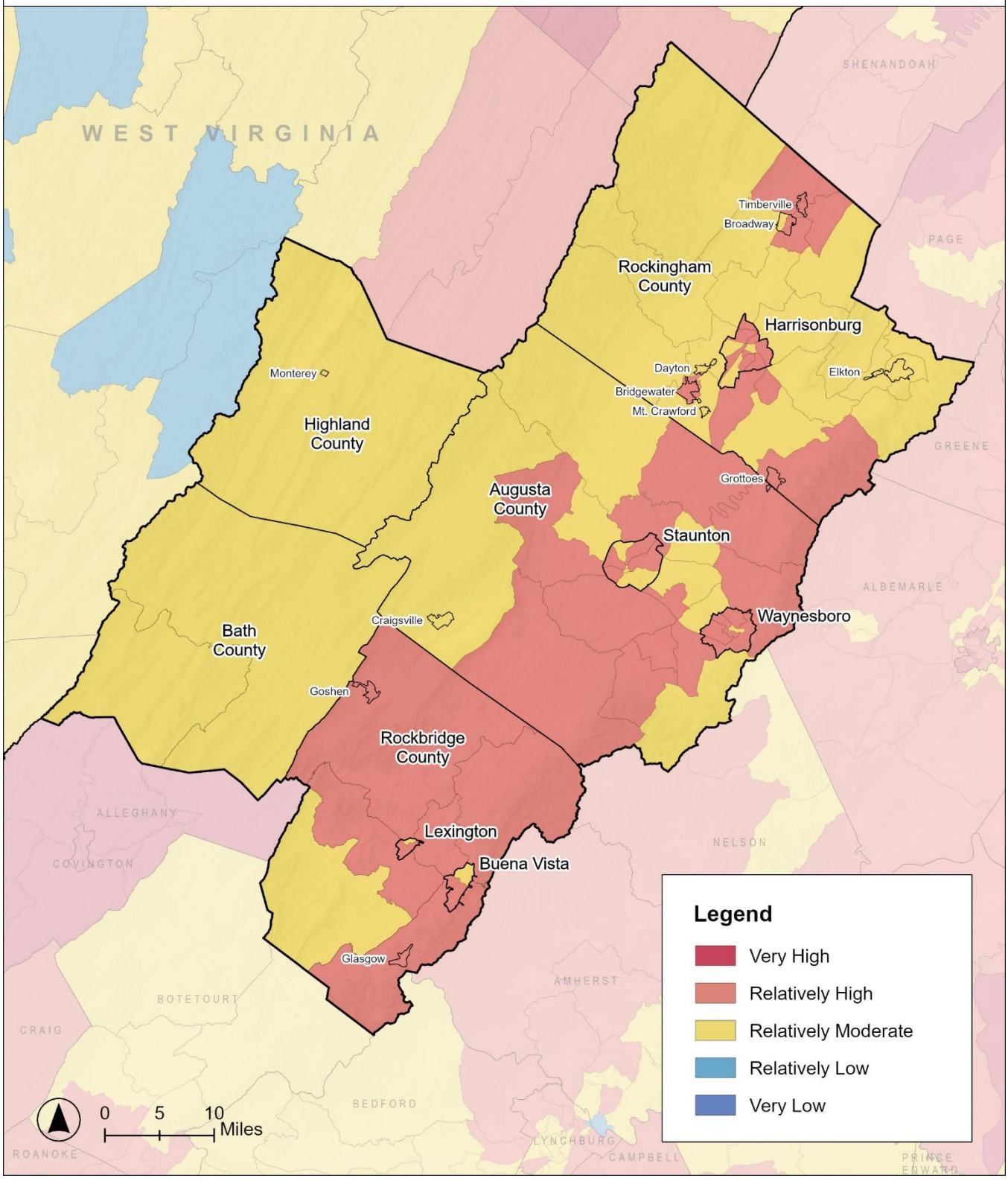
Map 4.3.5. shows the risk rating score by census tract in the region for tornado events. According to this dataset, the region generally has a low risk rating. Similarly, Map 4.3.6. shows the risk rating score by census tract for strong wind events. This data shows that Augusta and Rockbridge counties have relatively higher risk as well as the City of Harrisonburg.

Map 4.3.5. Risk Rating for Tornado Events by Census Tract



Data Source(s): FEMA National Risk Index Tornado Risk Rating, 2023

Map 4.3.6. Risk Rating for Strong Wind Events by Census Tract



Data Source(s): FEMA National Risk Index Strong Wind Risk Rating, 2023



HAZARD PROFILE 4

WILDFIRE

DEFINITION

An unplanned fire event, also known as a wildland fire, that burns in natural areas such as forests, prairies, or grasslands. Fire intensity and fire severity are both terms used to characterize a fire, but they describe different measurements. Fire intensity is a measure of the heat energy released, whereas fire severity is a measure of a fire's impact on a site (Keely, 2009). For the purposes of this plan, fire severity is used to describe the extent or range of impact a wildfire could have on the region's environment.

Table 4.4.1. Fire Severity Scale

Level	Definition
Low	A fire that has limited effect on overstory trees (<30% mortality), understory vegetation, and soils.
Moderate	A fire producing variable, moderate effects on overstory trees, averaging 30-80% of the vegetation killed, and/or moderate soil exposure.
High	A fire producing a high percentage of overstory tree mortality (>80%) and/or extensive mineral soil exposure.

Data Source(s): Northwest Fire Science Consortium (n.d.)

BACKGROUND

While lightning is the most common natural cause for wildfires, approximately 88% of wildfires are initiated by humans with burning debris being the number one cause, followed by unattended campfires, arson, or carelessness (National Interagency Fire Center, n.d.; Western Fire Chiefs Association, 2024). Wildfires are characterized by their uncontrollable, unpredictable, and fast-spreading behavior, loss of natural resources, structures, and in some cases human life. They often begin unnoticed and spread quickly and are usually signaled by dense smoke that fills the area for miles around.

A wildfire can happen any time of year, but the wildfire seasons for each region of the United States predominantly influences the occurrences of them. In the southeastern part of the United States, the spring wildfire season begins in March and goes through May; the fall wildfire season occurs from September to

October. Three primary factors, namely fuel types, topography, and weather, increase the probability of a wildfire igniting and spreading and can influence the behavior of a wildfire.

FUELS

Vegetation, such as naturally occurring and non-native species of grass, brushes, and trees, as well as structures fuel wildfires (Northwest Fire Science Consortium, n.d.). The chemical makeup, the level of moisture, and the amount of vegetation or material present affect wildfire potential. The composition of the plant materials determines how combustible the fire will be depending on the types of oils and resins in different types of grasses, shrubs, or trees (National Park Service, n.d.). The amount of moisture in the vegetation is an essential component for fuel as the drier the material is the more intense and fast the fire will spread. The denser the vegetation the faster, the hotter, and longer the wildfire will burn (NPS, n.d.; Wildland Fire Investigation Subcommittee, 2016).

TOPOGRAPHY

The slope, aspect, and reliefs of topography influence the speed, direction, and intensity of wildfires. The steeper the slope the faster wildfire will spread. Wildfires that occur on south facing slopes will be more intense than fires on north facing slopes due to the south facing slopes absorbing more heat from the sun. The change in topography regulates air movement which can change the direction of wildfire. A wildfire that moves upward will pre-heat fuels causing the fire to move faster (NPS, n.d.).

WEATHER

Weather affects the probability of wildfires and has a significant effect on its behavior. Temperature, humidity, and wind affect the severity and duration of wildfires, with wind being the most important factor. Wind influences the uncontrollable movement of fires to other fuel sources. Higher temperatures will cause less humidity and drier fuel sources, increasing the intensity of the fuel burning, as well as increase the likelihood for lightning strikes (NOAA, 2023). Areas that have experienced prolonged droughts or are excessively dry are also at risk for wildfires.

ASSOCIATED EFFECTS

Secondary effects include impaired air and water quality due to smoke and ash from burned sites, surface runoff and landslides due to loss of vegetation, transportation route closures, resident displacement, utility service interruptions, and the introduction of non-native species. A low intensity wildfire, though unplanned, can be beneficial to the forest by clearing out excess vegetation and creating a healthier habitat for wildlife. A high-severity wildfire, though, can be devastating, burning all the vegetation to the point where the soil is not viable for regrowth of trees, displacing wildlife corridors, killing wildlife, and in some cases causing ash and debris from the fire to leach into the streams and other water sources affecting aquatic life (Snow, 2022).

SIGNIFICANT HISTORICAL EVENTS

According to Virginia Department of Forestry (VDOF) data for the CSPDC region, 285 wildfire incidents occurred between 2014 and 2024. Historically, larger wildfires occur every 2-3 years on average; however, the average frequency has increased to every 1-2 years since 2014. Table 4.4.2 summarizes all wildfire incidents by county and acreage burned. These values do not include federal lands, towns, and cities which are not tracked in the VDOF data. Since 2014, 9 wildfires, burning over 1,000 acres each, have occurred (see Table 4.4.3). Refer to Appendix E – Detailed Hazard Histories for more information on past events.

Map 4.4.1 shows the annualized frequency of wildfires by census tract in the region based on FEMA's National Risk Index (NRI) dataset. Although wildfires occur less frequently in the eastern United States than in the West, the Shenandoah Valley shows notably elevated wildfire occurrence rates.

DISASTER DECLARATIONS

Wildfires have been a historical concern in the CSPDC region, though a disaster declaration has not been issued since 2011 for the region (Federal Emergency Management Agency, n.d.).

Table 4.4.2. Regional Wildfire Incidents Between 2014-2024

	Augusta	Bath	Highland	Rockbridge	Rockingham	Total
Incidents	122	29	17	32	85	285
Acres Burned	1,035	497	253	5,072	1,622	8,479

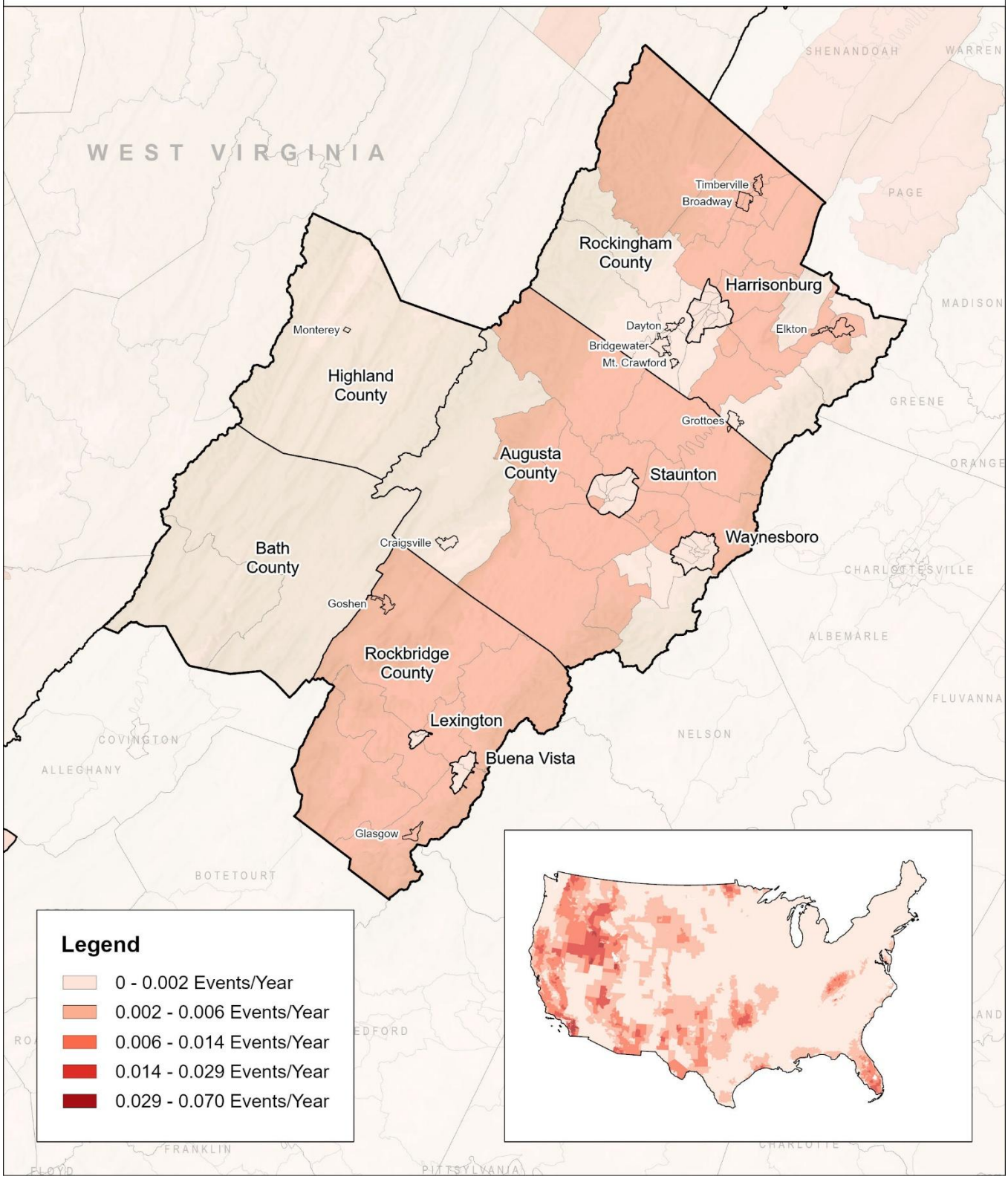
Table 4.4.3. Wildfires Larger than 1,000 Acres, 2014 – 2024

Year	Location	Description
2024	Augusta County (Big Levels Fire)	In December of 2024, approximately 1,300 acres burned in the St. Mary's Wilderness near Greenville, VA.
2024	Rockingham County (Capon/Brush Run Fire)	Several fires sparked during a period of strong westerly winds and extremely low relative humidity values, eventually burning 2,368 acres in the George Washington National Forest. The fires were part of a greater complex of fires, named the North Zone Complex.
2023	Rockbridge County (Matts Creek Fire)	A human-caused wildfire burned approximately 11,000 acres in the George Washington National Forest.
2021	Goshen Wildfire	A wildfire in Rockbridge County that burned 1,730 acres in the Goshen Wildlife Management Area.

Table 4.4.3. Wildfires Larger than 1,000 Acres, 2014 – 2024		
Year	**Location**	**Description**
2018	Rockingham County (Gate Mountain Fire)	Wildfire started from a miscellaneous source and burned 1,040 acres of private forest in the Gate Mountain area.
2018	Rockbridge & Augusta (Tye River Fire)	The wildfire was caused by a vehicle fire that quickly spread onto national forest lands and nearby private lands. The fire burned approximately 2,057 acres.
2018	Rockbridge County (Hog Back Fire)	Wildfire from an incendiary source burned 1,730 acres on Hog Back Mountain.
2017	Rockbridge County (Goshen Pass Wildfire)	The wildfire started in the Goshen area and burned 3,100 acres.
2016	Rockingham County (Rocky Mountain Fire)	The fire started as a 70-acre fire in the Shenandoah National Park. At its maximum size of 10,326 acres, it was the second largest forest fire in the history of Shenandoah National Park.

Data Source(s): Virginia Department of Forestry, 2024

Map 4.4.1. Annualized Frequency of Wildfires by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Wildfire, 2023

AREAS OF IMPACT

According to the 10-year average, 700 wildfires burn in Virginia annually, burning approximately 9,500 acres (*Wildlife in Virginia,* n.d.). Most fires occur in western Virginia, where steep mountain topography and abundant forest vegetation create favorable conditions for wildfire. The Central Shenandoah Region is situated between Blue Ridge Mountains to the east and the Allegheny Mountains to the west. Dense forest coverage characterizes much the region, including the Shenandoah National Park, George Washington National Forest, Jefferson National Forest, and adjacent private forested lands. Table 4.4.4 lists the extent of public land area in each county within the region.

Table 4.4.4. Extent of Public Lands in the CSPDC Region

County	Land Area (Rounded)	Public Lands	% of Land Area in Public Lands
Augusta	618,925 acres	George Washington National Forest and Shenandoah National Park (214,410 acres)	34.6%
Bath	338,688 acres	Public Land (172,231 acres); Gathright Wildlife Management Area (13,428 acres); Douthat State Park (4,545 acres)	56.2%
Highland	265,702 acres	Federal Lands (59,273 acres); The Highland Wildlife Management Area (14,889 acres)	27.9%
Rockbridge	381,786 acres	National Forests (66,007 acres); State-maintained land (29,841 acres)	25.1%
Rockingham	543,866 acres	George Washington and Jefferson National Forest (178,179 acres); State owned (1,513 acres)	33.0%

WILDLAND-URBAN INTERFACE

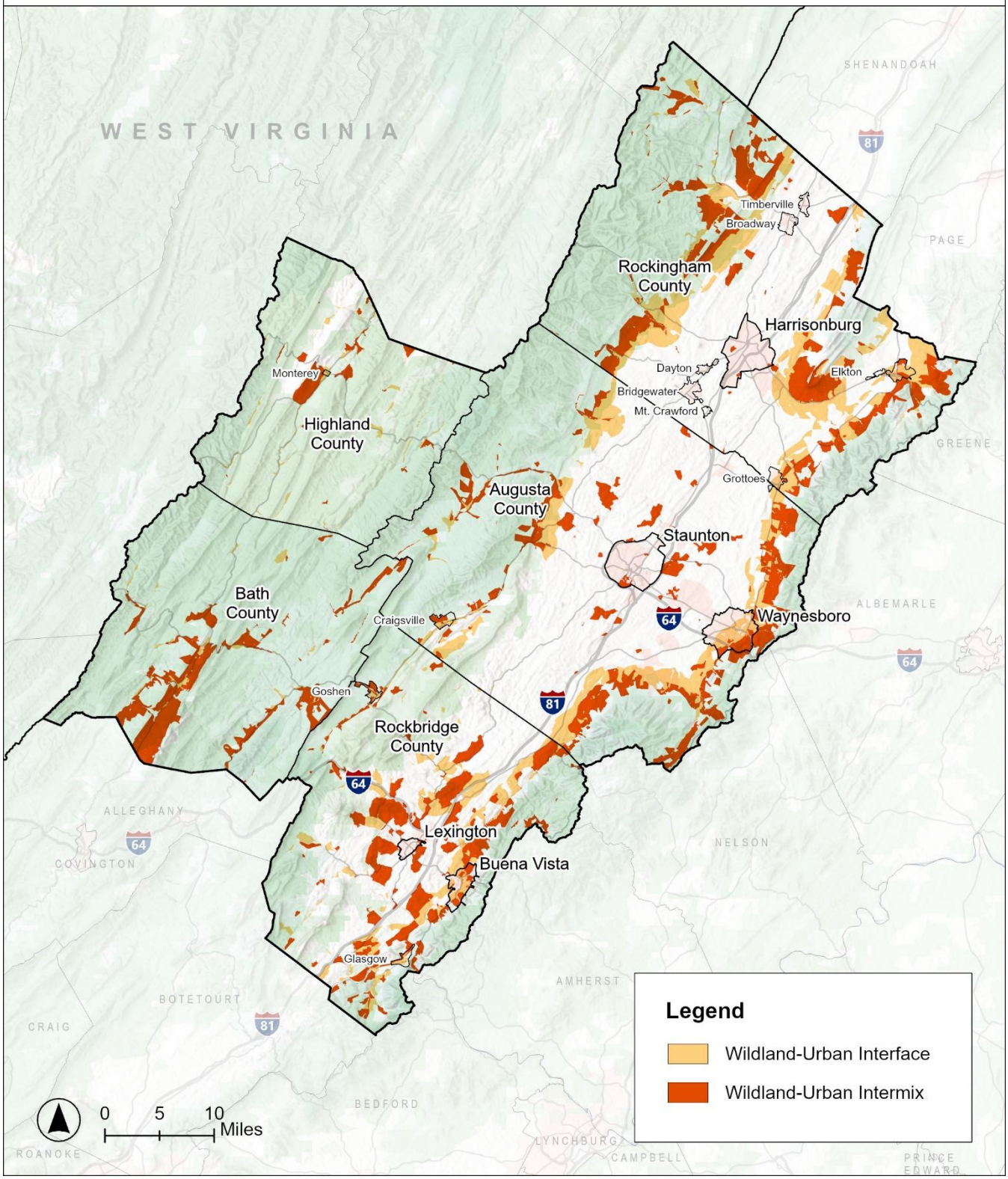
The Wildland-Urban Interface (WUI) refers to the zone where human-developed areas (such as homes, towns, and infrastructure) meet or intermingle with wildland areas, which are typically forested or other natural environments. This interface is important because it represents areas at risk of wildfire, especially in regions with dry conditions. Map 4.4.2 shows the WUI in the region, according to the USDA's dataset.

The Wildland-Urban Intermix represents the low-density development in the form of residential structures surrounded by woodlands and forests on more than two sides. The areas with the most risk tend to be the few houses along the ridge line of the Blue Ridge and Alleghany mountains, as Map 4.4.2 shows. There are a few orange areas near more urban areas of the counties, especially near the cities of Buena Vista, Harrisonburg, Lexington, Staunton, and Waynesboro.

CRITICAL FACILITIES

Table 4.4.5 shows the number of critical facilities identified by the steering committee in the Wildland-Urban Interface (WUI) areas. These vulnerable facilities were reviewed with stakeholders throughout the planning process and were considered in the development of final mitigation actions, as presented in Chapter 6.

Map 4.4.2. Wildland-Urban Interface (WUI) in the CSPDC Region



Data Source(s): USDA Research Data Archive, 2023.

Table 4.4.5. Number of Critical Facilities in Wildland-Urban Interface (WUI) Areas												
			Emergency + Medical	Public Service	Water Systems	Utility	Industrial	Transportation	Major Employers	Historic Places	Social Centers	Special Populations
Sub-Area	Harrisonburg-Rockingham	City of Harrisonburg	0	0	1	0	0	0	0	0	0	0
		Rockingham County	6	8	1	0	2	0	0	2	0	1
		Town of Bridgewater	0	0	0	0	0	0	-	-	1	0
		Town of Broadway	0	0	0	0	0	0	-	-	0	0
		Town of Dayton	1	0	0	0	0	0	-	-	0	0
		Town of Elkton	3	3	2	0	1	0	-	-	12	2
		Town of Grottoes	3	1	1	3	3	0	-	-	10	0
		Town of Mt. Crawford	0	0	0	0	0	0	-	-	0	0
		Town of Timberville	0	0	0	0	0	0	-	-	0	0
	Staunton-Augusta-Waynesboro	City of Staunton	0	0	0	3	0	0	0	0	1	0
		City of Waynesboro	2	13	5	16	7	0	2	3	27	3
		Augusta County	7	8	31	26	20	0	2	5	38	2
		Town of Craigsville	1	2	0	5	1	0	-	-	11	0
	Rockbridge-Lexington-Buena Vista	City of Buena Vista	2	5	2	0	5	0	1	4	15	2
		City of Lexington	0	0	1	0	0	0	0	1	0	0
		Rockbridge County	3	5	4	1	3	0	0	5	16	3
		Town of Glasgow	3	1	2	0	0	0	-	-	2	0
		Town of Goshen	2	0	0	0	0	0	-	-	3	0
	Bath-Highland	Bath County	5	5	2	1	2	1	2	6	12	3
		Highland County	4	4	2	0	0	0	0	5	7	0
		Town of Monterey	0	0	0	0	0	0	-	-	0	0
CSPDC Total			5	5	42	55	54	55	44	1	7	31

WOODLAND COMMUNITIES

The 2020 Central Shenandoah Regional Wildfire Protection Plan (CSRWPP) identifies 90 "woodland communities," which are neighborhoods within the region's Wildland-Urban Interface (WUI). Table 4.4.6 summarizes the number of woodland communities by county. The full list of communities can be found in the individual county profiles within the 2020 CSRWPP. Because of their location in the WUI, these communities face elevated wildfire risk. This makes them priority areas for fire safety outreach and the Firewise USA program, a national initiative led by the National Fire Protection Association (NFPA).

Table 4.4.6. Number of Woodland Communities by County

Augusta County	43	Rockbridge County	12
Bath County	8	Rockingham County	25
Highland County	2	CSPDC Region	90

Data Source(s): Central Shenandoah Regional Wildfire Protection Plan, 2020
Note: Data was only available at the County level

ESTIMATED LOSSES

Wildfire impacts both natural resources and human structures. Table 4.4.7 includes the total estimated damage to timber and structures since 2014. Timber losses by far account for most of the economic impact of wildfire in CSPDC; timber damages are almost 10 times the value of structural damage.

Table 4.4.7. Wildfire Timber and Structural Damage from 2014-2024

County	Timber Acreage	Total Timber Damage	Structures Damaged	Total Structural Damage
Augusta	905	$288,700	4	$8,750
Bath	493	$42,250	3	$60,200
Highland	193	$88,000	1	$5,500
Rockbridge	5009	$2,426,150	1	$10,000
Rockingham	1533	$290,600	9	$246,200
Total	8133	$3,135,700	18	$320,650

Data Source(s): Virginia Department of Forestry, 2024
Note: Data was only available at the County level

PROBABILITY OF FUTURE OCCURRENCES

Future wildfire probability depends on global warming, population shifts, and land use patterns. Global warming increases wildfire risk and lengthens fire seasons in two ways: extended droughts dry out vegetation that serves as fuel, while higher temperatures create conditions conducive to fires over longer periods each year (United States Environmental Protection Agency, n.d.; NOAA, 2023). Rising temperatures also enable

non-native plant species to establish in new areas, where they outcompete native vegetation after fires and reduce ecosystem diversity (Western Ecological Research Center, 2017).

The region's extensive public forests attract millions of visitors annually—over 24 million combined visited George Washington National Forest and the Blue Ridge Parkway in 2023 (NPS, 2024)—increasing human-caused ignition risks from uncontrolled campfires and debris. Meanwhile, rural migration has accelerated since 2020, with every regional county experiencing growth of 0-4% from 2020 to 2023 (Weldon Cooper Center for Public Service; Lombard, 2024). This migration increases population exposure to wildfire risk near heavily forested areas and challenges emergency response times in rural locations. New developments like solar facilities and data centers add localized fire risks and potential strain on water resources during droughts when wildfire danger peaks.

VULNERABILITY

Vulnerability patterns differ by setting. In densely populated cities and growth areas, wildfire impacts pose greater risk to human life, structures, and infrastructure, though ignition probability is lower. Conversely, rural areas face higher wildfire likelihood due to abundant vegetation that can fuel fires, with risk increasing as human activity—such as recreation, debris burning, and development—expands into forested areas.

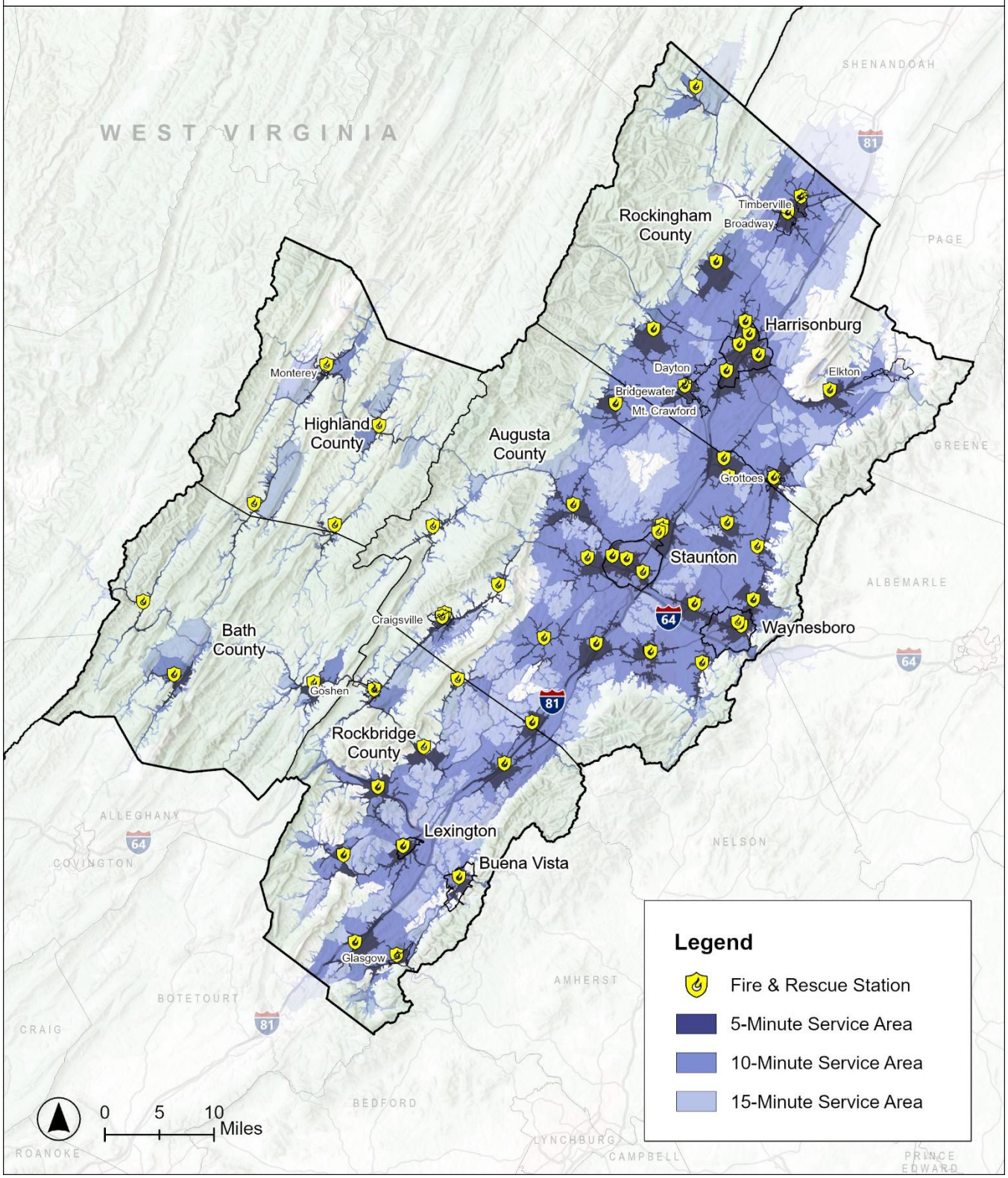
The Southern Wildlife Firescape map classifies counties based on social, built, biophysical, and ecological properties, as well as fire event history, illustrating these varied vulnerabilities across the region. Highland and Bath counties consist primarily of cool, wet broadleaf mountain forests with moderate potential for high-intensity fires but low burn probability. These counties have low structural risk due to sparse population and limited social vulnerability. Augusta, Rockbridge, and Rockingham counties exhibit more varied landscapes and, therefore, more varied vulnerability. Each is characterized by semi-rural areas that face low social vulnerability with moderate climate risks; agricultural rural areas that contain vulnerable communities but low wildfire potential; and urban areas that function as urban peripheries (Landscapes of fire, n.d.).

As mentioned earlier, rural migration has increased throughout the region, placing more residents near heavily forested areas where emergency response times are longer. Map 4.4.3 illustrates fire and rescue station service areas at 5-, 10-, and 15-minute response intervals, showing coverage gaps in rural portions where wildfire risk is higher. While much of the region's inhabited land area falls within a 15-minute response area, these longer response times in rural locations can delay initial suppression efforts.

HISTORICAL AND CULTURAL RESOURCES

The national landmarks, historic places, and buildings are the foundational resources making up the landscape of the region. They are especially vulnerable to wildfire due to the buildings being constructed when modern fire engineering standards did not exist, as well as being in natural areas surrounded by flammable vegetation and fire suppression resources not being readily available. The loss of historical and cultural resources would be devastating, not only for the historical materials but also the tangible memories of the past. Table 4.4.8 lists the historic places within the Wildland-Urban Interface (WUI) defined by USDA.

Map 4.4.3. Fire & Rescue Station Service Areas



Data Source(s): CSPDC Localities, ESRI, 2025

Table 4.4.8. Historic Places in Wildland-Urban Interface Areas		
City/County	**Property**	**NR Property ID**
Augusta	Mt. Zion Schoolhouse	85000392
Augusta	Crimora School	85000384
Augusta	Craigsville School	85000383
Augusta	Estaline Schoolhouse	85000385
Augusta	Walker's Creek Schoolhouse	85000396
Bath	Mustoe House	02000363
Bath	Ashwood School	16000484
Bath	Switchback School	13000985
Bath	T. C. Walker School	100005532
Bath	Millboro School	03001439
Bath	Reveille	100006499
Buena Vista	Old Courthouse	79003297
Buena Vista	Southern Seminary Main Building	72001501
Buena Vista	Seay, W.N., House	07000826
Buena Vista	Buena Vista Colored School	03000191
Highland	Mansion House	05001619
Highland	Jones, C.P., House & Law Office	13000989
Highland	McDowell Presbyterian Church	100004979
Highland	Monterey Hotel	74002130
Highland	Crab Run Lane Truss Bridge	09000728
Lexington	Lylburn Downing School	03001093
Rockbridge	Poague, Margaret E., House	07000236
Rockbridge	Church Hill	79003079
Rockbridge	Chapel Hill	11000350
Rockbridge	Rockbridge Inn	95000398
Rockbridge	Timber Ridge Presbyterian Church	69000278
Rockingham	Miller-Kite House	79003083
Rockingham	Joseph Funk House	75002036
Waynesboro	Rose Cliff	06000755
Waynesboro	Fishburne Military School	84000058
Waynesboro	Coiner-Quesenbery House	76002232

Data Source(s): NPS National Register of Historic Places, 2024; USDA Research Data Archive, 2023

RISK

USDA's Wildfire Risk to Communities tool evaluates how many structures in each locality could be exposed to wildfire. Structures with minimal exposure are unlikely to be affected by wildfire. Structures with indirect exposure may be ignited by embers or through home-to-home ignition. Structures with direct exposure may be ignited by adjacent vegetation, flying embers, or nearby structures.

As shown in Table 4.4.9, the rural counties—Bath, Highland, Rockbridge, and Augusta—have the highest percentages of structures facing direct wildfire exposure (ranging from 78% to 97%). In contrast, the cities show varied patterns: Harrisonburg and Staunton have the lowest direct exposure (12% and 22% respectively), while Buena Vista and Lexington have higher indirect exposure (85% each). Rockingham County, with its mix of rural and urban areas, falls between these extremes with 73% direct exposure.

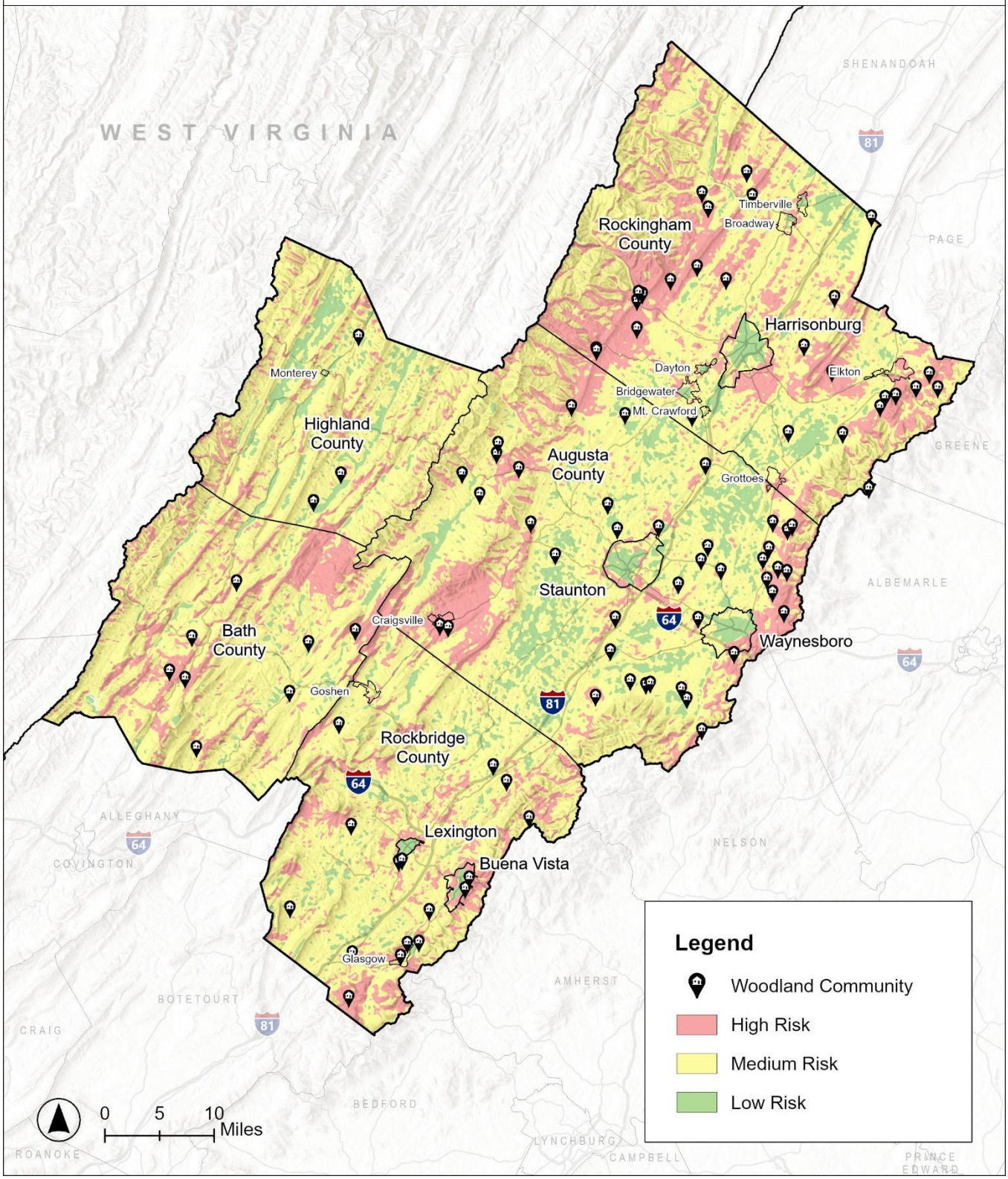
Table 4.4.9. Building Exposure to Wildfire by City/County, 2024

Locality	Minimal Exposure	Indirect Exposure	Direct Exposure
Augusta County	2%	20%	78%
Bath County	< 1%	5%	95%
City of Buena Vista	< 1%	85%	15%
City of Harrisonburg	59%	28%	12%
Highland County	< 1%	3%	97%
City of Lexington	< 1%	85%	15%
Rockbridge County	< 1%	9%	91%
Rockingham County	10%	17%	73%
City of Staunton	37%	41%	22%
City of Waynesboro	28%	55%	17%

Data Source(s): USDA Forest Service, Wildfire Risk to Communities, 2024

In addition to this national-level dataset, the 2020 Central Shenandoah Regional Wildfire Protection Plan (CSRWPP) provides complementary regional analysis using Virginia Department of Forestry data. Map 4.4.4 displays areas of high, medium, and low wildfire risk throughout the region, along with the 90 woodland communities identified at that time. This spatial analysis helps localities prioritize mitigation efforts and target outreach to the most vulnerable areas.

Map 4.4.4. Wildfire Risk in the CSPDC Region



Data Source(s): Central Shenandoah Regional Wildfire Protection Plan, 2020



HAZARD PROFILE 5

DROUGHT

DEFINITION

A period of abnormally dry weather due to a deficiency of precipitation that persists long enough to produce effects like agricultural losses; water supply shortages; and impacts on public health and energy production.

BACKGROUND

Droughts are a normal and recurrent feature of climate that can affect vast regions and a multitude of people. The severity of the drought depends upon the degree of moisture deficiency, the duration, and the size of the affected area, as well as the demands of human activity and agriculture on water supplies. According to the National Weather Service, there are four types of droughts:

- **Meteorological drought**, which is based on "the degree of dryness or rainfall deficit and the length of the dry period."
- **Hydrological drought**, which is based on "the impact of rainfall deficits on the water supply such as stream flow, reservoir and lake levels, and ground water table decline."
- **Agricultural drought**, which refers to "the impacts on agriculture by factors such as rainfall deficits, soil water deficits, reduced ground water, or reservoir levels needed for irrigation."
- **Socioeconomic drought**, which considers "the impact of drought conditions … on supply and demand of some economic goods …"

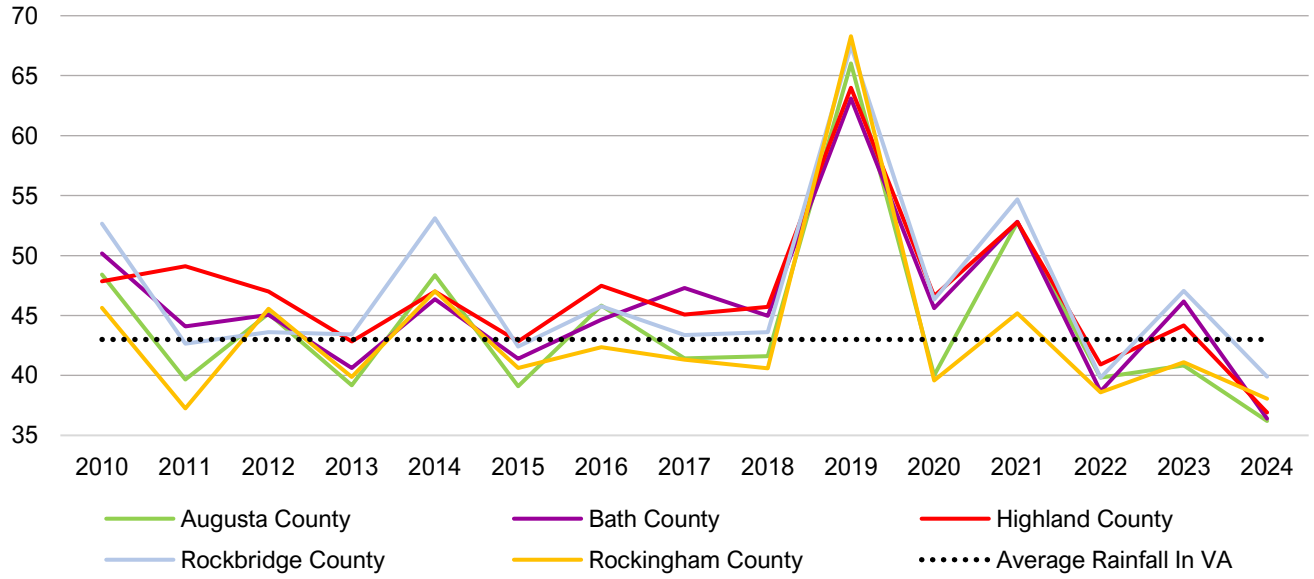
DROUGHT MONITORING

Drought conditions in Virginia are assessed by the Virginia Drought Management Task Force, (VA DMTF) on a needed basis when drought conditions are present or expected to develop (Worley, et. al., 2022). The VA DMTF is an interagency group comprised of Virginia Department of Agriculture and Consumer Services (VDACS), Virginia Department of Health (VDH), Virginia Department of Environmental Equality (DEQ), USGS and other agencies that make drought stage declarations and publishes monthly "Drought Status Reports."

Droughts are often measured by precipitation levels. The region receives an average of up to 40 inches of precipitation annually, making it relatively “water-rich” (NOAA, 2022). However, Virginia is prone to "flash droughts," which occur due to a combination of below-average rainfall and extreme heat. The state has a history of multi-year droughts, with the region experiencing many of them (National Integrated Drought Information System [NIDIS], n.d.).

The region frequently faces periods of abnormally dry conditions, depending on annual rainfall levels. Chart 4.5.6. shows the region’s precipitation levels from 2010 to 2024 (National Centers for Environmental Information [NCEI], 2025). The black line in the chart represents the state’s average annual rainfall of approximately 43 inches (NCEI, 2025). Any rainfall amount below this line indicates that the region experienced abnormally dry conditions or a drought, according to the Standard Precipitation Index (SPI).

Chart 4.5.6. Precipitation in the CSPDC Region, 2010-2024



Data Source(s): FEMA National Risk Index Annualized Frequency Drought, 2023
Note: Data was only available at the County level.

ASSOCIATED EFFECTS

Significant secondary impacts associated with droughts include impacts on local and regional economies focused on agriculture and tourism. The most significant secondary hazard from drought is its impact on drinking water supplies, which can lead to both human and economic stresses due to water use restrictions. Drought not only affects surface water sources but also groundwater supplies, potentially causing long-term issues such as land subsidence and ecosystem damage. Drought also increases the risks for wildfire, flash floods, and landslides, as it alters soil conditions and reduces vegetation.

SIGNIFICANT HISTORICAL EVENTS

Since the mid-twentieth century, the planning region has experienced moderate to severe droughts at least once per decade, with the frequency of these droughts increasing over the last 50 years (United States Department of Agriculture, 2017). Table 4.5.1. details the U.S. Drought Monitor (USDM) categories for droughts: Abnormally Dry (D0), Moderate Drought (D1), Severe Drought (D2), Extreme Drought (D3), and Exceptional Drought (D4). The categories are based on the values for the Standard Precipitation Index (SPI), which measures precipitation anomalies compared to a long-term average.

Table 4.5.1. Drought Categories

	Category		SPI Range	Possible Impact
	D0	Abnormally Dry	-0.5 to -0.7	Short-term dryness, slowing the growth of crops or pastures.
	D1	Moderate Drought	-0.8 to -1.2	Some damage to crops and pastures. Low water levels in streams, reservoirs, or wells. Voluntary water-use restrictions.
	D2	Severe Drought	-1.3 to -1.5	Crop or pasture losses likely. Water shortages are common. Water restrictions are imposed.
	D3	Extreme Drought	-1.5 to -1.9	Major crop and pasture losses, widespread water shortages or restrictions.
	D4	Exceptional Drought	-2.0 or lower	Widespread crop and pasture losses. Water emergencies declared due to shortages in reservoirs, streams, and wells.

Charts 4.5.1-4 show the frequency and severity of droughts since 2001, and the percentage of land affected in each subarea (National Drought Mitigation Center, 2025). Overall, the region experiences mostly abnormally dry periods. However, this dataset indicates that the region has had more intense drought spells since 2023. Table 4.5.2. summarizes the region's significant drought history over the last 10 years.

Chart 4.5.1. Historical Drought Conditions for the Bath-Highland Area

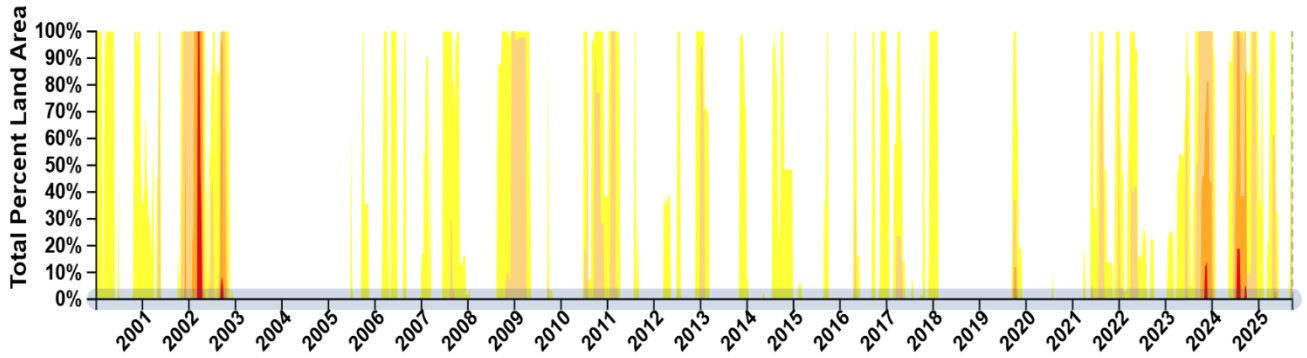


Chart 4.5.2. Historical Drought Conditions for the Harrisonburg-Rockingham Area

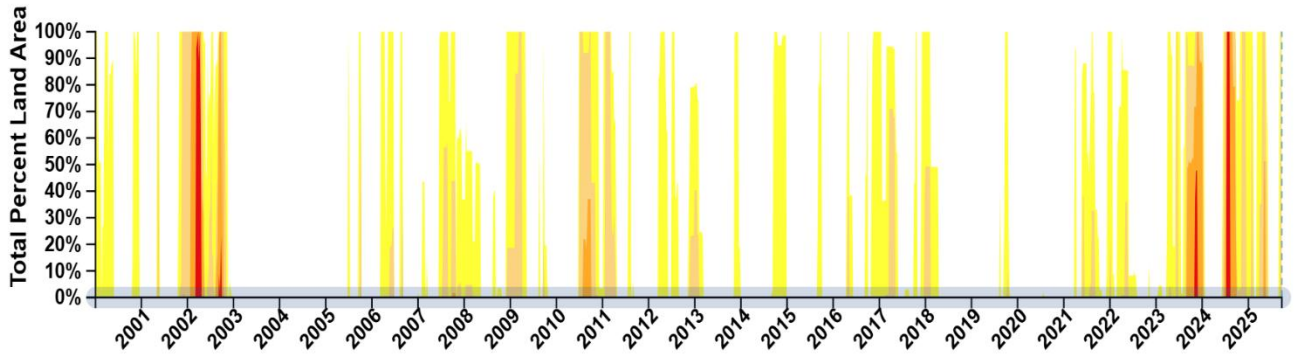


Chart 4.5.3. Historical Drought Conditions for the Staunton-Augusta-Waynesboro Area

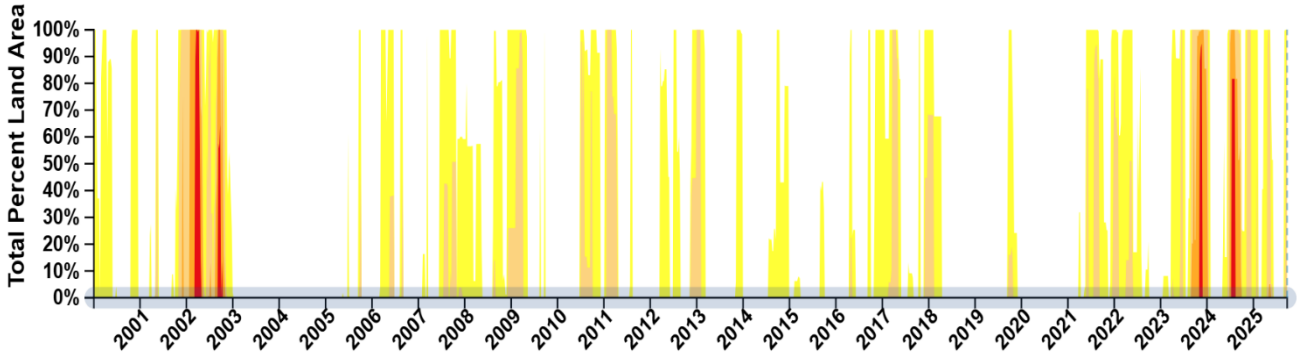


Chart 4.5.4. Historical Drought Conditions for the Lexington-Rockbridge-Buena Vista Area

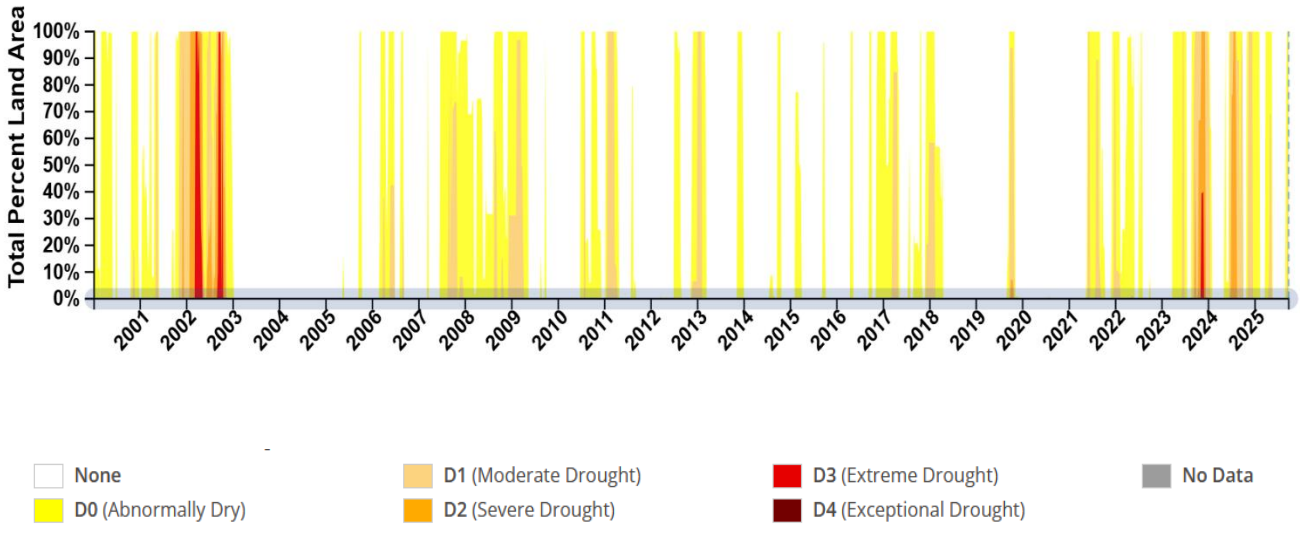


Table 4.5.2. CSPDC Drought History, 2014-2024		
Date	**Location**	**Description**
2014	Augusta, Bath, Highland, and Rockbridge Counties	The U.S. Secretary of Agriculture declared two agriculture disaster designations for the Region (S3782 and S3793). The first included Bath County as a primary county, and the counties of Augusta, Highland, and Rockbridge as contiguous counties. The second declared Highland County as a primary county, and the counties of Augusta and Bath as contiguous counties.
2016	Augusta, Highland, and Rockingham Counties	Localities experienced moderate drought conditions throughout the spring.
2017-2018	All localities	Moderate drought conditions in the Region began in February 2017 and ended in May 2017. Due to the drought, the Augusta County Service Authority provided two locations for people to purchase water. One water source was non-potable for livestock or gardening use. The second water source provided drinking water for purchase. The U.S. Secretary of Agriculture declared an agriculture disaster designation for Rockingham County as a contiguous county (S4297).
2019	All localities	Following a long-term wetness that was experienced in the Spring and Summer of 2019, the region experienced a “flash drought” in the Fall of 2019. The “flash drought” was caused by a significant lack of rain and unusual high temperatures. A statewide drought advisory was issued by the Virginia Department of Environmental Quality. During the “flash drought,” the counties of Augusta, Bath, Rockbridge, and Rockingham, and the cities of Lexington, Buena Vista, and Waynesboro experienced moderate drought conditions. Bath, Rockbridge, and Buena Vista also experienced severe drought conditions in October 2019.
10/17/2023-12/01/2023	Rockbridge and Bath Counties.	Severe drought conditions across the southern Shenandoah Valley. The lack of rainfall contributed to a gradual decrease in stream flows, groundwater. and soil moisture in this region. A notable impact was poor pasture growth, forcing ranchers to begin feeding hay to livestock more and/or earlier than they normally might. Wildland fire activity increased.
7/16/2024-10/01/2024	All Counties, Staunton, and Waynesboro	Severe drought is ongoing throughout all counties and 2 cities in the region.

DISASTER DECLARATIONS

Since 2012, the U.S. Secretary of Agriculture has declared five Agriculture Disaster Designations for localities within the Region impacted by drought.

Table 4.5.3. Agriculture Disaster Designations, 2012 – 2024

Date	Localities
10/15/2014	Augusta, Bath, Highland, and Rockbridge
6/25/2019	Rockbridge
10/16/2019	Rockbridge
9/05/2023	All Counties, Staunton, and Waynesboro
7/16/2024	All Counties, Staunton, and Waynesboro

AREAS OF IMPACT

Map 4.5.1. shows the annual frequency of drought events by census tract in the region, according to FEMA's National Risk Index database. Generally, the region ranks relatively low for the number of droughts per year. This dataset suggests that the region experiences zero to ten events per year, which is relatively low compared to the western part of the nation (FEMA, 2023).

ECONOMIC IMPACT

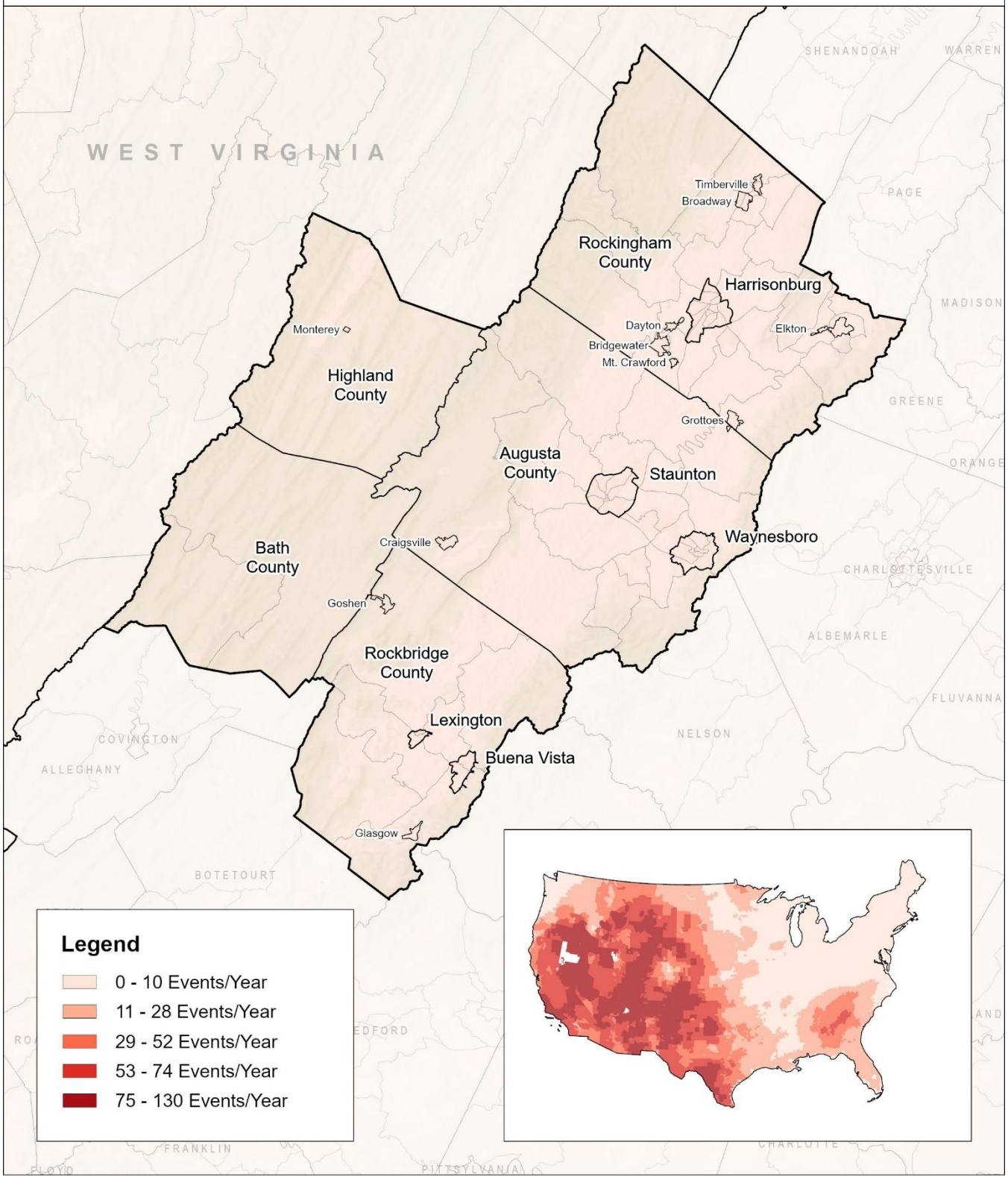
As mentioned in the Regional Setting chapter, agriculture is Virginia's largest private industry, generating $82.3 billion annually (Virginia Department of Agriculture and Consumer Services, 2021). Rockingham and Augusta counties lead the Commonwealth in agricultural sales, contributing 22% and 8% of the state's total respectively, according to the 2022 Census of Agriculture.

Droughts significantly impact Virginia agriculture by reducing soil moisture, limiting water supplies for irrigation and livestock, and decreasing available forage. These weather disasters have contributed to a decline in Virginia farms from 43,225 in 2017 to 38,995 in 2022 (Virginia Farm Bureau, 2024), with some operations forced to close. In October 2024, the USDA designated 33 Virginia counties as primary natural disaster areas due to growing season droughts. This designation enables emergency credit through USDA FSA loans for drought recovery. Augusta and Bath counties received primary designations, with contiguous counties Highland and Rockbridge, plus the cities of Harrisonburg, Staunton, and Waynesboro, also qualifying for emergency loans (USDA, 2024).

ESTIMATED LOSSES

Estimated losses from crop production, livestock, structural damage due to droughts can carry an average cost of $1 billion per event. The 2024 drought event cost $5.4 billion and 136 deaths across the southeast and northwest (NOAA, 2025).

Map 4.5.1. Annualized Frequency of Droughts



Data Source(s): FEMA National Risk Index Annualized Frequency Drought, 2023

PROBABILITY OF FUTURE OCCURRENCES

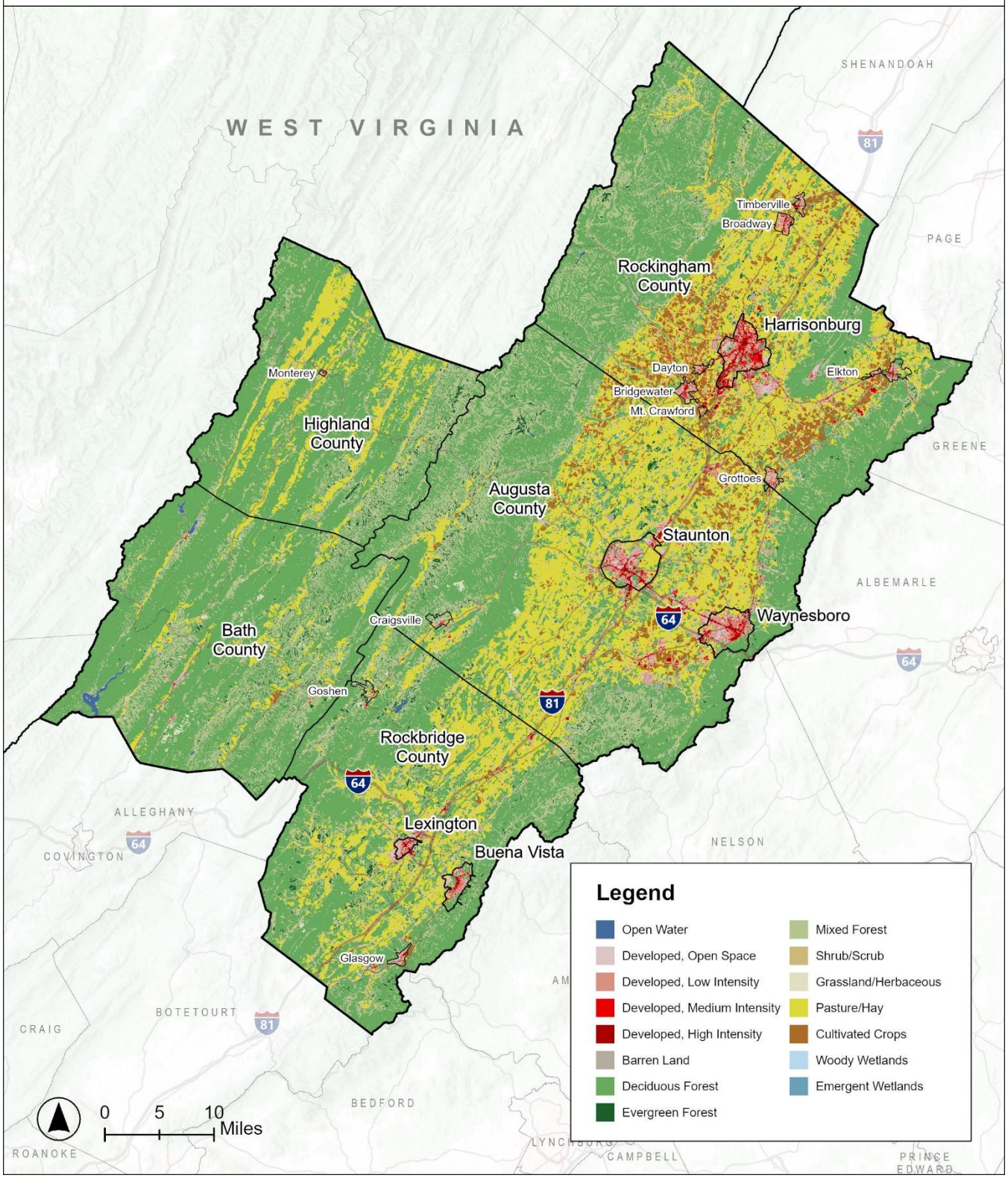
The probability of droughts is dependent on several factors. Climate predictions indicate that droughts are expected to become more frequent, longer, and more severe (NASA, 2023). In addition to climate change increasing the frequency and severity of droughts, population growth has also increased the demand for water usage, putting a strain on water supply and increasing the severity of drought. Currently, the region is estimated to have a population of about 310,528. This number is projected to grow to 316,725 by 2030; 334,354 by 20240; and 356,988 by 2050 (Weldon Cooper Center, 2022).

Developed areas can worsen drought conditions by increasing water runoff, as they do not absorb water like soil does. Additionally, they reduce evapotranspiration, the process where water evaporates from soil and transpiration occurs from plants into the atmosphere (Keck, 2021). In rural areas, warmer temperatures speed up evaporation from the soil, drying out both soil and vegetation faster, while also reducing rainfall. Table 4.5.3. provides descriptions of the developed and planted/cultivated land use classes, according to the USGS's National Land Cover Database. Map 4.5.1. shows the types of land cover in the region and Table 4.6.4. details the percentage of developed land and land used for pasture and crops. Notably, nearly one-third of the region's land is developed or used for agriculture.

Table 4.5.4. Select Categories and Descriptions from the National Landcover Database

Developed Land Cover Designations		
21	Developed, Open Space	Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
22	Developed, Low Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	Developed, Medium Intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	Developed, High Intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Planted/Cultivated Land Cover Designations		
81	Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.
82	Cultivated Crops	Areas used for producing annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Map 4.5.2. Land Cover in the CSPDC Region



Data Source(s): USGS National Land Cover Database, 2023

Table 4.5.5. Percent of Land Area Developed or Cultivated					
		Total Land Area	% Land Low-Intensity Developed[1]	% Land Higher-Intensity Developed[2]	% Land Pasture or Crops[3]
Harrisonburg-Rockingham	City of Harrisonburg	17.34 mi^2	48.15%	38.11%	7.79%
	Rockingham County	840.60 mi^2	7.66%	0.94%	33.07%
	Town of Bridgewater	2.52 mi^2	64.91%	17.69%	13.98%
	Town of Broadway	2.40 mi^2	61.83%	17.69%	18.17%
	Town of Dayton	1.03 mi^2	58.31%	16.87%	24.93%
	Town of Elkton	3.42 mi^2	39.55%	9.14%	23.36%
	Town of Grottoes	2.07 mi^2	62.89%	7.20%	11.18%
	Town of Mt. Crawford	0.51 mi^2	37.02%	7.54%	49.61%
	Town of Timberville	1.35 mi^2	57.82%	13.53%	23.92%
Staunton-Augusta-Waynesboro	City of Staunton	19.98 mi^2	43.98%	13.25%	25.56%
	City of Waynesboro	15.11 mi^2	48.44%	17.53%	12.97%
	Augusta County	968.68 mi^2	7.73%	0.74%	34.16%
	Town of Craigsville	2.07 mi^2	29.13%	2.47%	10.54%
Lexington-Rockbridge-Buena Vista	City of Buena Vista	6.52 mi^2	40.34%	11.49%	7.10%
	City of Lexington	2.53 mi^2	72.62%	18.96%	1.00%
	Rockbridge County	596.65 mi^2	6.39%	0.33%	23.49%
	Town of Glasgow	1.53 mi^2	51.40%	10.87%	11.46%
	Town of Goshen	1.77 mi^2	26.62%	1.91%	17.06%
Bath-Highland	Bath County	534.62 mi^2	2.77%	0.07%	6.17%
	Highland County	415.58 mi^2	2.70%	0.04%	16.69%
	Town of Monterey	0.27 mi^2	45.87%	18.30%	16.01%
	CSPDC Total	3,436.55 mi^2	7.03%	0.95%	25.13%

Note: (1) Includes NLCD classes 21 & 22; (2) Includes NLCD classes 23 & 24; (3) Includes NLCD classes 81 & 82.

VULNERABILITY

Vulnerability to drought is measured through indicators including land development patterns, water sources, and population characteristics. A 2020 study from the University of Alabama's Center for Complex Hydrosystems Research found that drought severity is more closely tied to a locality's ability to cope and recover—determined by sensitivity and adaptive capacity—than to drought frequency. The study designated Virginia as having 'Low' overall vulnerability to drought events (Engström, et al., 2020).

However, certain areas and populations face heightened risk. Water-limited regions, croplands, and grazing lands are particularly vulnerable. When droughts cause crop and livestock losses, food prices rise, creating socioeconomic impacts that disproportionately affect low-income residents. Populations with chronic medical conditions, lower incomes, and children face greater vulnerability to drought impacts (Bolinger, 2019). Rural areas are especially at risk of water shortages due to their reliance on groundwater and wells.

While loss of agriculture from droughts is the most economically impactful, other resources, like historical landmarks, can be impacted by severe and long droughts. The historic building fabric is especially vulnerable to drought due to the increase in deterioration caused by drier and hotter conditions. Extended periods of extreme dry air and heat can cause the materials to expand and weaken and crack due to the lack of moisture (National Trust, n.d.).

RISK

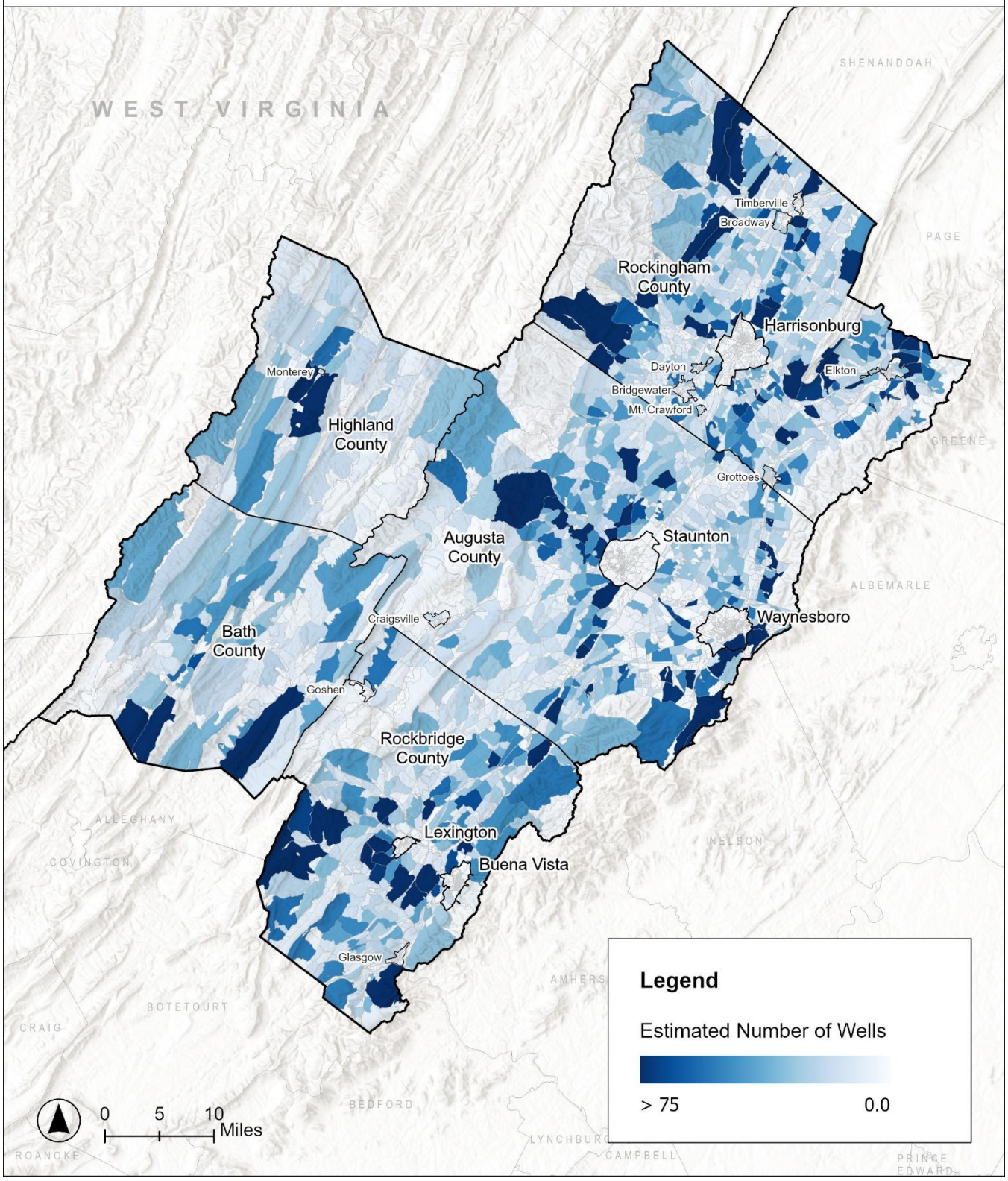
Droughts develop gradually and can persist for years, making them particularly dangerous. They threaten human health, infrastructure, agricultural production, livestock, and economic stability—especially in low-income and rural communities. Rural vulnerability is compounded by dependence on groundwater, as shown in the regional data below. Half of the population in each of the Region's counties are estimated to be served by wells; this ratio is even higher in Bath, Highland, and Rockbridge counties. Map 4.5.3. shows the estimated number of private wells per census block in the region, according to 2020 census data.

Table 4.5.6. Estimated Population Served by Wells in the Region (2020)

County	Total Population (2020)	Est. Pop. Served by Wells	Percentage
Augusta	77,487	40,359	52.1%
Bath	4,209	3,131	74.4%
Highland	2,232	1,983	88.8%
Rockbridge	22,418	17,618	78.6%
Rockingham	83,757	46,887	56.0%

Data Source(s): EPA, 2020 Well Application, n.d. Note: Data was only available at the County level.

Map 4.5.3. Estimated Number of Private Wells per Census Block in 2020



Data Source(s): EPA U.S. Private Well Estimates (2020), 2024



HAZARD PROFILE 6

SINKHOLES

DEFINITION

Geological hazards that form when the land surface sinks or collapses due to the dissolution of soluble rock underneath. Sinkholes can be bowl-shaped, funnel-shaped, or vertical sided.

BACKGROUND

Sinkholes are a natural hazard in karst landscapes, which underlie much of the planning region. Managing this hazard requires understanding best practices for this sensitive terrain. Karst forms when acidic water dissolves soluble rocks like limestone and dolomite, carrying away mineral compounds (National Park Service [NPS], 2023). As water flows through cracks in the rock, it creates caves, sinkholes, and springs. Most karst features are underground, though some appear at the surface (Department of Conservation & Recreation [DCR], n.d.).

Karst aquifers, or underground water systems in caves, provide 40% of U.S. drinking water (United States Geological Survey [USGS], 2021). However, karst's porous structure allows water to pass through without filtration, making it vulnerable to contamination (NPS, 2022). Sinkholes act as entry points where water recharges aquifers (DCR, n.d.). In developed karst areas, sinkholes can form chains called solution valleys where streams disappear underground (Virginia Department of Energy, n.d.). Sinkholes may develop slowly or collapse suddenly, causing severe damage (USGS, 2018).

ASSOCIATED EFFECTS

The secondary effects associated with karst topography features, such as land subsidence and sinkholes, are damage to the foundation buildings and personal property, transportation infrastructure and utility infrastructure. Impacts to infrastructure include damages to roadways, bridges, railroads, storm drains, sanitary sewer, water lines, gas lines, power lines and telecommunications. Sinkhole flooding can be caused by natural or man-made conditions. Increased surface runoff can result in sedimentation blocking the natural drain, resulting in ponding or flooding.

Groundwater contamination is a major concern in karst areas. Pollutants easily reach groundwater through the porous rock, threatening water supplies. Common contaminants include petroleum products,

herbicides, solvents, fertilizers, sewage from failing septic systems, and household garbage. Despite being illegal under Virginia Code Title 10, Chapter 12.2, Section 10-150.14, dumping of household waste, agricultural waste, and dead livestock still occurs (Virginia Department of Energy, n.d.). Human activities including agriculture, construction, cave vandalism, mining, and development can damage this landscape, increasing the likelihood of sinkholes and groundwater pollution.

SIGNIFICANT HISTORICAL EVENTS

There is no existing long-term record of sinkholes throughout the region or for Virginia because sinkholes caused by karst are very site-specific and often occur in undeveloped areas. However, VDOT has recorded approximately 500 sinkholes that have damaged roads in the state over the last 30 years (Virginia Department of Energy, n.d.). A number of those sinkholes have opened on Interstate 81 which runs through the Region. Documented occurrences of sinkholes between 2013 and 2025 are included in Table 4.6.1.

Table 4.6.1. Sinkhole Events from 2013-2025

Date	Damages
April 2013	**Rockbridge County:** A sinkhole opened along the shoulder of I-81 near Fairfield, VA, appearing beneath a storm water drain. The sinkhole measured 15 feet wide and nearly 20 feet deep.
September 2015	**Augusta County:** A sinkhole opened on a Dominion Virginia Power electric transmission line easement near Breezy Knoll Lane and Warren Oaks Lane. The sinkhole exposed telephone, cable, and high voltage electric lines on the underground easement
January 2016	**City of Staunton:** Following a snowstorm with 18 inches of snow in Staunton, fluctuating temperatures caused 9 main water breaks. Three occurred on Skymont Road, leaving several homes without water. During the same period, a sinkhole opened on Skymont Road swallowing a car and condemning a house.
June 2016	**Augusta County:** A sinkhole opened on Broad Run Road (Route 774) in Mount Sidney.
June 2017	**Augusta County:** A sinkhole opened on Interstate 81 near Greenville closing the right lane of southbound I-81. The closure caused traffic backups of 10 miles on the interstate, and traffic congestion on Route 11.
September 2018	**Augusta County:** A sinkhole opened on Hundley Mill Road in Staunton measuring about three feet wide, six feet long and fifteen feet deep. A 700-pound cow fell into the sinkhole. After attempts to rescue the cow alive by County authorities, a veterinarian and a backhoe operator were unsuccessful, the animal had to be euthanized.
August 2023	**Rockbridge County:** A sinkhole opened on Interstate 64 westbound at mile marker 53.8, just past the Maury River bridges near Lexington. It measured 9 feet wide, 11 feet long, and 20 feet deep.

March 2024	**Augusta County:** A sinkhole opened on Interstate 81 near the Weyers Cave and Grottoes exit. The sinkhole measured 5 feet across and 8 feet deep.
December 2024	**City of Lexington:** A 4-foot by 4-foot sinkhole opened at the base of Moores Creek Dam causing water seepage.
February 2025	**City of Waynesboro:** A sinkhole was settling in an area near Hopeman Parkway. While the ground did not collapse, it caused traffic detour impacts for several days as the public works department remedied the sinkhole.

AREAS OF IMPACT

In Virginia, sinkholes and caves are most common in the Valley and Ridge physiographic province, characterized by parallel ridges and valleys of limestone and dolomite. Most regional localities fall within this province. Small eastern portions of Augusta, Rockbridge, and Rockingham Counties, along with the cities of Buena Vista and Lexington, lie in the Blue Ridge province along the Blue Ridge Mountains. A 2003 Virginia Speleological Survey estimated that karst terrain covers 40% of Augusta, Bath, Rockbridge, and Rockingham Counties, and 50% of Highland County (Belo, 2003).

Sinkholes occur near streams and along Interstate 81, which runs through the Valley and Ridge province from Washington County to Frederick County (Hubbard, 1988). In the region, I-81 passes through Rockbridge and Augusta Counties, and the cities of Staunton and Harrisonburg. Interstate 64 runs through Rockbridge County and the cities of Lexington, Staunton, and Waynesboro. Between Lexington and Staunton, I-64 and I-81 run concurrently through Rockbridge and Augusta Counties.

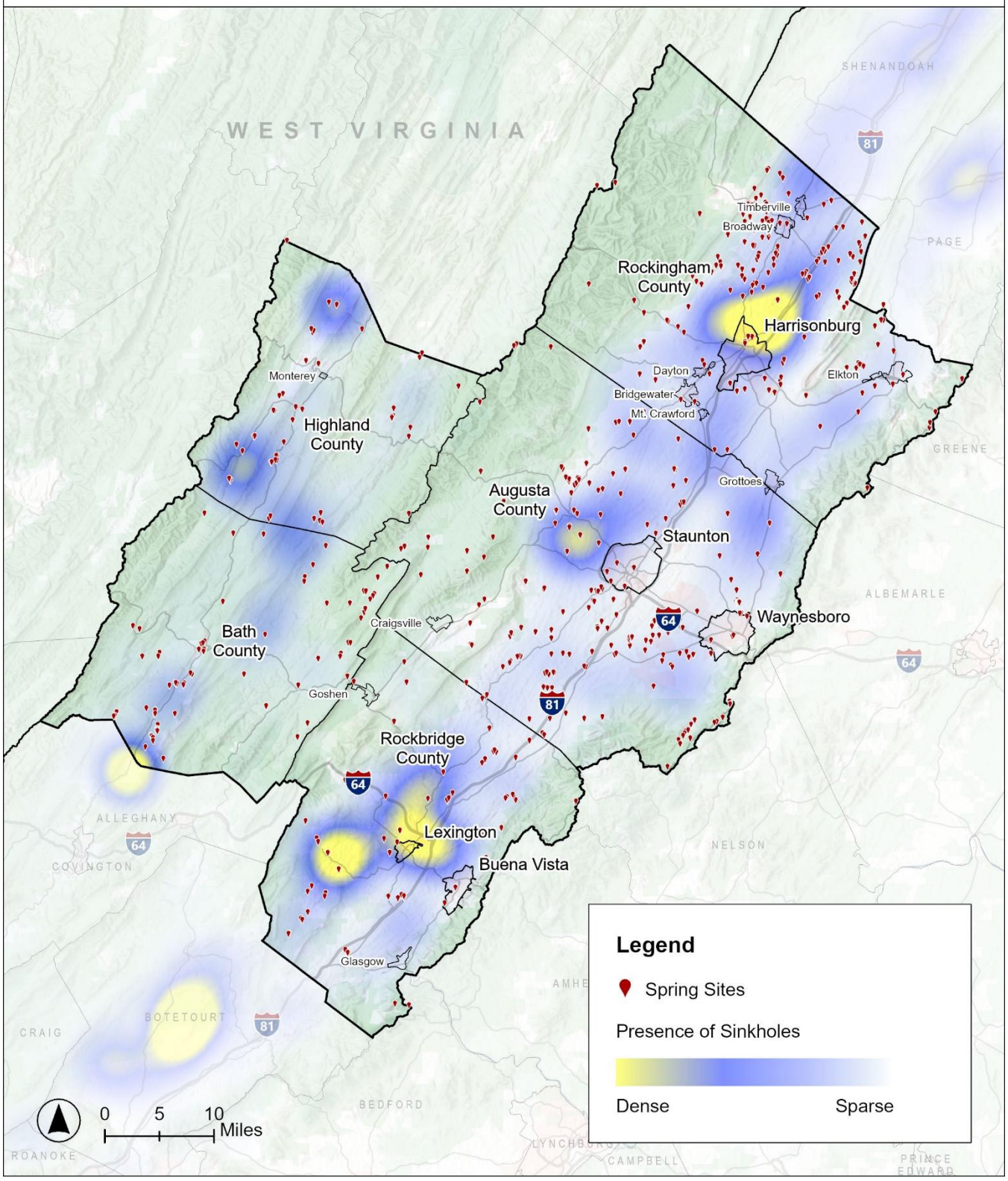
Sinkholes have repeatedly closed I-81/I-64, causing major traffic backups along alternate routes in this critical trucking corridor. The Virginia Department of Transportation maintains an emergency sinkhole repair contract, with costs ranging from tens of thousands to hundreds of thousands of dollars per sinkhole. These interstate systems also increase groundwater contamination risk from hazardous materials transport. Spills can contaminate groundwater for years. Map 4.6.1. illustrates the presence of sinkholes, the yellow indicating an area where more sinkholes can be found, especially along I-81 from Rockbridge to Rockingham Counties.

Another potential area for impact to karst features are natural springs. According to the Virginia Department of Environmental Quality database, majority of Virginia's springs are along the Valley and Ridge and Blue Ridge provinces. Out of the 1,638 springs documented in Virginia, the CSPDC region has 622 springs, including more notable ones that have been nominated on the Virginia Landmarks Register and the National Register of Historic Places, such as Warm Springs (VDEQ, 2025; Preservation Bath, n.d.). Map 4.6.1., which shows sinkhole concentrations, also shows known spring sites in the region.

Table 4.6.2. Springs by County

Augusta County	224
Bath County	81
Highland County	51
Rockbridge County	67
Rockingham County	199

Map 4.6.1. Concentrations of Sinkholes Compared to Groundwater Spring Sites



Data Source(s): Virgina Department of Energy, Geology and Minerals Resources; VDEQ Spring Sites, 2023

ESTIMATED LOSSES

In general, sinkhole occurrence is unpredictable, and the size of a sinkhole cannot be estimated from the surface collapse, so repair costs could range from tens of thousands to hundreds of thousands of dollars per sinkhole. Table 4.6.1. provides some description of region-specific losses, such as structures and livestock, due to recorded sinkhole events. The most common impact, however, is disruption of services due to response efforts like traffic detours and road closures, water quality remediation, and dam maintenance.

PROBABILITY OF FUTURE OCCURRENCES

Much like earthquakes, the probability of sinkholes opening or other geologic hazards related to karst topography is hard to predict given the number of factors involved. However, research indicates that karst topography is highly sensitive to climate changes as it is one of the planet's most sensitive ecosystems (Government of British Columbia 2024).

Climate predictions indicate that with an increase and severity of droughts could potentially increase the frequency of sinkholes collapsing. Climate models show seasonal precipitation patterns in which rainfall events are concentrated into shorter, heavier events with longer, hotter dry periods in between. Shorter heavier rain events can also cause the bedrock to be saturated and result in land subsidence (Wood, et al., 2023). As pollutants, such as carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, and particulate matter from sources like factories, vehicles, and wildfires, continue to enter the atmosphere creating acid, the potential for karst topography to be weathered at a faster rate increase (USGS, 2022).

VULNERABILITY

Karst topography is highly vulnerable to groundwater contamination from acid rain and human activities including land development, littering, and agricultural practices. The extensive underground drainage systems allow pollutants to travel long distances, threatening drinking water supplies from rural wells and springs (National Cave & Karst Research Institute, n.d.). Pollution can also endanger rare species such as bats, cave-adapted invertebrates, fish, and mussels that depend on karst ecosystems (DCR, n.d.).

HUMAN IMPACTS AND NATURAL HAZARDS

Nearly half of the region consists of karst terrain, which is naturally hazardous and increasingly impacted by development. Construction activities (altered drainage patterns, excessive grading, and building loads) can cause ground failure, while impervious surfaces like roads accelerate sinkhole formation (Chesapeake Bay Watershed Karst Working Group, 2013). Wildfires compound these issues by removing vegetation, leading to soil erosion and bedrock exposure (British Columbia, 2024).

Direct contamination occurs through littering, waste dumping in sinkholes, vehicle maintenance, and on-site sewage disposal (Zokaites, 1997). Agricultural practices like livestock grazing, excessive pesticide and fertilizer use, and manure runoff can further pollute groundwater. Land clearing, plowing, and overgrazing cause soil erosion that can expose karst bedrock (Mulvihill, 2021).

Although karst landscapes can provide raw materials for construction, mining activities physically alter and destroy the terrain. Blasting fractures rock and releases particles and silt into groundwater systems (Rauch,

2015). While Virginia requires all mines to be reclaimed under the Surface Mining Control and Reclamation Act of 1977, reclamation cannot restore the original karst topography. Abandoned and restored mines, however, can still experience subsidence or sink over time (USGS, 2019).

Table 4.6.3. Number of Mines per County

County	# of Mines	Minerals being Mined
Augusta	60	Manganese, Iron, Aluminum, Cobalt, Nickel, Kaolin, Lead
Bath	6	Manganese and Cobalt
Highland	1	Iron
Rockbridge	23	Iron, Manganese, Tin, Cobalt, and Lead
Rockingham	41	Manganese, Zinc, Lead, Sulfur-Pyrite, Iron, Cobalt, Nickel, Copper, Gold, Arsenic, Asbestos, Cadmium, Antimony

Data Source(s): U.S. Geological Survey (USGS)

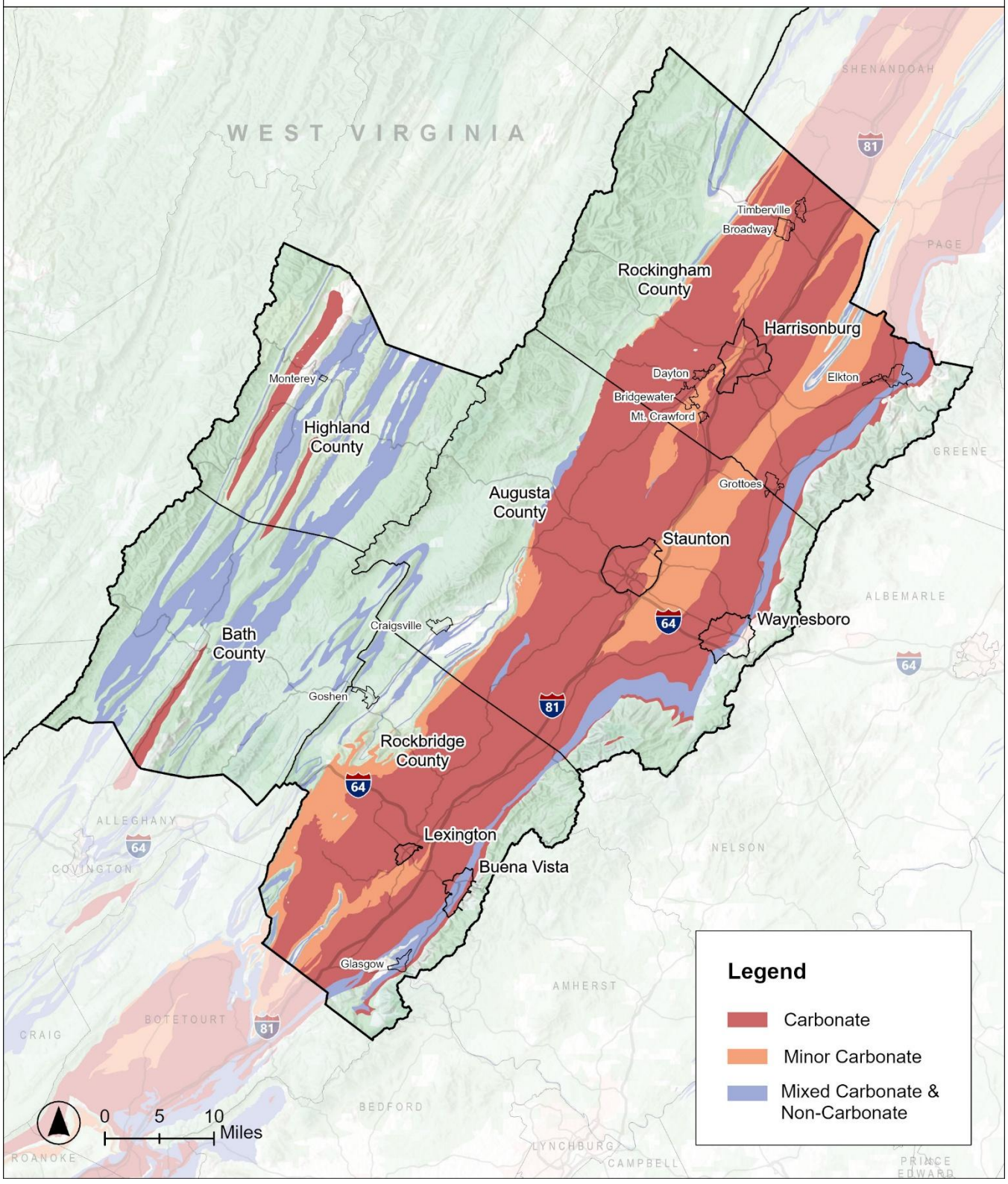
RISK

While sinkholes pose risks to humans and infrastructure, assessing these risks is challenging due to karst's slow, underground evolution. Map 4.6.2. shows varying degrees of carbonate bedrock in the region; as mentioned earlier, carbonate bedrock is susceptible to karstification. Much of the valley's land area between the Blue Ridge and Allegheny Highlands Mountain ranges has carbonate as either the primary or secondary bedrock. Therefore, much of the development in the region is at risk to sinkholes and land subsidence. Table 4.6.4. shows the number and type of critical facilities over carbonate bedrock. This excludes the areas with 'Minor Carbonate' or 'Mixed Carbonate & Non-Carbonate' bedrock designations. According to this analysis, just over 1,000 critical facilities identified in this plan are over hazard-prone topography. These vulnerable facilities were reviewed with stakeholders throughout the planning process and were considered in the development of final mitigation actions, as presented in Chapter 6.

DAMS AND RESERVOIRS

The region's karst landscape poses additional risks for dam construction. Because karst features continue to evolve over time, dissolving rock beneath dam walls and foundations can cause leaks. This reduces the dam's ability to store water and increases the risk of dam failure, which could flood downstream communities. Table 4.6.5. lists 30 dams in the region built on carbonate bedrock, according to DCR and Virginia Energy databases. A more detailed discussion of the region's risk of dam failure can be found in the Utility & Infrastructure Failure profile.

Map 4.6.2. Carbonate Bedrock in the CSPDC Region



Data Source(s): Virgina Department of Energy, Geology and Minerals Resources

Table 4.6.4. Number of Critical Facilities over Carbonate Bedrock												
			Emergency + Medical	Public Service	Water Systems	Utility	Industrial	Transportation	Major Employers	Historic Places	Social Centers	Special Populations
Sub-Area	Harrisonburg-Rockingham	City of Harrisonburg	11	31	11	5	16	0	8	8	90	9
		Rockingham County	9	7	4	0	5	0	15	14	0	2
		Town of Bridgewater	2	4	3	0	0	0	-	-	6	3
		Town of Broadway	4	2	3	0	0	0	-	-	0	0
		Town of Dayton	2	4	7	1	1	0	-	-	4	0
		Town of Elkton	1	2	5	0	1	0	-	-	11	2
		Town of Grottoes	4	2	3	3	4	0	-	-	12	0
		Town of Mt. Crawford	0	1	0	2	0	0	-	-	2	0
		Town of Timberville	3	1	7	0	0	0	-	-	4	2
	Staunton-Augusta-Waynesboro	City of Staunton	5	12	2	32	10	3	1	24	31	9
		City of Waynesboro	0	9	2	18	8	0	1	2	29	3
		Augusta County	20	52	37	64	53	1	10	21	0	8
		Town of Craigsville	0	0	0	0	0	0	-	-	0	0
	Rockbridge-Lexington-Buena Vista	City of Buena Vista	1	1	0	0	2	0	1	0	1	0
		City of Lexington	10	14	2	0	0	0	0	14	18	6
		Rockbridge County	9	13	9	2	6	0	1	17	28	6
		Town of Glasgow	0	0	0	0	0	0	-	-	0	0
		Town of Goshen	0	0	0	0	0	0	-	-	0	0
	Bath-Highland	Bath County	2	5	0	0	1	0	1	5	7	3
		Highland County	0	0	0	0	0	0	0	0	3	0
		Town of Monterey	0	0	0	0	0	0	-	-	0	0
CSPDC Total			83	160	95	127	107	4	38	105	246	53

Table 4.6.5. Dams over Carbonate Bedrock		
County/City	**Dam Name**	**Hazard Class**
Augusta County	Coiner Mill Dam	Unknown
	Fauber Dam	Unknown
	Upper Wallace Dam	High
	Lower Wallace Dam	Unknown
	Smith Dam	Unknown
	Smithleigh Dam	Significant
	South River Dam #3	Significant
	South River Dam #4	High
	South River Dam #7	High
	South River Dam #19	High
	Sugarloaf Farm Dam	Unknown
Rockbridge County	Holbrook Farm Dam	Unknown
	Jordans Point Dam	Low
	Moomaws Dam	Low
	Natural Bridge Dam #1	Unknown
	Natural Bridge Dam #2	Unknown
	Natural Bridge Dam #4	Unknown
	Natural Bridge Dam #5	High
	Robertson Dam	High
	Rockbridge County Dam	Unknown
	Turner Pond Dam	High
	Willow Lake Dam	Unknown
Rockingham County	Broadway Town Dam	Unknown
	Lake Shenandoah Dam	High
	North Fork Shenandoah River Dam No.2	Unknown
	Old Mill Dam	Unknown
	Silver Lake Dam	Unknown
City of Harrisonburg	JMU Amphitheatre Dam	Unknown
	Lake Terrace Dam	Unknown
	Newman Lake Dam	High

Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024



HAZARD PROFILE 7

EXTREME TEMPERATURES

DEFINITION

A measure of temperature variations above (extreme heat) or below (extreme cold) normal conditions. Extreme heat is defined as a period of high heat and humidity with temperatures above 90°F for at least 2-3 days. Extreme cold is defined as temperatures at or below normal conditions for the region and considers wind chill temperatures.

BACKGROUND

Both extreme heat and cold may cause severe health risks, such as heat stroke and hyperthermia, respectively. Vulnerable populations such as the elderly, children, outdoor workers, and low-income individuals are most susceptible to extreme temperatures. Additionally, extreme temperatures can cause infrastructure degradation and stress systems, such as the power grid (WaterISAC, 2024), potentially creating utility outages (large-scale utility outage/interruptions in the form of electricity, gas, or water due to technical issues). These outages can lead to an inability to heat or cool areas and create a lack of access to critical medical equipment requiring electricity. Extreme heat can be a contributing factor for droughts and create economic impacts caused by agricultural and livestock losses.

SIGNIFICANT HISTORICAL EVENTS

Extreme heat is a historical concern for Virginia. A review of CDC National Environmental Public Health Tracking Network Heat and Heat Related Illness data indicates there have been 26 extreme heat days for the CSPDC region from 2014 – 2023. The data shows that Rockingham County has the highest average number of extreme heat days of 27.9 between 2014 and 2023. The max number of extreme heat days totaled 53 in 2022 for Rockingham County.

Table 4.7.1. provides a summary of reported events in the National Centers for Environmental Information (NCEI) database for Cold/Wind Chill and Extreme Cold/Wind Chill in the region from January 2015 to December 2024. Compared to the region and the state, Highland County has more extreme cold events.

DISASTER DECLARATIONS

There have been no reported instances of state or federally declared disasters caused by extreme temperatures in Virginia.

Table 4.7.1. Cold/Wind Chill and Extreme Cold/Wind Chill Events, 2015 – 2024		
Date	**Jurisdictions/Zones**	**Type**
2/14/2015	Highland, Bath, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Extreme Cold/Wind Chill
2/19/2015	Bath	Extreme Cold/Wind Chill
12/15/2016	Highland, Augusta, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
3/14/2017	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
12/27/2017	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
1/1/2018	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
1/4/2018	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
1/5/2018	Highland, Bath, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Extreme Cold/Wind Chill
1/5/2018	Augusta, Rockingham, Highland	Cold/Wind Chill
11/28/2018	Highland	Cold/Wind Chill
1/21/2019	Highland, Bath, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Extreme Cold/Wind Chill
1/21/2019	Augusta, Rockingham	Cold/Wind Chill
1/30/2019	Highland, Bath, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Extreme Cold/Wind Chill
3/6/2019	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
12/25/2020	Highland	Cold/Wind Chill
1/29/2021	Highland	Cold/Wind Chill
2/17/2021	Highland	Cold/Wind Chill
3/12/2022	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
11/19/2022	Highland	Cold/Wind Chill
12/23/2022	Highland, Bath, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Extreme Cold/Wind Chill
12/23/2022	Augusta, Rockingham	Cold/Wind Chill
12/24/2022	Rockbridge	Extreme Cold/Wind Chill
12/24/2022	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
2/4/2023	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
1/16/2024	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill
1/20/2024	Highland, Central Virginia Blue Ridge, Northern Virginia Blue Ridge	Cold/Wind Chill

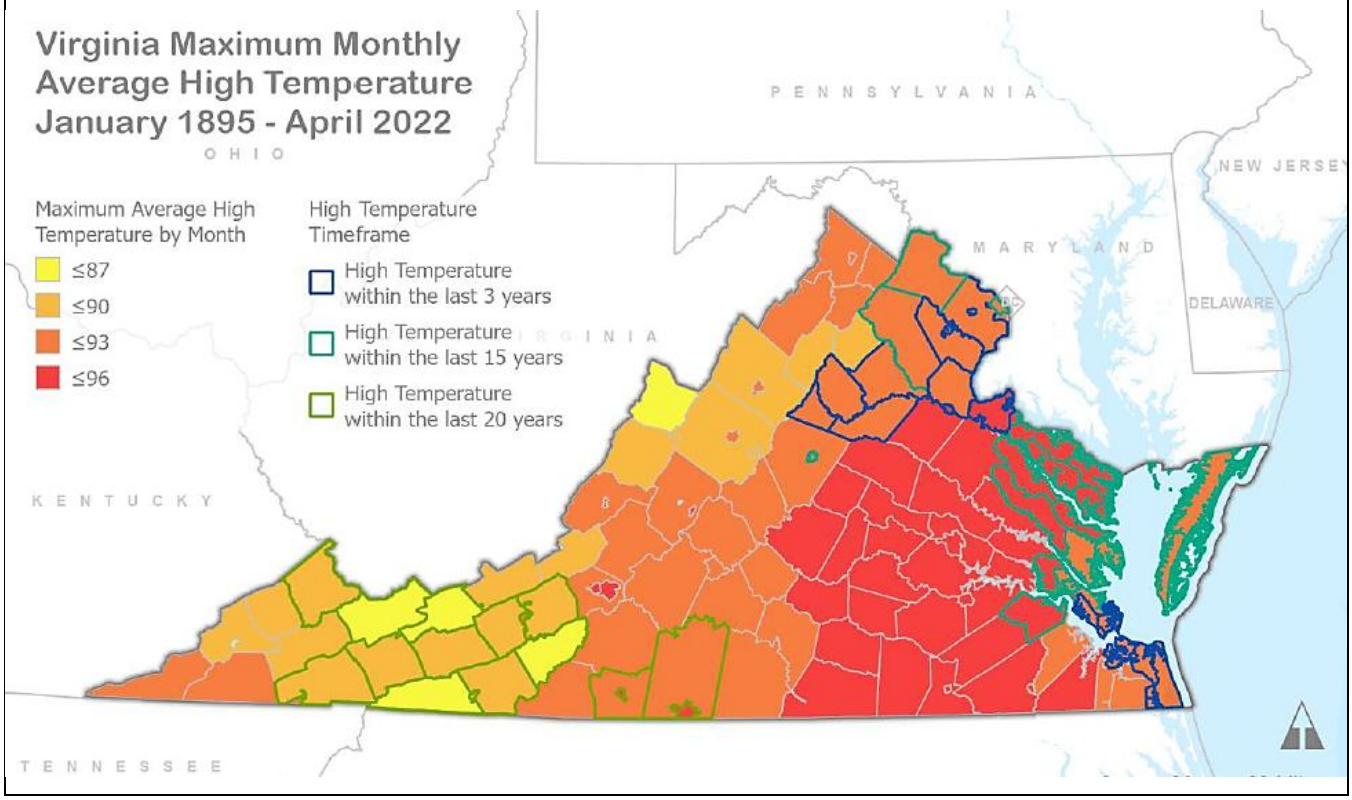
AREAS OF IMPACT

The areas in the region affected by extreme temperatures are different in extreme heat and extreme cold events. Generally, Bath and Highland counties are more affected by cold weather events than the other localities in the region. In terms of areas affected by heat, the region is less variable. Still, data indicates that Rockingham, Augusta, and Rockbridge Counties and the cities of Harrisonburg, Staunton, Waynesboro, Lexington, and Buena Vista are slightly more prone to higher temperatures. More urbanized areas may be more susceptible to extreme heat given the Urban Heat Island (UHI) effect. This effect describes how cities tend to be significantly warmer than surrounding rural areas, primarily due to the presence of heat-absorbing surfaces like pavements and buildings, and the lack of natural cooling mechanisms like trees.

EXTREME HIGH TEMPERATURES

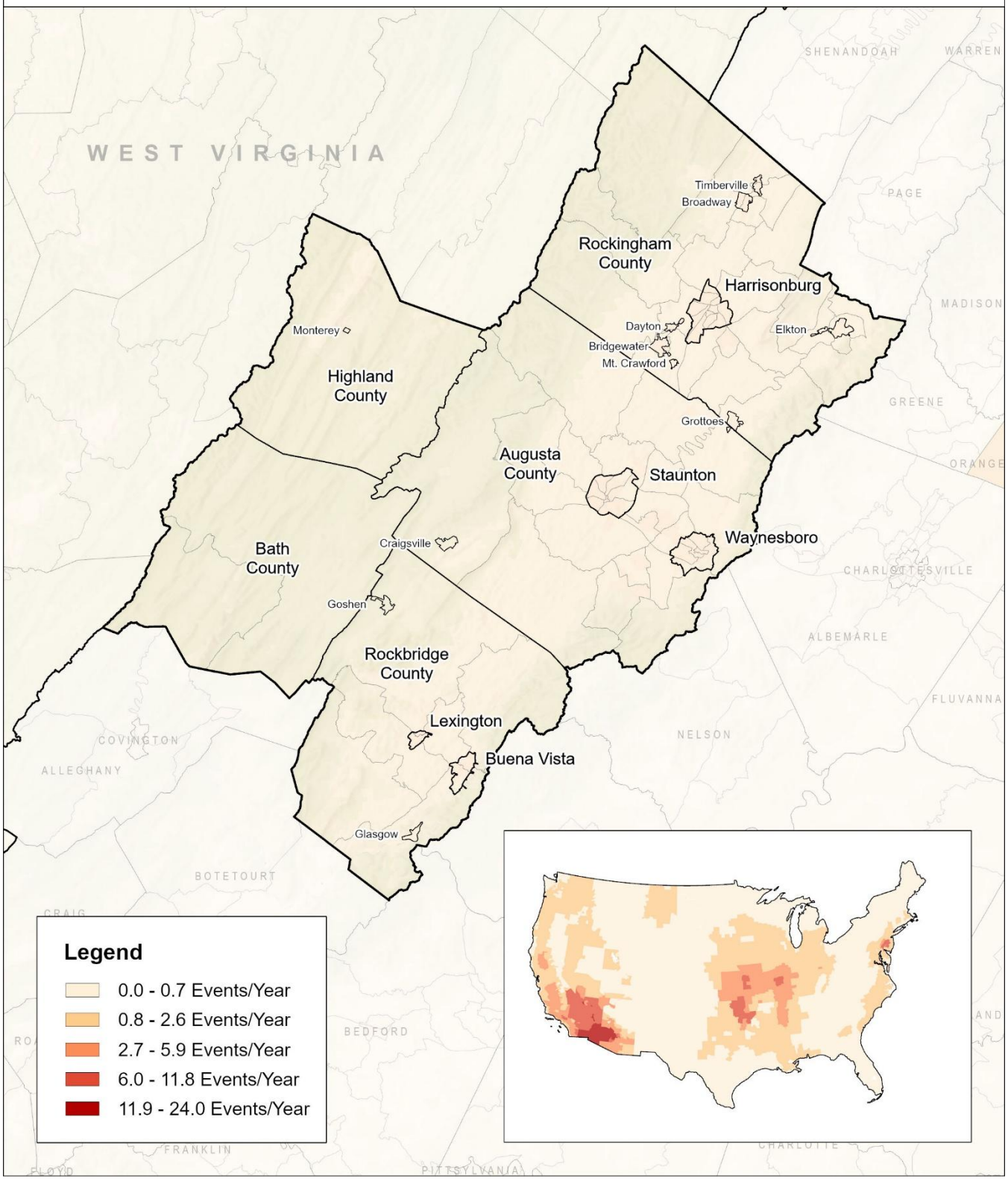
Map 4.7.1. shows the maximum average high temperatures across the state of Virginia between 1895 and 2022. It depicts Rockbridge County and the cities of Harrisonburg and Staunton as having the highest average high temperatures by month within the region, while Highland County shows the lowest average high temperature by month. Map 4.7.2. shows the annualized frequency of heat wave events by census tract according to FEMA's National Risk Index (NRI) dataset. According to this data, the region experiences a relatively low number of heat wave events compared to the rest of the nation.

Map 4.7.1. Statewide Maximum Average High Temperatures, 1895-2022



Data Source(s): Commonwealth of Virginia 2023 Hazard Mitigation Plan (Figure 3-51)

Map 4.7.2. Annualized Frequency of Heat Wave Events by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Heat Wave, 2023

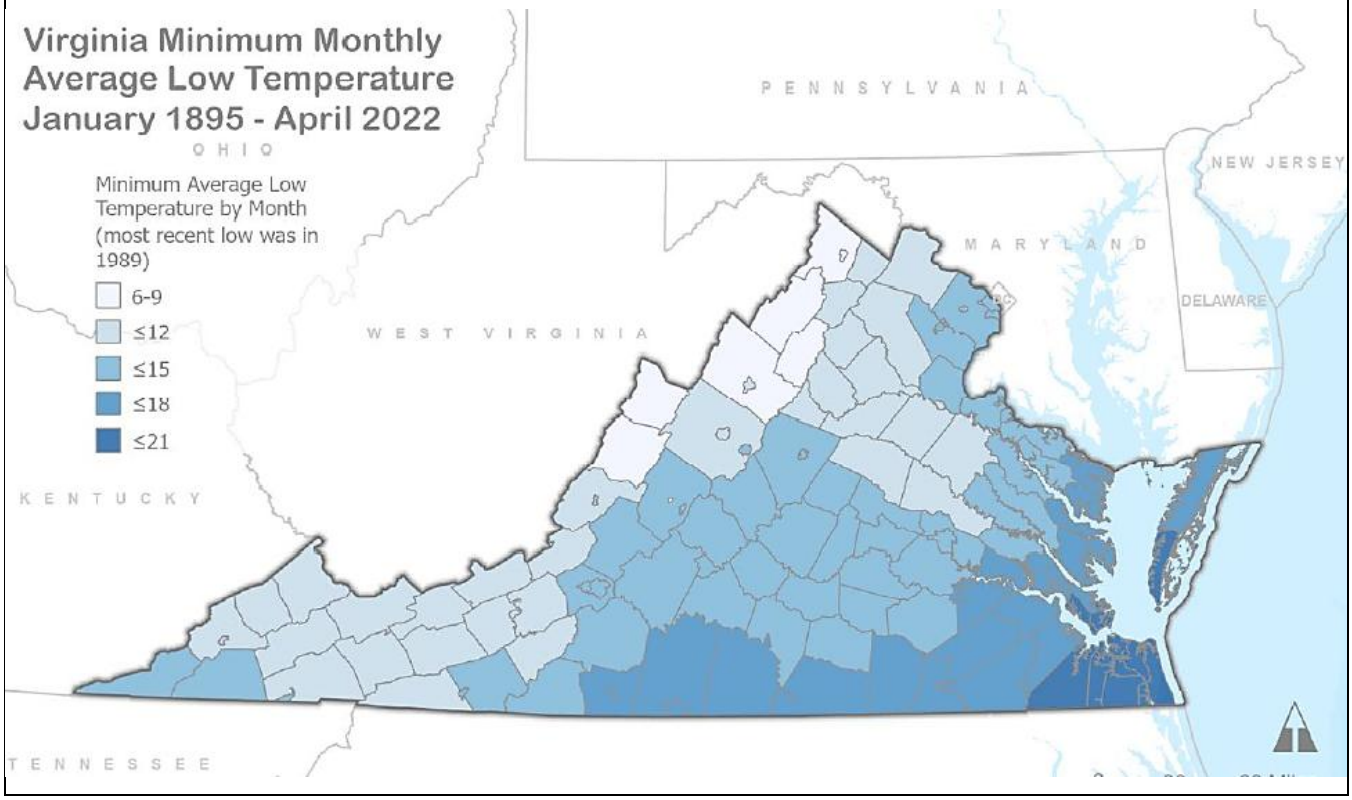
EXTREME LOW TEMPERATURES

Extreme cold can vary dramatically across Virginia. Although these events pose an occasional threat to the region, wind chill advisories are commonly issued each year. Wind chill is used to describe the rate at which heat is removed from the body eventually reducing internal body temperature caused by wind and low temperatures.

Virginia has not experienced a lowest-low temperature since 1989. According to the 2023 Commonwealth of Virginia Hazard Mitigation Plan, Bath, Highland, and Rockingham counties had the lowest average low temperature by month within the region between 1895 – 2022. A review of NOAA's extreme cold/wind chill since 2000 shows that these events occur on average once per year within the region, with the most extreme cold/wind chill events occurring in Highland County.

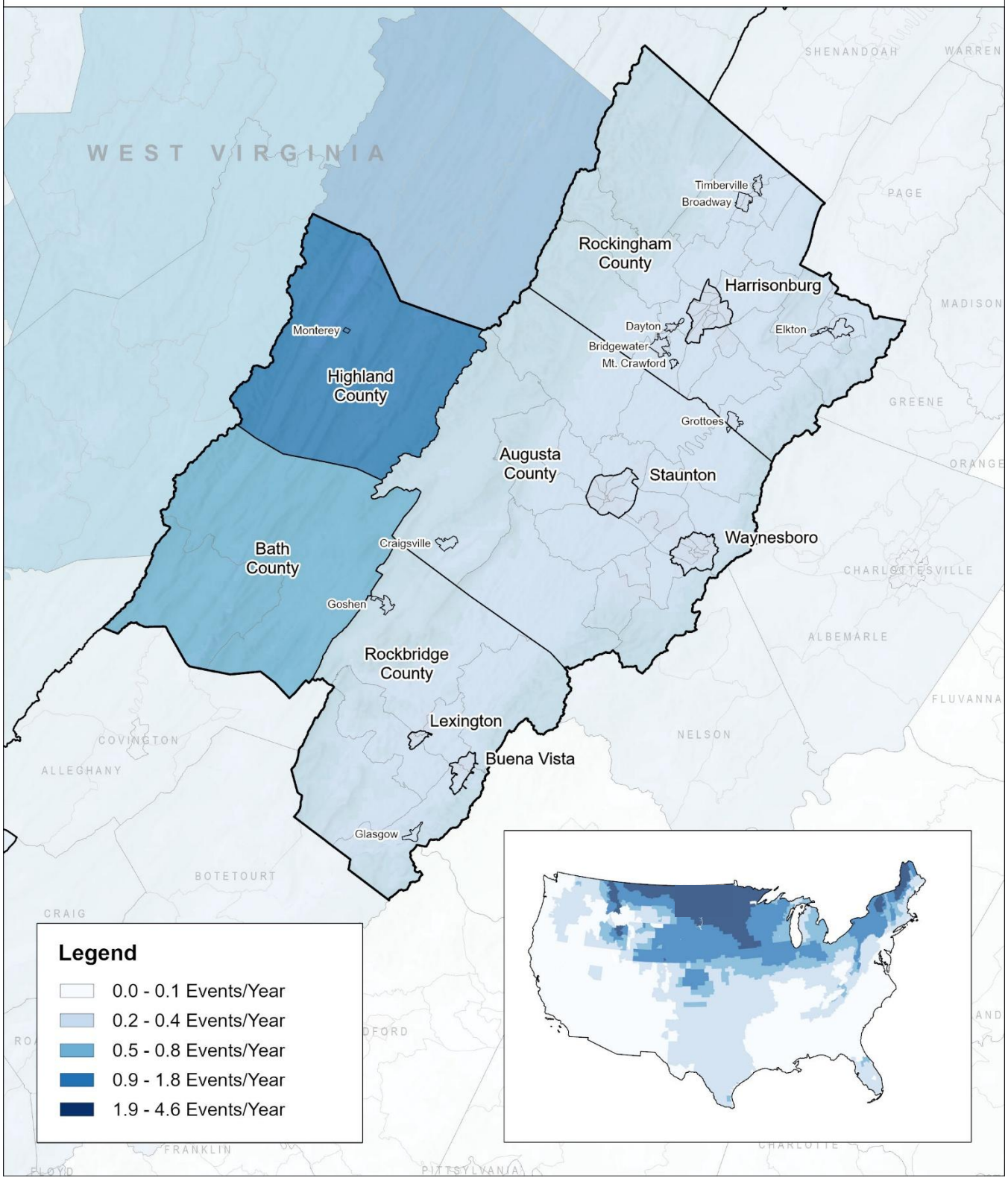
Map 4.7.4. shows the annualized frequency of cold wave events by census tract. This data shows that Bath and Highland counties experience more cold wave events than the other localities in the region. Highland County has the most frequent occurrences, which is estimated to range between 0.8 to 1.8 events per year. This is supported by the historical record of Cold/Wind Chill and Extreme Cold/Wind Chill events in the National Centers for Environmental Information (NCEI) database, shown earlier in Table 4.7.1.

Map 4.7.3. Statewide Minimum Average Low Temperatures, 1895-2022



Data Source(s): Commonwealth of Virginia 2023 Hazard Mitigation Plan (Figure 3-48)

Map 4.7.4. Annualized Frequency of Cold Wave Events by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Cold Wave, 2023

ESTIMATED LOSSES

Agricultural and livestock losses, power outages, and utility restoration are the main cost associated with this hazard. Due to the impact of extreme temperatures on large regions, which can lead to multi-state events and associated cascading effects, estimating losses by jurisdiction can be challenging. Freeze events alone can average $4.2 billion per event per NOAA (National Oceanic and Atmospheric Administration, 2024); however, the administration averages freeze estimates between $5-100 million for Virginia. Estimates for extreme heat could not be located via open-source data.

PROBABILITY OF FUTURE OCCURRENCES

The Climate Explorer provides interactive graphs and maps showing how climate conditions in the United States are projected to change over the coming decades. This information is derived from global climate models and is available for counties and county-equivalents. The tool graphs projections for two possible futures: one in which humans drastically reduce and stabilize global emissions of heat-trapping gases (labeled Lower emissions, also known as RCP4.5), and one in which we continue increasing emissions through the end of the 21st century (labeled Higher emissions, also known as RCP8.5).

Charts 4.7.1. – 4.7.5. show the projected average daily temperature for each County in the region. In these charts, red indicates the Higher emissions scenario and blue indicates the Lower emissions scenario. In both cases, the average daily temperatures are predicted to increase across all localities.

With increases in temperature, more destabilizing weather patterns are expected to impact the region. Both average and extreme temperatures are increasing due to climate change (Center for Disaster Philanthropy, 2024), although it is expected to impact extreme cold across the country by creating less frequent events.

Chart 4.7.1. Projected Average Daily Temperature for Augusta County

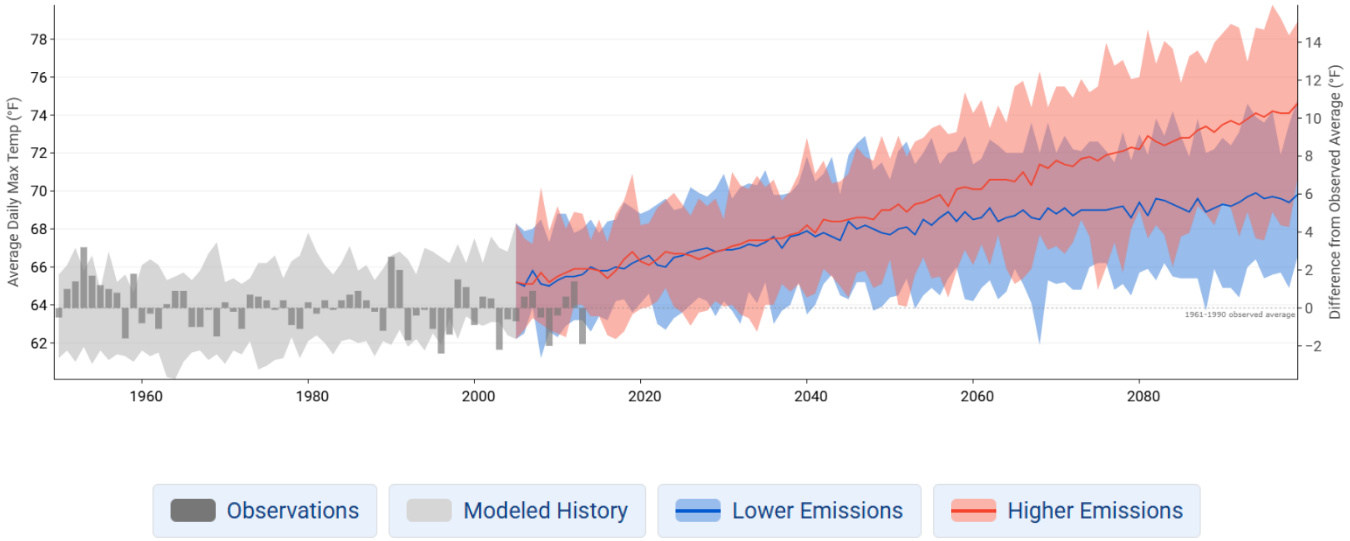


Chart 4.7.2. Projected Average Daily Temperature for Bath County

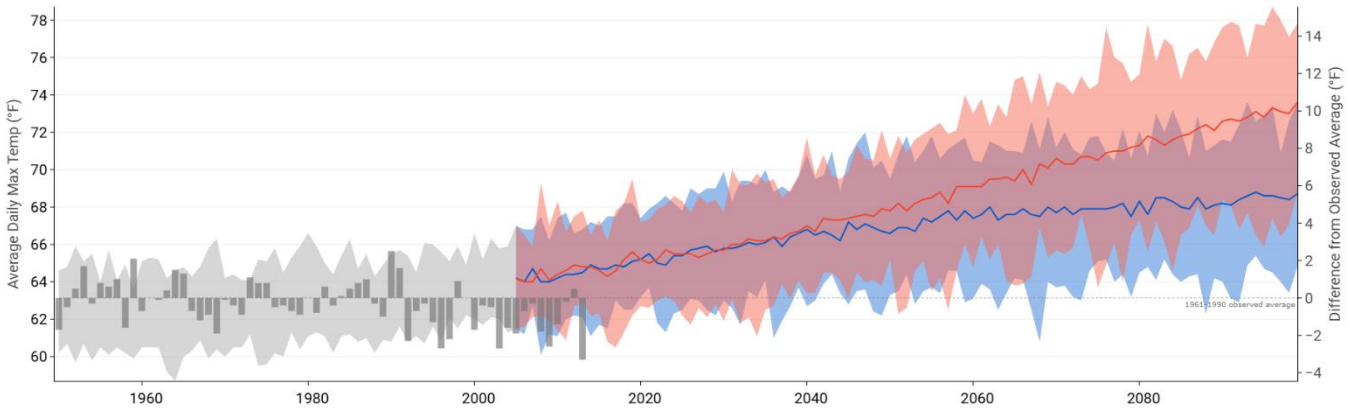


Chart 4.7.3. Projected Average Daily Temperature for Highland County

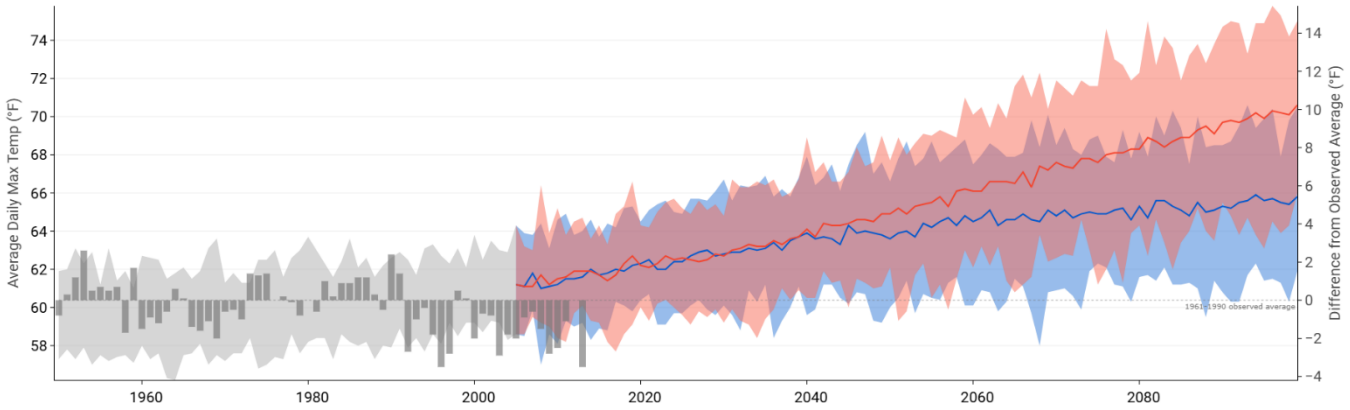


Chart 4.7.4. Projected Average Daily Temperature for Rockbridge County

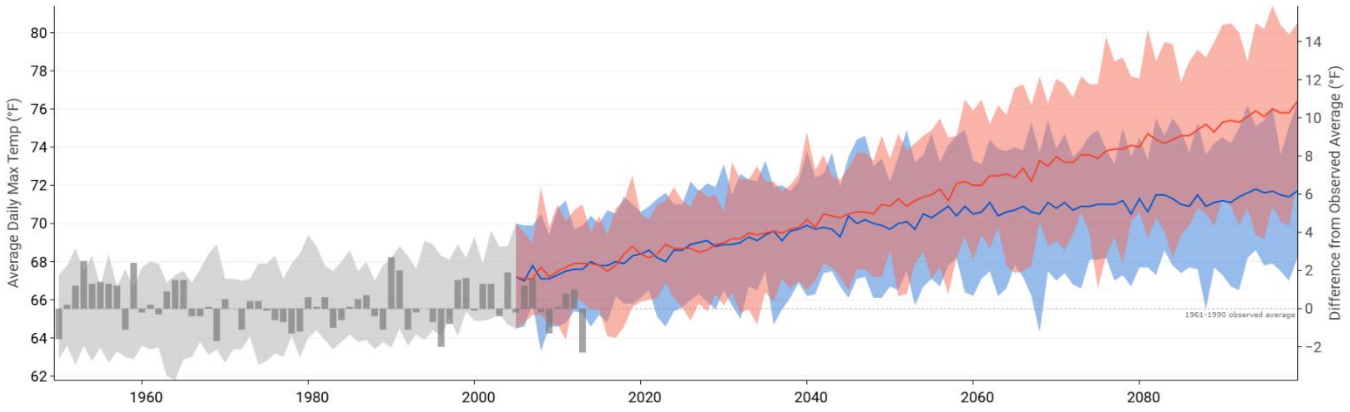
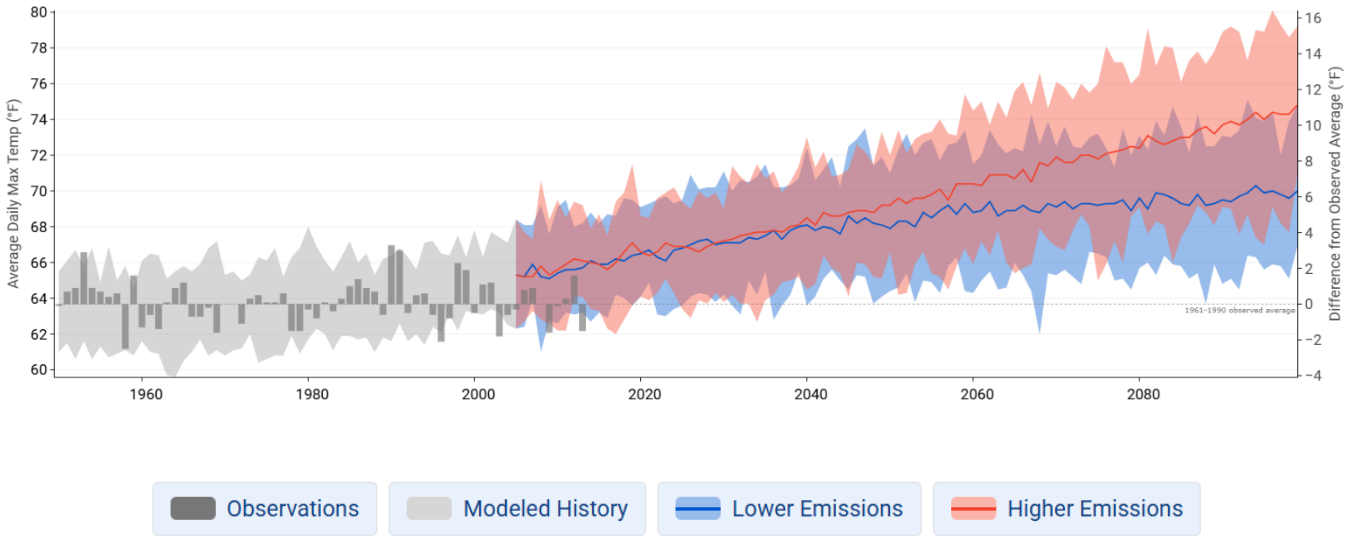




Chart 4.7.5. Projected Average Daily Temperature for Rockingham County

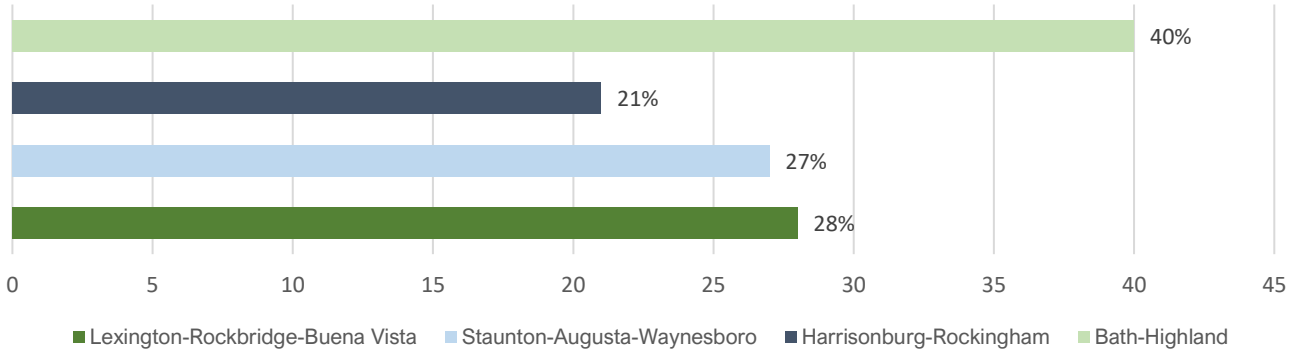


VULNERABILITY

According to the Centers for Disease Control and Prevention, populations most vulnerable to extreme temperatures include older adults, infants and children, people with chronic conditions, people without air conditioning, and outdoor workers.

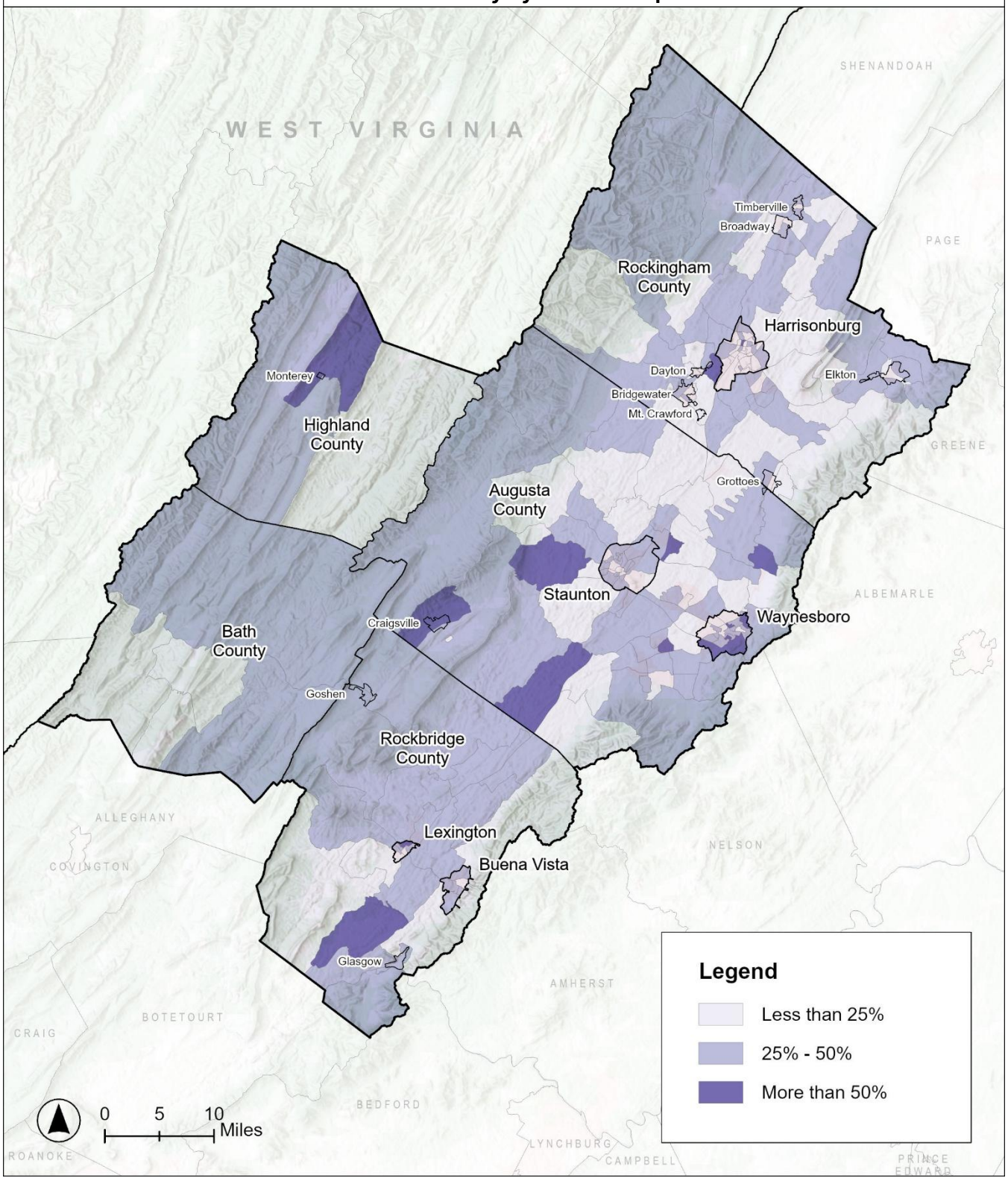
Chart 4.7.6. indicates that the Bath-Highland area may face elevated risk during extreme temperature events, as approximately 40% of its population is over age 60. Additionally, Map 4.7.5. displays the estimated percentage of households with at least one person with a disability within each census block group across the region. Most of the region's block groups fall in the 25-50% range, while some areas, including portions of Bath County, Buena Vista, and Staunton, show lower percentages (less than 25%).

Chart 4.7.6. Percent of Population Age 60+ by Subarea



Data Source(s): U.S. Census Bureau, American Community Survey (5-year Estimates), Table B01001, 2023

Map 4.7.5. Percent of Households Estimated to have One Person with a Disability by Block Group



Data Source(s): U.S. Census Bureau, American Community Survey (5-year Estimates), Table B22010, 2023

RISK

In 2024, the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), and Centers for Disease Control and Prevention (CDC) launched HeatRisk, a nation-wide indicator for health risk from hot weather. HeatRisk identifies risk through integrating temperature and health data to define days when temperatures may increase harm.

HeatRisk takes into consideration:

- How unusual the heat is for the time of the year,
- the duration of the heat including both daytime and nighttime temperatures,
- and if those temperatures pose an elevated risk of heat-related impacts based on CDC data.

The HeatRisk for a given census tract is scored on five levels: Little to No Risk (score <1); Minor Risk (score <2); Moderate Risk (score <3); Major Risk (score <4); and Extreme Risk (score <5).

Table 4.7.2. HeatRisk Categories

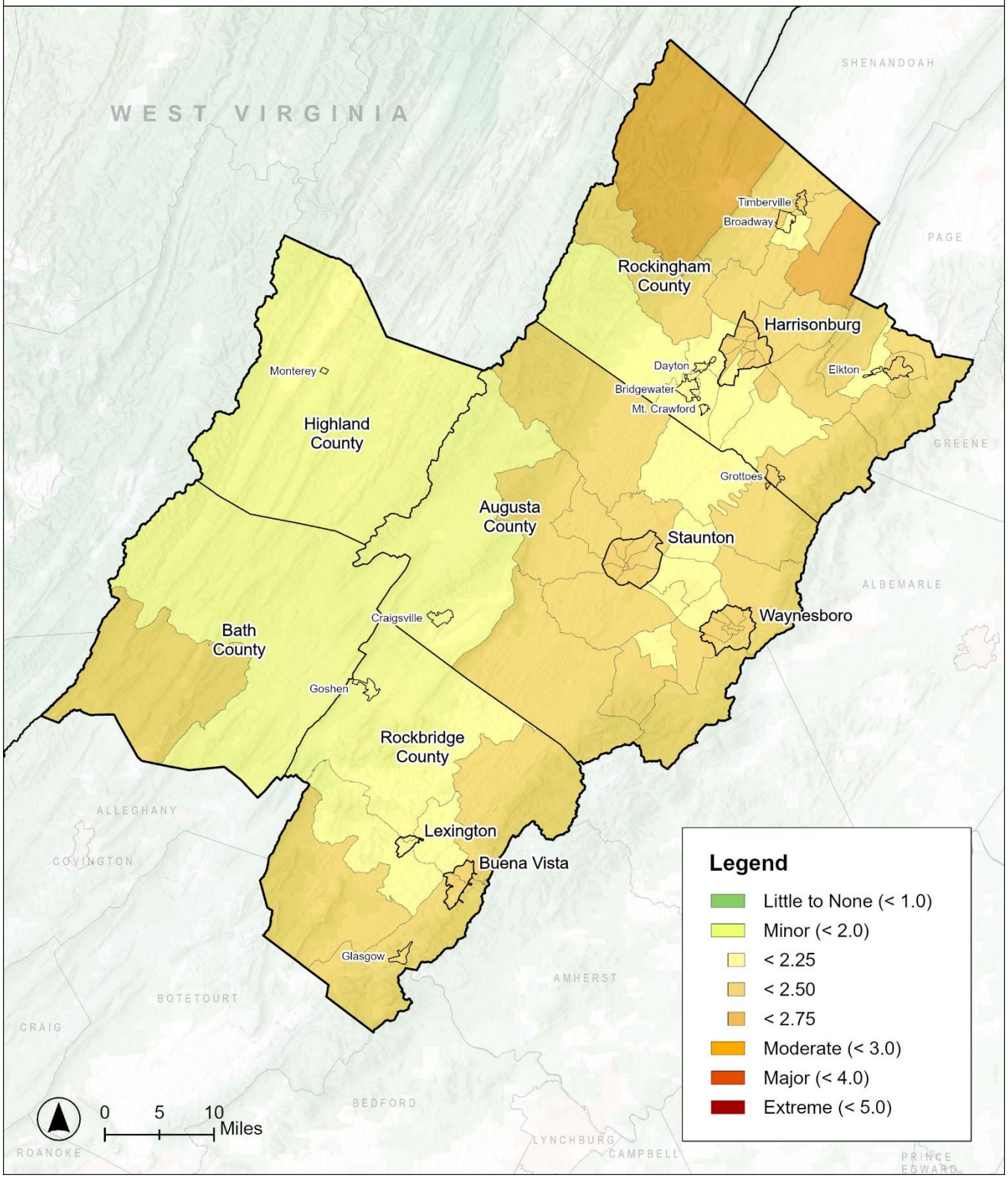
Little to No Risk	Minor	Moderate	Major	Extreme
Little to no risk from expected heat.	This level of heat affects primarily those individuals extremely sensitive to heat, especially when outdoors without effective cooling and/or adequate hydration.	This level of heat affects most individuals sensitive to heat, especially those without effective cooling and/or adequate hydration. Impacts possible in some health systems and in heat-sensitive industries.	This level of heat affects anyone without effective cooling and/or adequate hydration. Impacts likely in some health systems, heat-sensitive industries, and infrastructure.	This level of rare and/or long-duration extreme heat with little to no overnight relief affects anyone without effective cooling and/or adequate hydration. Impacts likely in most health systems, heat-sensitive industries, and infrastructure.

Data Source(s): NOAA National Weather Service, NWS HeatRisk, 2025

Map 4.7.6. shows the average daily HeatRisk score for each census tract in the region between June and August 2024. During these months, the region averaged between 'Minor' and 'Moderate' risk. The two census tracts with the highest scores, 2.63 and 2.51, were in northern Rockingham County. Highland County had the lowest average score, 2.11.

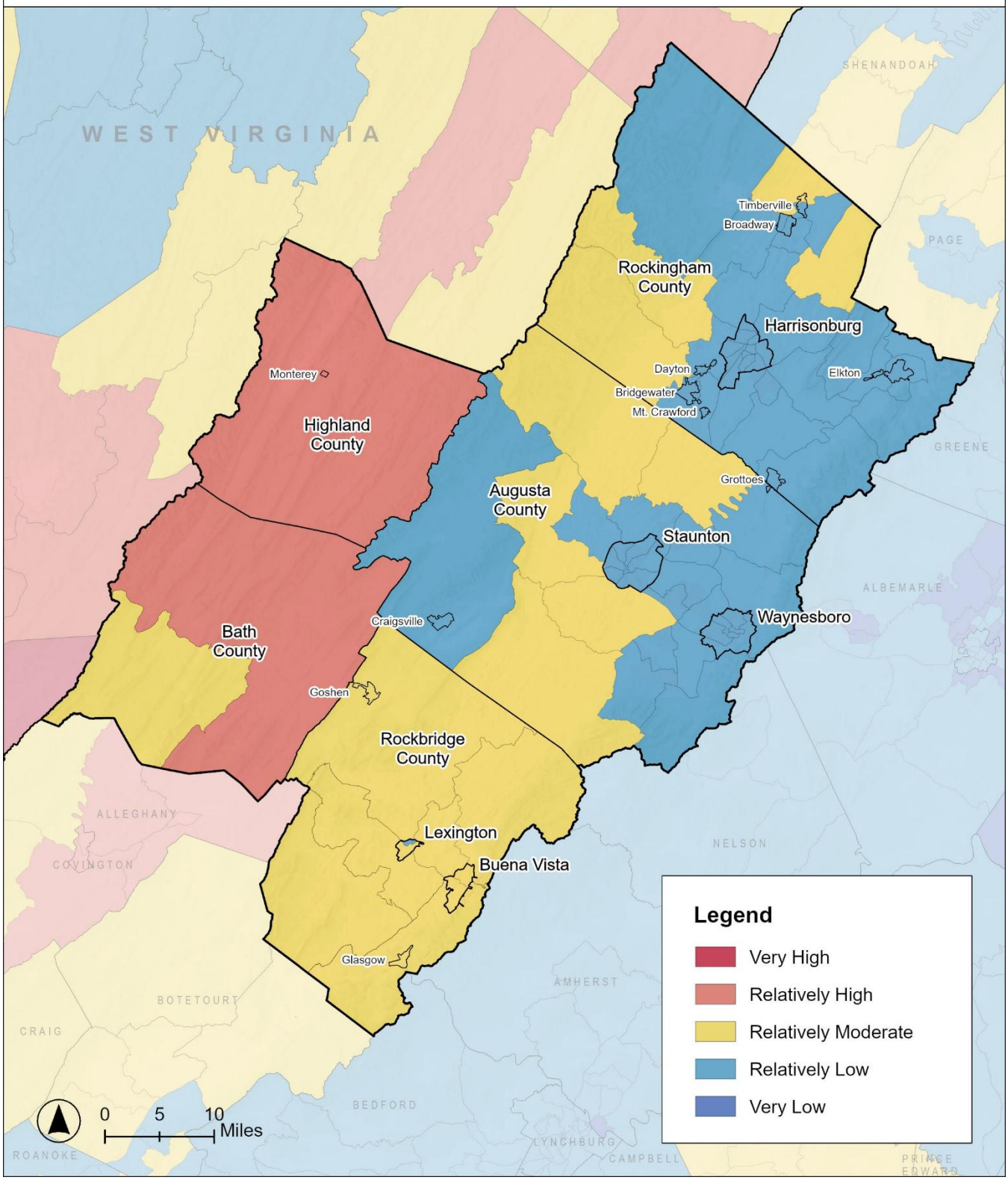
The CSPDC did not locate a similar risk index for extreme cold temperatures. Therefore, the best available data is FEMA's National Risk Index risk rating for cold wave events. Map 4.7.7. shows that Highland, Bath, and the Town of Monterey are comparatively more at-risk to cold wave events than the other localities.

Map 4.7.6. Average Daily HeatRisk Score, June – August 2024



Data Source(s): CDC National Environmental Health Public Tracking Network, HeatRisk Indicator, June-August 2024

Map 4.7.7. Risk Rating for Cold Wave Events by Census Tract



Data Source(s): FEMA National Risk Index Cold Wave Risk Rating, 2023



HAZARD PROFILE 8

SEVERE WINTER WEATHER

DEFINITION

Storms including snow, sleet, freezing rain, or a mixture of these forms of precipitation. Ice storms are a specific type of winter weather event characterized by significant accumulations of freezing rain that coat surfaces with a layer of glaze ice, typically defined as accumulations of one-quarter inch or more. The Winter Storm Severity Index (WSSI) can be used to indicate the level of winter precipitation (snow and ice) severity and its potential related societal impacts.

Table 4.8.1. Winter Storm Severity Index (WSSI)

Descriptor	Expected Storm Severity Impacts
Limited	Small accumulations of snow or ice forecast. Minimal impacts, if any, are expected. In general, society goes about their normal routine.
Minor	Roughly equated to National Weather Service Advisory Level criteria. Minor disruptions, primarily to those who were not prepared. None to minimal recovery time needed.
Moderate	Roughly equated to a National Weather Service Warning Level criteria. Definite impacts to those with little preparation. Perhaps 1-2 days of recovery time needed.
Major	Significant impacts, even with preparation. Typically, several days of recovery time needed.
Extreme	Historic. Widespread severe impacts. Many days to at least a week of recovery time needed.

Source: National Oceanic and Atmospheric Administration, n.d.

BACKGROUND

Winter storms include a variety of cold weather conditions and may last from just a few hours to several days. The impacts of winter storms could include, but are not limited to, downed power lines and trees; hazardous walking and driving conditions; utility or service disruptions; and business, school, and government office closures. Furthermore, winter storms may generate significant expenses, as public funds can be associated with labor and equipment costs for snow removal, road clean-up and repair, and utility restoration. Health

risks may include hypothermia and frostbite if exposed to winter storm conditions, heart attacks due to overexertion, and asphyxiation due to improper use of heating systems.

ASSOCIATED EFFECTS

Winter weather events are considered deceptive killers, as most fatalities occur indirectly through vehicle accidents on icy roads, roof collapses from heavy snow loads, and house fires sparked by alternative heating sources. Freezing rain and sleet transform road surfaces into treacherous conditions, making automobile accidents the leading cause of death and injury during winter storms. Each year, 24 percent of weather-related vehicle crashes occur on snowy, slushy, or icy pavement, and 15 percent take place during active snowfall or sleet, collectively killing more than 2,200 people and injuring nearly 193,000 others annually (U.S. Department of Transportation, n.d.). Additionally, ice storms can damage agricultural assets, including orchards and livestock facilities, and may coat aviation infrastructure, disrupting emergency air transport.

SIGNIFICANT HISTORICAL EVENTS

The winter weather history defined in this analysis accounts for snow and ice storms. A complete list and description of extreme winter weather events that have impacted the region is included in Appendix E.

Snow-related events include both heavy snowfall events with an accumulation of 4 inches of snow or more using NOAA data and snow events which are less than 4 inches using data from the 2023 Commonwealth of Virginia HMP. While the frequency and severity of snow events can vary significantly from year to year, NOAA data indicates that, on average, the CSPDC region can experience up to 3 snow events per year with blizzard events occurring once every 3-4 years. Historically one of these blizzard events will produce over 20 inches of snow or over 1 inch of ice at least once per decade.

Ice storms are less frequent than snow events in the region but tend to produce more severe and longer-lasting impacts on utilities and transportation infrastructure. On average, the region experiences one to two significant ice events per year, with major ice storms — those producing accumulations of one-quarter inch or greater — occurring roughly once every two to three years. The risk is not uniform across the region: lower elevations in the Shenandoah Valley and areas near the Blue Ridge are particularly prone to ice storm conditions, as temperature inversions and the transition between cold air masses and warmer air aloft create ideal conditions for sustained freezing rain.

DISASTER DECLARATIONS

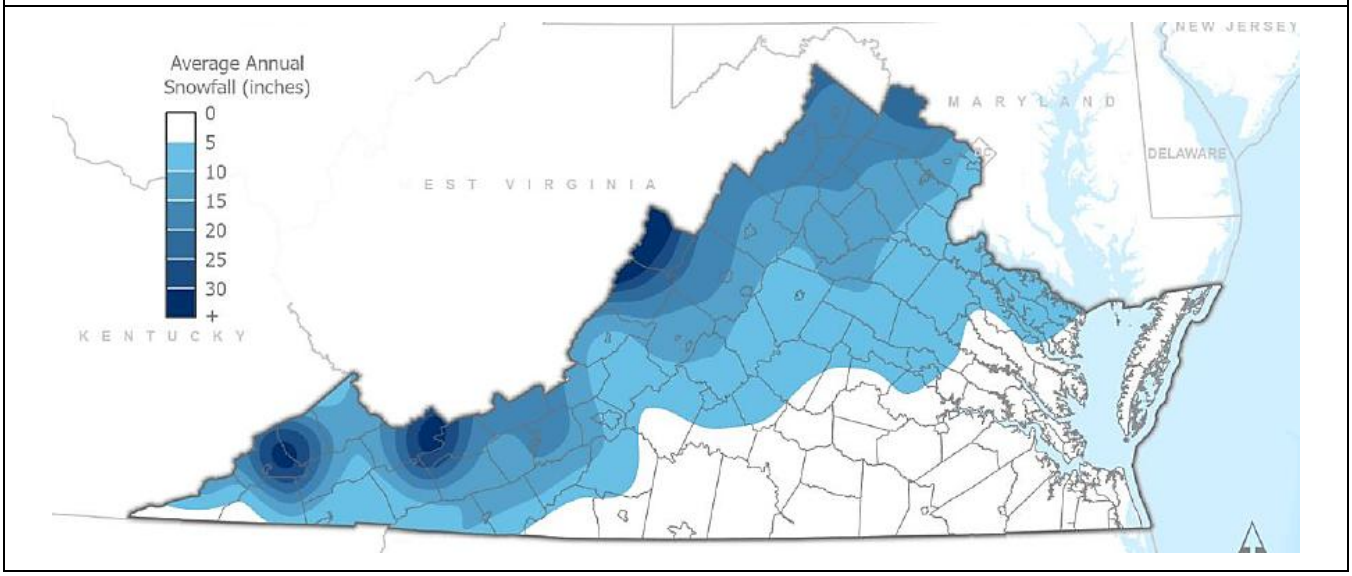
Previous State or Federal disaster declarations specific to the CSPDC region include:

- **February 2016:** a storm impacts Highland, resulting in $23.69 per capita in public assistance
- **November 2012:** a severe winter storm occurred in Highland County
- **February 2010:** a severe winter storm with significant snowfall and winds, referred to as “Snowmageddon” to much of the nation, impacted Augusta and Highland Counties
- **December 2009:** severe winter storm with significant snowfall affected the entire region
- **February 2003:** a severe winter storm occurs in Bath and Highland Counties
- **January 2000:** a blizzard event impacts Augusta, Bath, Highland, Rockbridge, and Rockingham
- **January 1996:** a blizzard coupled with a flood impacts Augusta, Bath, Highland, Rockbridge, and Rockingham Counties; total damage between the combined event exceeded $30 million

AREAS OF IMPACT

Winter weather impacts all 21 jurisdictions in the planning area, though Highland and Bath Counties experience it most frequently. According to Map 4.8.1, portions of Highland and Bath Counties experience more than 30 inches of snowfall on average, annually. Augusta, Rockbridge, and Rockingham Counties experience an average of 10 to 20 inches of snow annually.

Map 4.8.1. Virginia Average Annual Snowfall, 1991-2020



Source: Commonwealth of Virginia 2023 Hazard Mitigation Plan

Areas with higher concentrations of infrastructure such as roads, power lines, and water systems face greater vulnerability to ice storm impacts. The lower-elevation communities experience relatively higher ice storm frequencies compared to the higher-elevation areas of Bath and Highland Counties, where temperatures more consistently fall below freezing and precipitation falls as snow rather than freezing rain. This means that the communities with the densest road and utility networks are often those most exposed to ice storm events, creating concentrated vulnerability in the region's most populated areas. Areas along U.S. Route 11, Interstate 81, and the primary transmission corridors in the Valley are particularly at risk of ice-related disruptions.

ESTIMATED LOSSES

Comprehensive damage estimates for winter weather or ice storms were not available or easily accessible; however, NOAA estimates that winter storms carry a state-wide cost of $500 million to $1 billion per year (NOAA, 2024) depending on size, severity, frequency, and associated hazards. The January 1996 blizzard and associated flood that impacted Augusta, Bath, Highland, Rockbridge, and Rockingham Counties totaled $30 million in damage alone, with more densely populated areas seeing higher costs. Nationally, major ice storms are among the costliest weather-related utility events, with restoration costs frequently exceeding those of comparable snowstorms by two to five times. In the CSPDC region, ice-related utility outages also

carry indirect economic costs through lost business activity, spoiled agricultural products, disrupted government services, and increased demand on emergency services and warming shelters.

PROBABILITY OF FUTURE OCCURRENCES

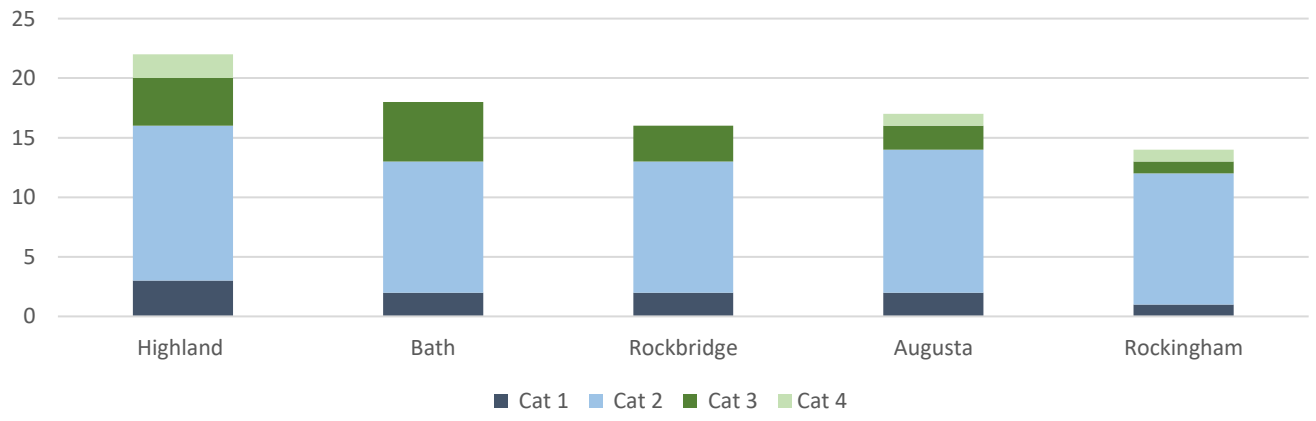
The probability of future winter weather events is determined primarily from historical frequency data. Snow and blizzard events typically impact the region between November and April, with the greatest average annual snowfall concentrated in the western and northern parts of Virginia, as shown in Map 4.8.1. This pattern is reflected in Map 4.8.2, which shows the estimated annualized frequency of winter weather events. Ice storm probability follows a distinct geographic pattern: unlike snowfall, which intensifies at higher elevations, freezing rain events are most likely at lower valley elevations where surface temperatures hover near the freezing mark. As shown in Map 4.8.3, ice storm frequency is therefore highest in the more densely populated Valley communities rather than in the higher-elevation counties of Bath and Highland. Ice storms are most probable between December and March, with secondary risk during the transitional periods of November and April.

The Regional Snowfall Index (RSI), an index of significant snowstorms that impact the eastern two thirds of the U.S. RSI categories snowstorm impacts on a scale from 1 to 5 based on the amount of snowfall. Since RSI only documents snow events that have a regional impact, it does not capture every local snow event. However, it is a useful indicator of how often major snowfall events affect the region. Chart 4.8.1 shows that since 2016, regional heavy snow events typically occur about two times per year on average, with major snowstorms (5+ inches) occurring every other year in Bath and Highland County and once every three years in Augusta, Rockbridge, and Rockingham Counties (Squires et. al., 2011).

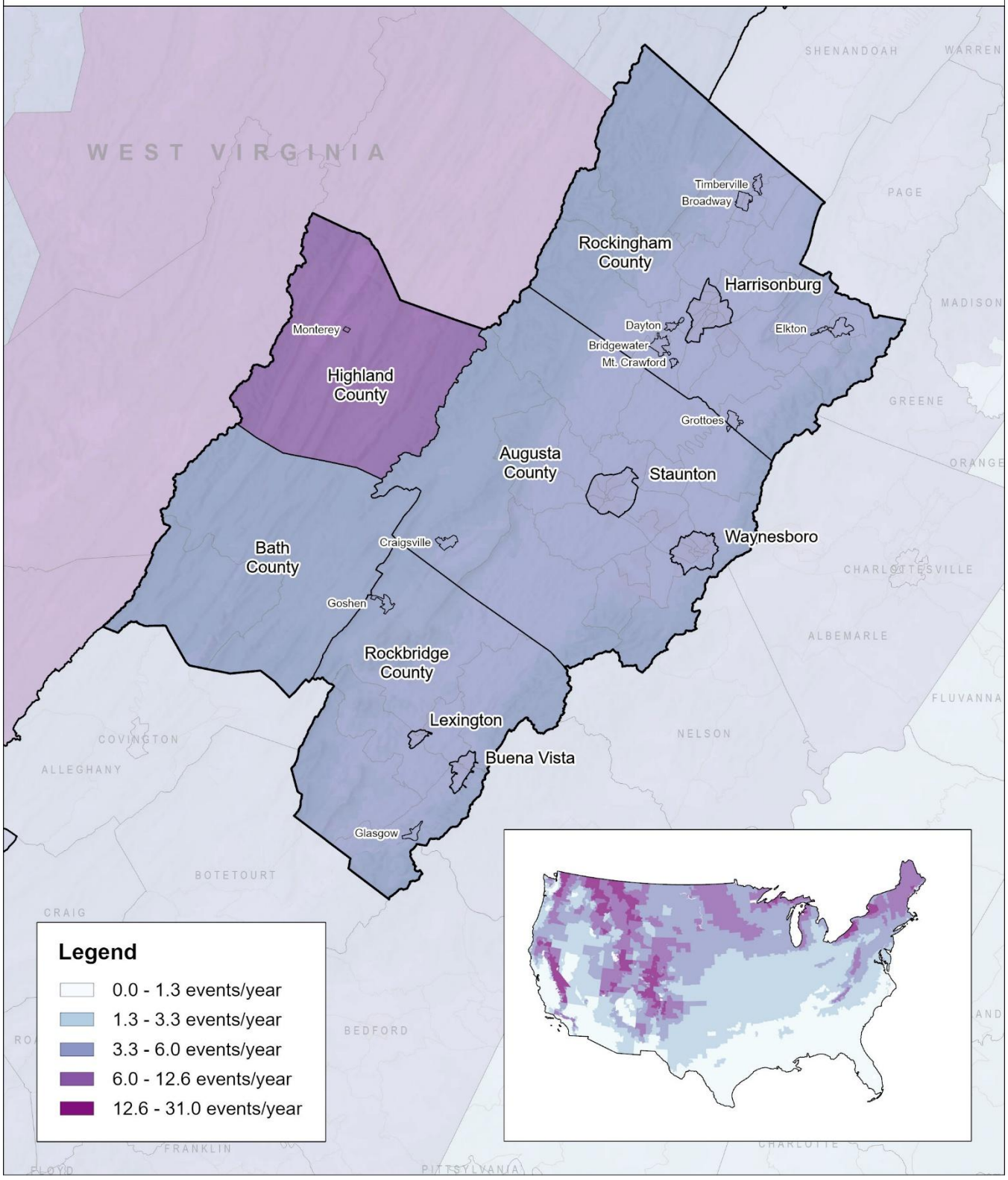
Table 4.8.2. RSI Category Definitions for SE Region

Category	1	2	3	4	5
Snow Accumulation	1-2 in.	2-5 in.	5-10 in.	10-15 in.	Over 15 in.

Chart 4.8.1 RSI Snow Events by County and Severity, 2016-2024

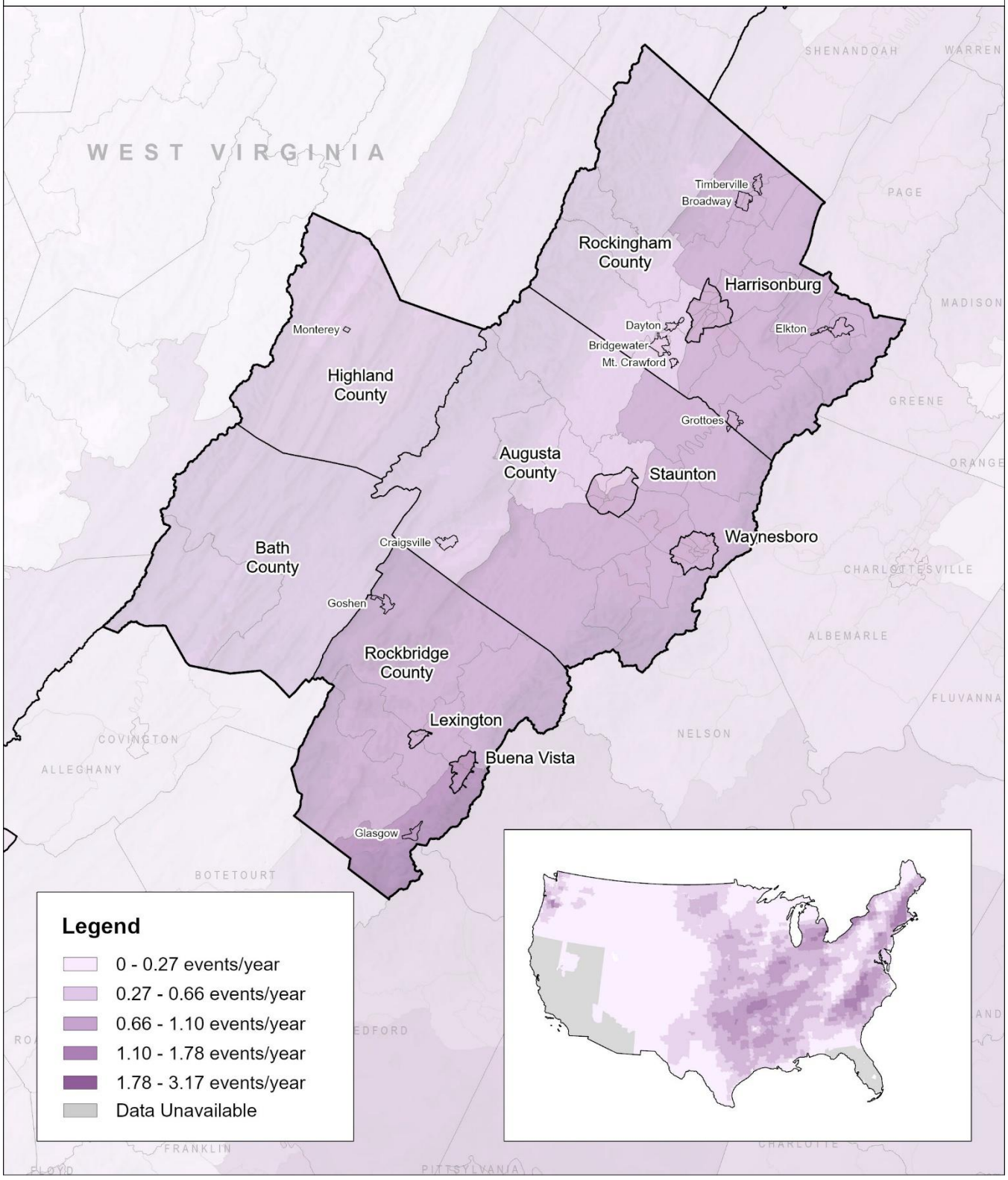


Map 4.8.2. Annualized Frequency of Winter Weather by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Winter Weather, 2023

Map 4.8.3. Annualized Frequency of Ice Storms by Census Tract



Data Source(s): FEMA National Risk Index Annualized Frequency Ice Storms, 2023

CLIMATE CHANGE CONSIDERATIONS

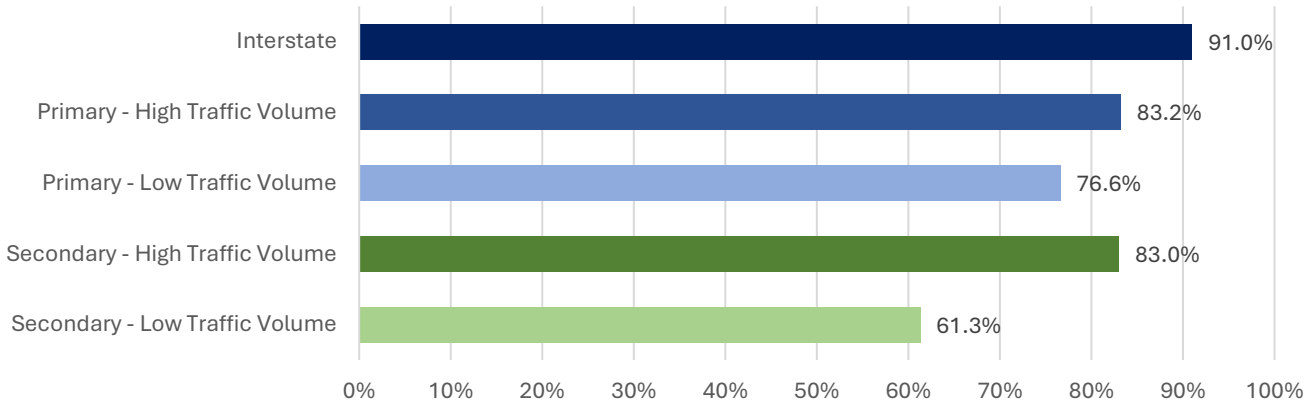
Climate change has an impact on several factors surrounding snow events, such as the frequency, amount of precipitation and intensity, and the rate of snow melting. Snow events and late spring snow cover have declined by 2.7% globally since 1973. On average, winters are getting warmer and shorter, with fewer places experiencing extremely cold temperatures. However, because the warmer atmosphere holds more moisture, snowfall is expected to be heavier and more severe in places where temperatures are still cold enough for snow (National Geographic, 2025).

VULNERABILITY

Severe winter weather poses a significant and recurring threat to the CSPDC region, with historical data showing winter-related disaster declarations averaging once every four years since 1996. Highland and Bath Counties experience the highest average annual snowfall in the region (over 30 inches), though all 21 jurisdictions face winter weather impacts including utility disruptions, road closures, and limited access to critical facilities.

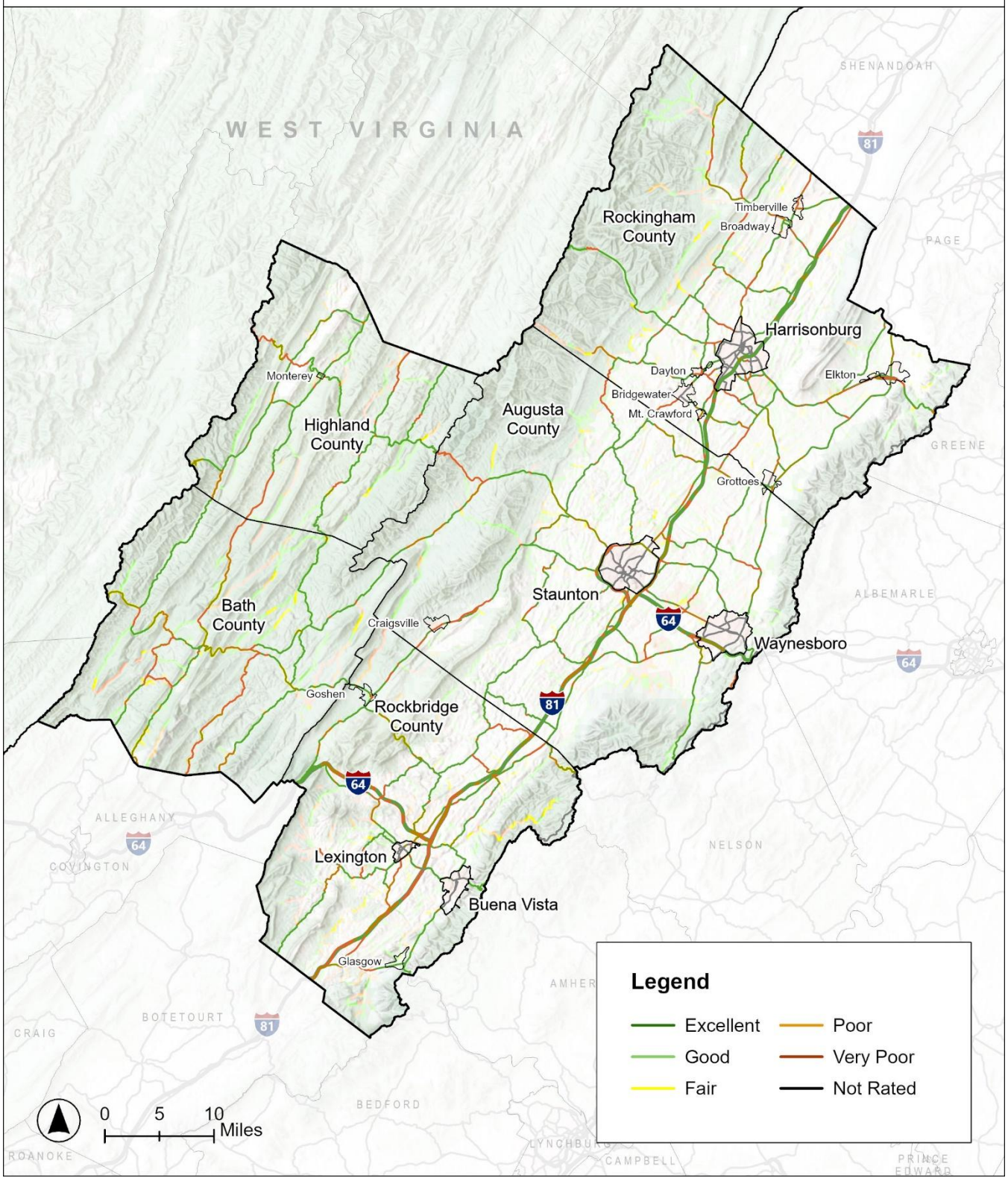
One of the most at-risk assets in the region is the transportation network. The Virginia Department of Transportation (VDOT) maintains the majority of the roads in the region, as they own the County road networks. Each year, VDOT assesses the condition of the pavement on a 5-point scale: Excellent, Good, Fair, Poor or Very Poor. Chart 4.8.2 shows the state-wide percent of pavement in Excellent, Good, or Fair condition by road type. Map 4.8.4 shows the condition of the pavement on VDOT-maintained roads in the region. It primarily shows main roads and not local secondary roads. These datasets do not account for the condition of pavement in Cities, as they own and maintain their own road network.

Chart 4.8.2. Statewide Percent of Pavement in Excellent, Good, or Fair Condition, 2025



Data Source(s): Virginia Department of Transportation, Transportation Performance Program Dashboard, 2025

Map 4.8.4. Pavement Conditions of VDOT-Maintained Roads



Data Source(s): Virginia Department of Transportation, Pavement Conditions Dataset, 2025

Bridges represent another critical transportation vulnerability during severe winter weather events. Ice accumulation and freeze-thaw cycles stress bridge decks and structural components more acutely than standard road surfaces, as bridges lose heat from both above and below. Table 4.8.3 summarizes the number and condition of VDOT-maintained bridges across the region. Bridges in Poor condition—such as those in Harrisonburg (11%), Highland County (7%), and Bath County (6%)—face heightened risk of closure or failure under heavy snow and ice loads, with cascading impacts on emergency access and regional connectivity.

Table 4.8.3. Number and Condition of Bridges (VDOT-Maintained)

		Number of Bridges	Condition			
			% Good	% Fair	% Poor	% Unclassed
Harrisonburg-Rockingham	City of Harrisonburg	79	49%	38%	11%	1%
	Rockingham County	523	43%	51%	5%	1%
	Town of Bridgewater	0	N/A	N/A	N/A	N/A
	Town of Broadway	9	33%	56%	11%	0%
	Town of Dayton	10	20%	40%	20%	20%
	Town of Elkton	16	6%	94%	0%	0%
	Town of Grottoes	6	33%	67%	0%	0%
	Town of Mt. Crawford	2	0%	100%	0%	0%
	Town of Timberville	3	33%	67%	0%	0%
Staunton-Augusta-Waynesboro	City of Staunton	22	68%	18%	0%	14%
	City of Waynesboro	50	18%	70%	8%	4%
	Augusta County	728	22%	72%	3%	3%
	Town of Craigsville	16	13%	63%	13%	13%
Rockbridge-Lexington-Buena Vista	City of Buena Vista	17	41%	47%	0%	6%
	City of Lexington	20	30%	40%	10%	15%
	Rockbridge County	680	32%	62%	4%	2%
	Town of Glasgow	2	100%	0%	0%	0%
	Town of Goshen	9	22%	56%	0%	22%
Bath-Highland	Bath County	171	27%	66%	6%	0%
	Highland County	153	32%	59%	7%	2%
	Town of Monterey	0	N/A	N/A	N/A	N/A

Data Source(s): Virginia Department of Transportation, Bridge Management System Data, 2025

Beyond transportation, the region's utility infrastructure represents a critical vulnerability to ice storms. Major ice storms have historically left tens of thousands of customers across Augusta, Rockingham, and Rockbridge Counties without power for multiple days. Water and wastewater systems face secondary risks, as pump stations and treatment facilities dependent on grid power may lose function during extended outages, and above-ground water lines are vulnerable to freezing and rupture during prolonged cold. Communications infrastructure, including cell towers and broadband facilities, is similarly at risk from ice accumulation and backup generator fuel exhaustion, with the potential to disrupt emergency communications across the region.

STATE-LEVEL RISK ANALYSIS

The 2023 Commonwealth of Virginia Hazard Mitigation Plan identifies the top five agencies in a high hazard zone for winter weather. Of this list, three agencies were in the CSPDC region. They include James Madison University, the Woodrow Wilson Rehabilitation Center, and Western State Hospital (VDEM, 2023, pg. 3-403). The plan also identifies the jurisdictions across the state with higher winter weather risk. The top 33 jurisdictions included Augusta County, Rockingham County, Highland County, and the cities of Harrisonburg, Staunton, and Waynesboro. The state-level risk ranking was based on available data for event frequency, historical crop or property damage, the number of injuries or fatalities, population density, and population vulnerability (VDEM, 2023, pg. 3-406). The three high-hazard institutional facilities identified in the state plan are particularly sensitive to ice-related utility outages given their populations' dependence on continuous heating, medical equipment, and emergency access.

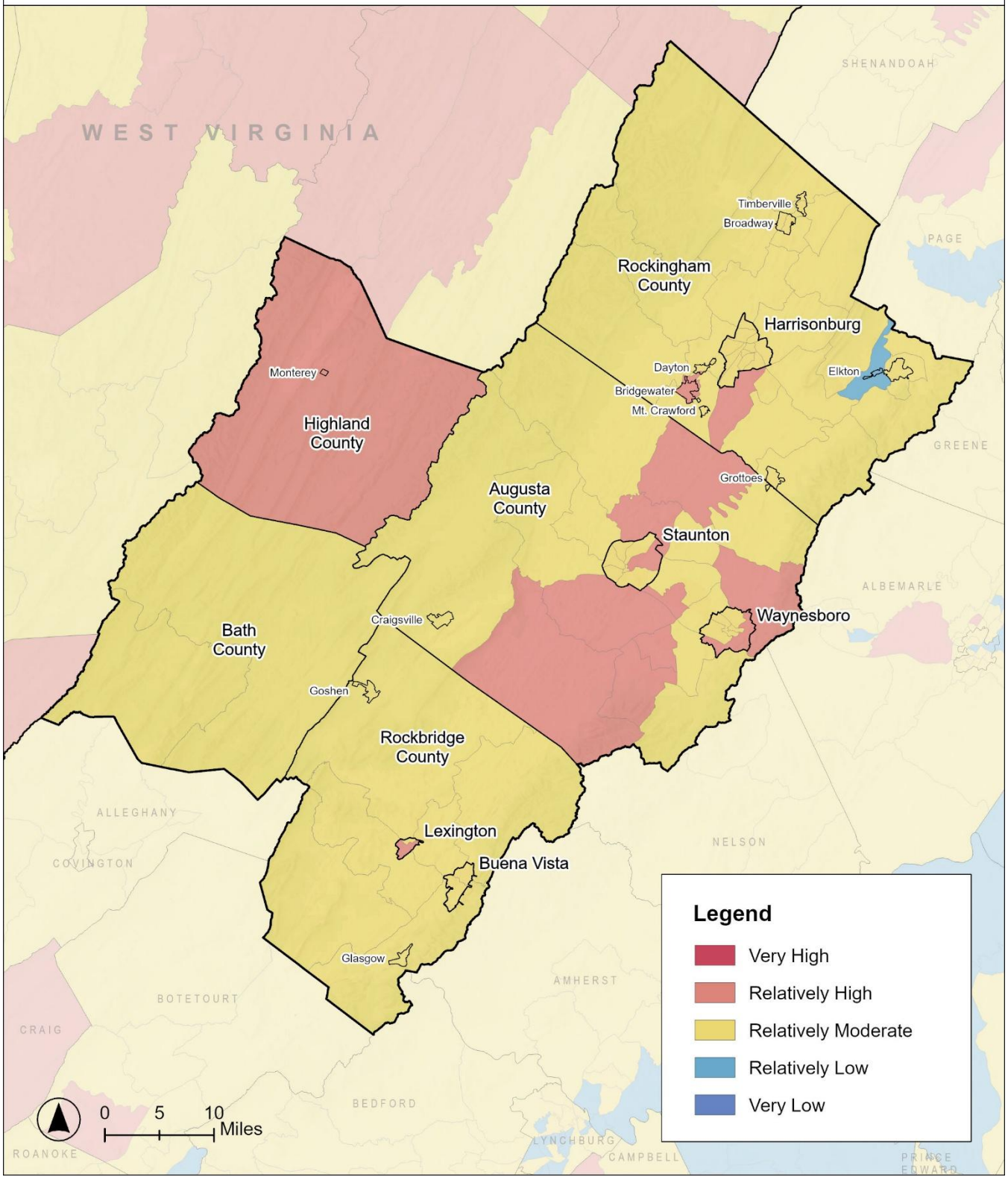
NATIONAL RISK INDEX

Due to limited data, detailed vulnerability assessments specific to the region's assets and populations are not currently available but should be incorporated in future plan updates when possible. Instead, to estimate the region's risk to severe winter weather, this profile uses FEMA's National Risk Index (NRI). The tool provides a risk rating score for each of the 18 natural hazards included in the national database. Each hazard's risk rating is a composite score that incorporates the:

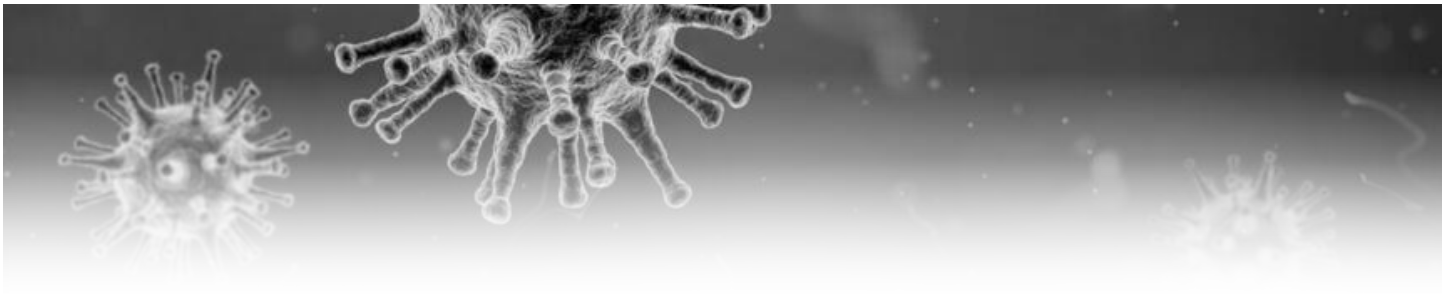
- Frequency of the hazard.
- Severity or intensity of the event.
- Vulnerability of the area (e.g., population density, building construction).
- Resilience of the area (e.g., preparedness, mitigation measures).

Map 4.8.5 shows the risk rating score by census tract in the region for winter weather. According to this dataset, most of the region is estimated to have relatively moderate risk to severe winter weather. The localities estimated to have a higher risk to winter weather include Highland, Augusta, and Rockingham Counties; the Cities of Staunton, Waynesboro, and Lexington; and the Town of Bridgewater. It is important to note, however, that this data is limited by its lack of granularity. State and local data would provide a better understanding of the region's vulnerability to winter weather.

Map 4.8.5. Winter Weather Risk Rating by Census Tract



Data Source(s): FEMA National Risk Index Winter Weather Risk Rating, 2023



THREAT PROFILE 9

INFECTIOUS DISEASE OUTBREAK

DEFINITION

A biological disease outbreak beyond normal expectancy; this profile includes epidemics and pandemics. The following definitions are adapted from the U.S. Centers for Disease Control and Prevention:

- **Epidemic:** an unexpected increase in the number of disease cases in a specific geographical area.
- **Pandemic:** an unexpected increase in the number of disease cases in a widespread area.

BACKGROUND

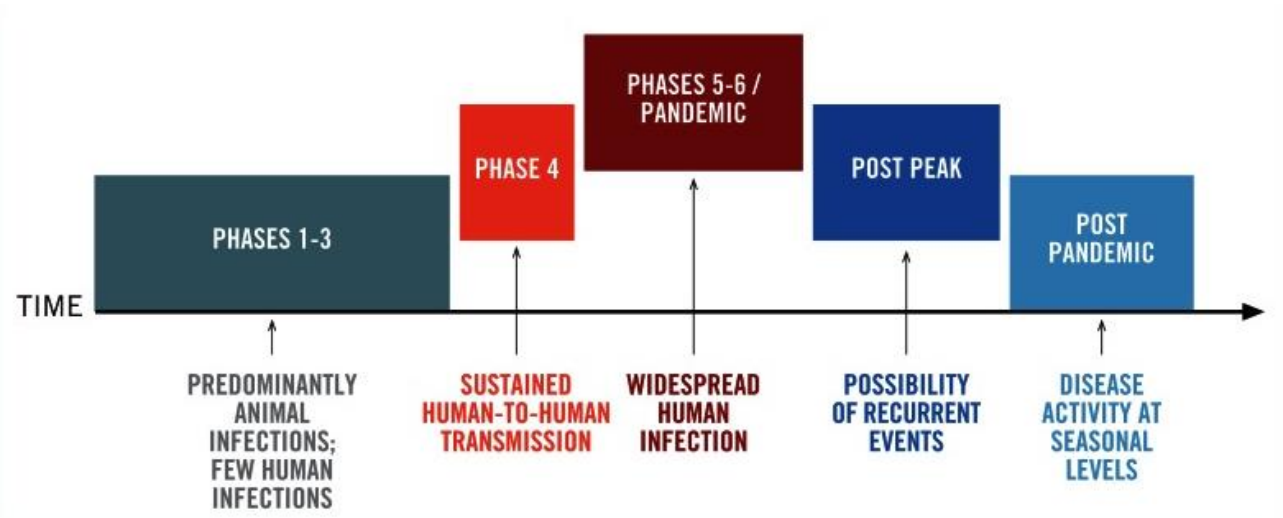
Infectious disease outbreaks pose significant risks to public health, economic stability, and community resilience. An outbreak occurs when disease cases exceed normal expectations within a specific geographic area or population, ranging from localized clusters to widespread epidemics or pandemics. These events can strain communities through multiple pathways: direct health impacts from illness and death, and indirect consequences including overwhelmed healthcare systems, workforce depletion across critical sectors, business disruptions, supply chain failures, and economic hardship.

Infectious disease threats extend beyond humans to include animal diseases that can devastate agricultural communities. The CSPDC region's substantial agricultural production, particularly its economically significant poultry industry, faces vulnerability to outbreaks such as Highly Pathogenic Avian Influenza. These agricultural disease events can result in mass livestock or poultry deaths, mandatory culling operations, trade restrictions, and severe financial losses for farmers.

The Center for Disease Control and Prevention evaluates infectious disease outbreaks based on the Pandemic Severity Assessment Framework (PSAF), which is based on the transmissibility (a 5-point scale) and clinical severity (a 7-point scale) of an influenza pandemic and combines these into an overall impact estimate.

To guide response efforts across the globe, the World Health Organization (WHO) has developed Pandemic Influenza Phases, which are illustrated in Table 4.9.1. These phases are intended to characterize the progression of transmission that may be experienced during the course of an event.

Table 4.9.1. World Health Organization Pandemic Influenza Phases	
Phase 1	No viruses circulating among animals have been reported to cause infections in humans.
Phase 2	An animal influenza virus circulating among domesticated or wild animals is known to have caused infection in humans, and is therefore considered a potential pandemic threat.
Phase 3	An animal or human-animal influenza reassortant virus has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks.
Phase 4	Characterized by verified human-to-human transmission of an animal or human-animal influenza reassortant virus able to cause "community-level outbreaks."
Phase 5	Characterized by human-to-human spread of the virus into at least two countries in one WHO region.
Phase 6	The pandemic phase, is characterized by community level outbreaks in at least one other country in a different WHO region in addition to the criteria defined in Phase 5. Designation of this phase will indicate that a global pandemic is under way.



Source: World Health Organization, 2009

SIGNIFICANT HISTORICAL EVENTS

In 2009, the H1N1 influenza created a global pandemic, with Virginia experiencing over 300 cases and 37 deaths. The most recent disease outbreak in the region, COVID-19 in 2020, had staggering impacts on Virginia, with over 2.3 million cases and over 23,000 deaths statewide between March 2020 and July 2023. Critical services, especially hospital care, were significantly impacted and supply chains were disrupted.

Beyond human disease, the region has also experienced significant agricultural disease events. A 2002 avian flu outbreak in the Shenandoah Valley highlighted the importance of biosecurity and rapid response planning in managing avian influenza outbreaks. The outbreak affected 197 farms and resulted in the destruction of

over 4.7 million birds. The event led to the development of the Virginia Poultry Disease Task Force and the Virginia Initial State Response and Containment Plan (ISRCP) for avian influenza (Akey, 2003).

Two decades later, in 2022, highly pathogenic avian influence (HPAI) re-emerged as a national threat. From January 2022 through December 2023, the U.S. Department of Agriculture (USDA) reported virus detections in more than 1,000 commercial and backyard flocks, affecting 77.9 million birds across the nation (CDC 2023). The first reported commercial case in Virginia was in Rockingham County. All of Virginia's HPAI infections in commercial operations in 2023 involved commercial meat turkeys. Two affected flocks collectively included 36,400 turkeys (Graber 2024).

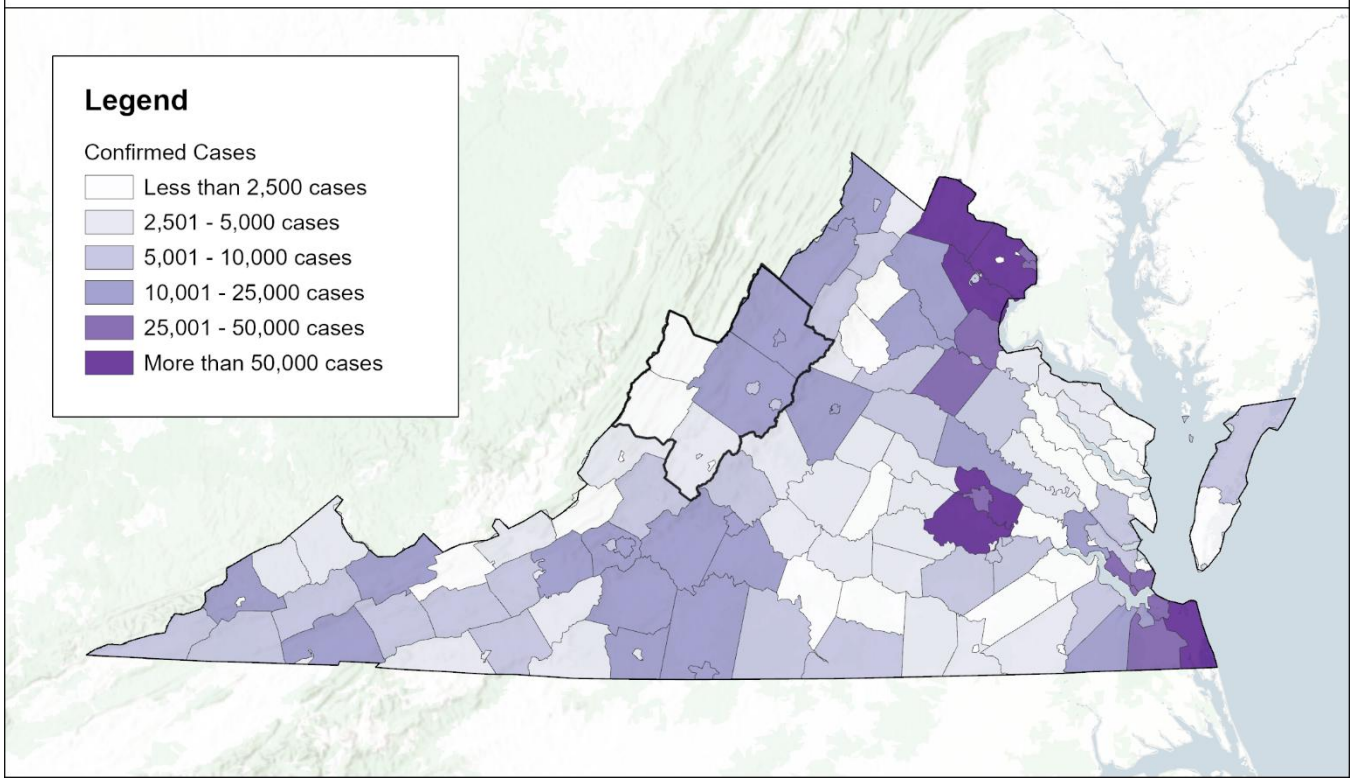
DISASTER DECLARATIONS

Previous disaster declarations include:

- Virginia COVID-19 Pandemic, 2020 (Federal)

Map 4.9.1. shows a snapshot of the estimated number of confirmed COVID-19 cases in Virginia by city/county. Table 4.9.2. details this information for the region. Notably, Table 4.9.2. shows that the City of Lexington, with 1 case for every 2.6 people, had the most reported cases per estimated population compared to the rest of the region. Rockbridge County had the least reported cases per estimated population.

Map 4.9.1. COVID-19 Case Counts by City/County, 2022



Data Source(s): Virginia Department of Health, Case Counts for COVID-19 (as of March 8, 2022)

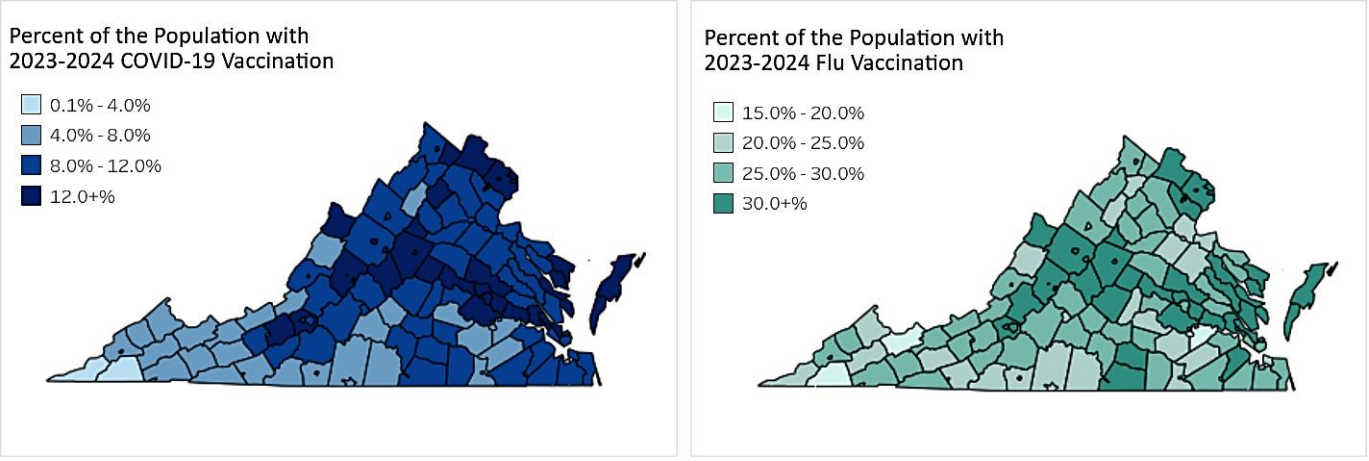
Table 4.9.2. Case Counts for COVID-19 in the CSPDC Region, 2020 – 2022					
Locality	**Reported Cases**	**Ratio of Cases to Estimated Population**	**Locality**	**Reported Cases**	**Ratio of Cases to Estimated Population**
Augusta County	18,821	1 case per 4.1 people	City of Lexington	2,821	1 case per 2.6 people
Bath County	883	1 case per 4.6 people	Rockbridge County	3,214	1 case per 7.0 people
City of Buena Vista	1,991	1 case per 3.3 people	Rockingham County	14,389	1 case per 5.9 people
City of Harrisonburg	13,174	1 case per 3.9 people	City of Staunton	5,554	1 case per 4.7 people
Highland County	359	1 case per 6.4 people	City of Waynesboro	5,281	1 case per 4.3 people

Data Source(s): Virginia Department of Health, Case Counts for COVID-19 (2022); U.S. Census American Community Survey 5-Year Estimates, Table DP05 (2022).

AREAS OF IMPACT

This hazard has the potential to impact each of the 21 jurisdictions in the planning area. Areas with higher vaccination rates for viruses such as COVID-19, influenza, whooping cough, and others are less likely to be highly impacted by outbreaks of those diseases. However, areas with lower vaccination rates, or areas impacted by a disease outbreak for which there is no vaccination program in place, coupled with higher population densities may experience severe impacts. Map 4.9.2 shows the vaccination rates by county/city for COVID-19 and influenza between 2023 and 2024 across the state.

Map 4.9.2. Vaccination Rates by County



The spread of infectious disease among livestock in the region also has a high potential for impact, particularly compared to other parts of the state. As mentioned throughout this plan, the region has some of the highest producing agricultural counties in the state, specifically Rockingham and Augusta counties. Areas with greater populations of livestock may also be at greater risk for outbreaks of animal-to-human diseases. Table 4.9.3 details the estimated number of chickens, turkeys, and cattle in each county in the region, according to 2022 census data.

Table 4.9.3. Livestock Inventory by County (2022 Estimate)

	Chickens			Turkeys	Cattle
	Broilers	Pullets	Layers		
Augusta	5,571,022	246,701	134,098	1,320,971	86,078
Bath	-	-	128	-	3,493
Highland	-	66	1,450	154,293	11,179
Rockingham	19,650,195	410,117	641,510	2,483,317	87,565
Rockbridge	425,214	94	2,267	53,060	29,919

Data Source(s): USDA National Agricultural Statistics Service (2024), 2022 Census of Agriculture, County Profiles

ESTIMATED LOSSES

Infectious disease outbreaks generate substantial economic losses across multiple sectors, affecting individuals, businesses, healthcare systems, and government operations. While the scale and nature of losses vary depending on the disease type, transmission characteristics, and outbreak severity, examining recent events provides insight into potential future impacts.

DIRECT HEALTHCARE COSTS

The initial costs incurred by a pandemic, such as COVID-19, are seen first at the patient level, impacting individuals with healthcare costs. On average in the state of Virginia, the fee for a single outpatient COVID-19 healthcare visit averaged out to $2,239 whereas a single complex inpatient visit (e.g. a patient in the intensive care unit on ventilator) associated with COVID-19 averaged around $279,741 (FAIR Health, 2021).

These individual costs aggregate into massive healthcare system expenditures during widespread outbreaks. Based on the region's approximately 66,000 reported COVID-19 cases through March 2022 (Table 4.9.2), and using conservative estimates that 15% required hospitalization and 2% required ICU care, the region likely experienced direct medical costs exceeding $150 million for COVID-19 treatment alone. This figure does not include long-term care costs for patients experiencing persistent health effects, rehabilitation services, or ongoing treatment for complications.

ECONOMIC DISRUPTION AND BUSINESS LOSSES

The COVID-19 pandemic demonstrated that infectious disease outbreaks cause economic damage extending far beyond direct healthcare costs. According to the CSPDC's 2022 Pandemic Recovery and Resiliency Plan, the region experienced severe economic impacts:

1. At the height of the pandemic, more than 15,000 jobs based in the region were lost, equivalent to 10.7% of the regional workforce; the regional GDP dropped by $315 million.
2. The pandemic had a disparate impact on various segments of the regional economy. The manufacturing and agricultural sectors were more resilient and thus experienced smaller impacts, while the accommodation and hospitality sectors were the hardest hit. This was evident in Bath County, where one of its largest employers, the Omni Homestead Resort, was particularly affected.
3. Small businesses and downtown areas experienced more damaging impacts, such as loss of revenue and employment, compared to the rest of the region.

AGRICULTURAL AND LIVESTOCK LOSSES

Beyond human health and economic impacts, the region's significant agricultural sector faces distinct infectious disease risks, particularly from diseases affecting livestock and poultry.

- **2002 Avian Influenza Outbreak:** This outbreak affected 197 farms and resulted in the destruction of over 4.7 million birds. Adjusted for inflation, equivalent losses today would exceed $85-100 million for a similar outbreak scale.
- **Recent HPAI Events:** The 2022-2023 highly pathogenic avian influenza (HPAI) outbreak affected commercial operations in Rockingham County. Two turkey flocks totaling 36,400 birds were destroyed. While smaller in scale than the 2002 event, these losses still represented approximately $1.5-2 million in direct bird value, plus associated costs for depopulation, disposal, cleaning, disinfection, and production downtime.
- **Ongoing Risk:** Table 4.9.3 shows the region's substantial poultry and livestock inventory. Rockingham County alone houses over 19.6 million broiler chickens, more than 2.4 million turkeys, and additional pullets and layers. Augusta County maintains 5.5 million broilers and 1.3 million turkeys. These concentrations represent significant economic value—an outbreak affecting even 5% of the region's commercial poultry could destroy birds valued at $15-20 million, with total economic impacts potentially exceeding $50 million when considering secondary effects.

PROBABILITY OF FUTURE OCCURRENCES

Infectious disease events — ranging from localized outbreaks to widespread pandemics — are highly probable future occurrences for the region. However, the frequency and severity of infectious disease events is more difficult to predict. Seasonal influenza, foodborne illnesses, and vector-borne diseases (such as Lyme disease) occur annually and are considered near-certain recurring hazards. Pandemic-scale events are infrequent but historical precedent, including the 1918 influenza pandemic, the 2009 H1N1 outbreak, and the COVID-19 pandemic, demonstrates that the region remains vulnerable to both novel and re-emerging pathogens.

VULNERABILITY

Multiple population groups and settings within the region face heightened risk during infectious disease outbreaks. Understanding these vulnerabilities enables targeted preparedness planning.

AGE-RELATED VULNERABILITY

Certain age groups are particularly susceptible to infectious disease outbreaks, including infants and small children and individuals aged 65 and older. These populations face elevated risk due to developmental factors in young children (whose immune systems are still maturing) and age-related immune decline in older adults, often compounded by chronic health conditions. Table 4.9.4 details the estimated number of individuals under 5 years old or 65 and above by city/county in the region, according to 2023 estimates.

Table 4.9.4. Population Estimates by City/County, 2023

Locality	Total Population	Under 5 Years	65 and Above
Augusta County	78,622	2,630 (3.3%)	18,836 (24.0%)
Bath County	4,123	180 (4.4%)	1,128 (27.4%)
City of Buena Vista	6,612	330 (5.0%)	1,213 (18.3%)
City of Harrisonburg	51,492	2,643 (5.1%)	5,189 (10.1%)
Highland County	2,265	60 (2.6%)	776 (34.3%)
City of Lexington	7,420	242 (3.3%)	1,214 (16.4%)
Rockbridge County	22,578	868 (3.8%)	6,048 (26.8%)
Rockingham County	87,674	5,238 (6.0%)	18,015 (20.5%)
City of Staunton	25,765	1,575 (6.1%)	5,409 (21.0%)
City of Waynesboro	22,574	1,496 (6.6%)	3,998 (17.7%)

Data Source(s): U.S. Census Bureau, ACS Demographic and Housing Estimates, Table DP05

With over 60,000 residents aged 65 and above across the region, older adults constitute a significant portion of the population requiring prioritized protection during infectious disease events. Augusta County contains the largest absolute number of older residents (18,836), while Highland County, despite its small size, has more than one-third of its population in this age group.

Rockingham County has both the largest absolute number (5,238) and highest percentage (6.0%) of children under age 5 in the region, followed closely by the City of Waynesboro at 6.6% and the City of Staunton at 6.1%. The regional total of approximately 15,262 young children requires pediatric healthcare capacity, age-appropriate medical interventions, and childcare-focused infection control measures during outbreaks.

CHRONIC HEALTH CONDITIONS

Individuals with underlying chronic health conditions face significantly higher risk of severe illness, hospitalization, and death from infectious diseases. Conditions that increase vulnerability include diabetes, heart disease, chronic lung disease, kidney disease, liver disease, cancer, and immunocompromising conditions. The Central Shenandoah Health District, which includes much of the CSPDC region, shows chronic disease rates near or slightly above state averages. With more than one in ten adults living with diabetes and nearly one in three adults experiencing obesity, thousands of residents face elevated risk during infectious disease outbreaks. Table 4.9.5 shows the prevalence of select conditions across the region.

Table 4.9.5. Prevalence of Chronic Health Conditions, 2021

	Diabetes	Heart Disease	COPD	Obesity
Central Shenandoah Health District	10.8%	6.2%	7.1%	32.4%
Virginia (State Average)	10.2%	5.8%	6.8%	31.2%

Data Source: Virginia Department of Health, County Health Rankings

HEALTHCARE SYSTEM CAPACITY

The region's healthcare infrastructure faces constraints that affect outbreak response capability. The region has approximately 625 total hospital beds serving a population of over 309,000, or roughly 2 beds per 1,000 residents. This ratio falls below the national average of 2.4 beds per 1,000 people. More critically, the region has only 38 ICU beds across all facilities. During the COVID-19 pandemic, ICU capacity was frequently at or near 100%, requiring transfers to facilities outside the region and delaying care for non-COVID patients.

Rural counties face particular challenges. Bath County's 25-bed facility provides essential local care but cannot manage complex cases requiring intensive care or specialized treatment. Highland County has no hospital, requiring residents to travel to Staunton, Harrisonburg, or outside the region for hospital care. This limited capacity means that even moderate infectious disease outbreaks can quickly overwhelm local healthcare systems. Table 4.9.6 summarizes key healthcare resources across the region.

Table 4.9.6. Healthcare Facilities and Capacity

Facility	Location	Total Beds	ICU Beds
Augusta Health	Staunton	255	18

Table 4.9.6. Healthcare Facilities and Capacity			
Sentara RMH Medical Center	Harrisonburg	238	20
UVA Health Rockingham	Harrisonburg	82	0
Carilion Stonewall Jackson Hospital	Lexington	25	0
Bath Community Hospital	Bath	25	0

Data Source: Virginia Department of Health, Healthcare Facility Database (2023)



THREAT PROFILE 10

HAZARDOUS MATERIALS RELEASE

DEFINITION

An unintentional leak, spillage, discharge, or release of HazMat (chemical, biological, or radiological) that poses a threat to human health and safety and the surrounding environment.

BACKGROUND

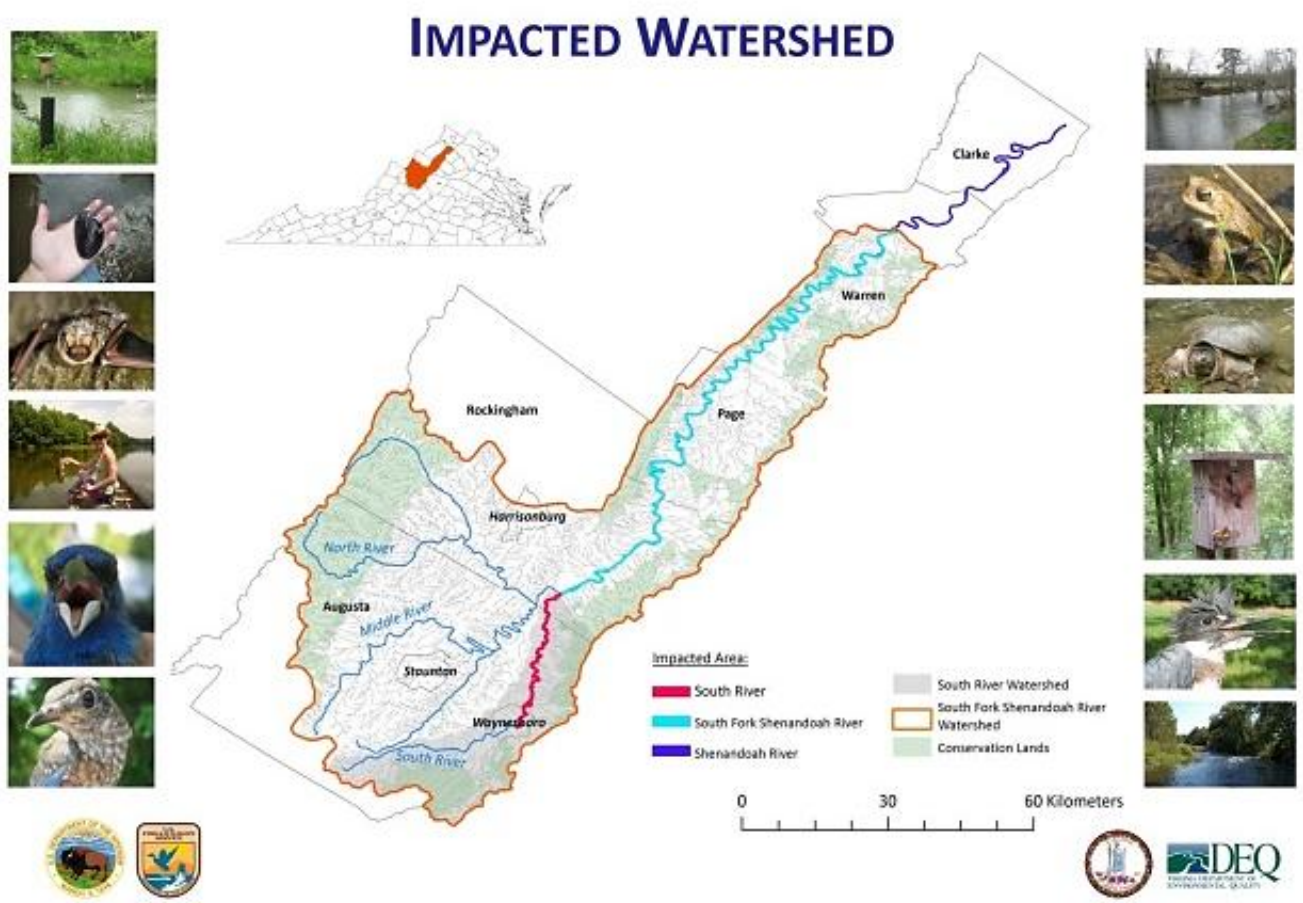
"HazMat" is a comprehensive term that includes a variety of materials that, if released, can cause significant harm to living organisms. The effects of these materials can vary depending on their type, with some causing long-term impacts and/or remaining undetectable for a period, as seen with radioactive substances or biologicals that have incubation periods. The consequences to health and the environment can be severe, as evidenced by numerous historical incidents.

This specific hazard profile analyzes effects from unintentional releases. Effects can include mass casualty events that can inundate healthcare facilities; contamination of water sources and/or soil (particularly given the region's karst topography); disruption or destruction of ecosystems; evacuation or shelter-in-place orders; and disruption of local utility services. HazMat accidents can also cause fires, explosions, oxygen enrichment and displacement in confined spaces, and damage to equipment and supplies.

SIGNIFICANT HISTORICAL EVENTS

The region, and more specifically the former DuPont industrial facility (now Invista Incorporated), is the site of the largest natural resource damage settlement in Virginia's history (U.S. Department of the Interior, 2020). The facility is located on approximately 177 acres on the eastern shore of the South River in the City of Waynesboro. From 1929 to the 1970s, mercury was used to manufacture acetate flake at the facility. Over time, mercury releases contaminated and impacted soil and groundwater on-site. Subsequently, mercury was transported to the South River through storm sewers. The mercury release was discovered in the 1970s, and a fish consumption ban, then advisory, was enacted for the South River and South Fork Shenandoah River (U.S. Department of the Interior, n.d.).

Map 4.10.1. Impacted Watershed from Mercury Release at DuPont Facility



Source: U.S. Department of the Interior, Natural Resource Damage Assessment and Restoration Program

Mercury continues to be transported and re-circulated downstream via surface water, sediments, and floodplain soils to the South River, South Fork Shenandoah River, and Shenandoah River. As a result, a wide variety of natural resources have been exposed to facility-related mercury. Remedial activities for the South River are ongoing. In July 2017, the Trustees, Department of the Interior, through the US Fish and Wildlife Service, and the Commonwealth of Virginia, received a settlement of $42,069,916.78 to address natural resource damages and to implement restoration projects related to the impacted resources in the watershed (U.S. Department of the Interior, n.d.). Proposed restoration includes:

- projects improving water quality and habitat (agricultural and urban best management practices);
- freshwater mussel propagation and restoration;
- neotropical migratory songbird full life cycle restoration;
- land protection, property acquisition, and recreational and wildlife enhancements;
- recreational fishing improvement projects; and
- renovation of a Virginia fish hatchery.

In addition to the landmark settlement in Waynesboro, there have been minor to moderate incidents at industrial sites during production, use, and transport of HazMat. The most likely scenario involving a HazMat spill involves industrial and agricultural facilities. Table 4.10.1. below describes the number of facilities in the planning district that handle toxic chemicals (not biological or radiological material) and their associated on- and off-site releases in 2022. For more information regarding facility releases, including type of material and release, in specific jurisdictions, refer to the EPA's TRI Program online database.

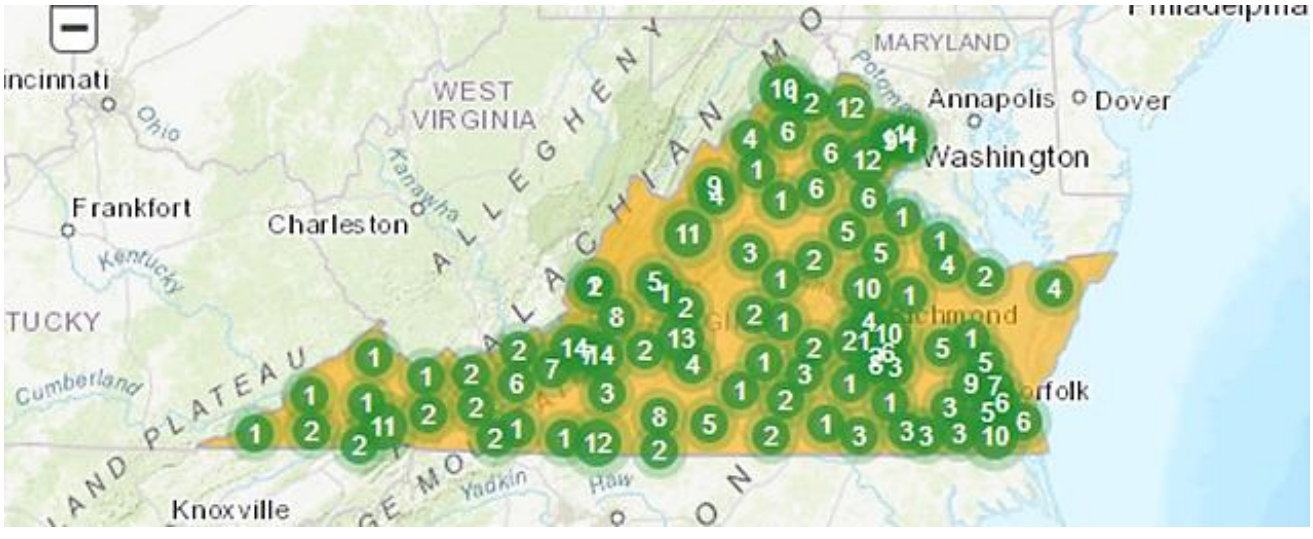
Spills have a higher probability on either Interstate I-64 or I-81, where HazMat is transported almost daily. Given that these two major roadways cross through the planning district, an accident involving vehicles on one of these routes could lead to a spill that adversely affects the soil and nearby water reservoirs, as well as impact individuals involved in the accident.

Finally, railway accidents have increased across the nation as the U.S. rail infrastructure continues to age. The Chesapeake and Ohio (C&O) Railroad cuts through a southern portion of the planning district and, since cutting its passenger services in 1971, has been operated by CSX and focuses on transporting freight. According to their website, CSX specifically carries the following through Virginia: "consumer products, automobiles, food and agriculture products, and coal [...] containerized consumer goods, aggregates, petroleum products, and packaging paper."

AREAS OF IMPACT

Due to the region's agriculture, manufacturing, and transportation industries, each of the 21 jurisdictions are susceptible to impacts from a HazMat release. However, for a more focused look, the remainder of this section details facilities in 14 specific jurisdictions where an unintentional release is more likely due to local industrial facilities. The EPA TRI Program tracks facilities that produce, use, store, and dispose of toxic chemicals (including type and quantity of accidental releases). Map 4.10.2. indicates the general areas of the 425 facilities spread throughout the state.

Map 4.10.2. TRI Facilities in Virginia (as of 2022)



Source: Environmental Protection Agency, 2023

The following table shows 44 of the 425 facilities in the state are located within CSPDC jurisdictions, along with the number of chemical releases in those areas in 2022. Localities without facilities have been omitted from the list, while data for Highland County, City of Lexington, Town of Craigsville, and Town of Monterey were not available via the database. Finally, of the top 5 facilities that contributed to the largest HazMat releases in Virginia in 2022, none are in the planning region.

Table 4.10.1. TRI Facility Count by Jurisdiction, 2022

Jurisdiction	Facilities	Toxics Released On-Site	Toxics Released Off-Site
Augusta County	11	63,300 lbs.	35,900 lbs.
Rockbridge County	5	6,900 lbs.	0 lbs.
Rockingham County	9	149,000 lbs.	152,500 lbs.
City of Buena Vista	3	111 lbs.	11 lbs.
City of Harrisonburg	6	2,300 lbs.	841 lbs.
City of Staunton	1	1 lbs.	0 lbs.
City of Waynesboro	1	37,000 lbs.	18,200 lbs.
Town of Goshen	1	6,800 lbs.	0 lbs.
Town of Grottoes	1	0 lbs.	0 lbs.
Town of Broadway	1	0 lbs.	0 lbs.
Town of Dayton	1	0 lbs.	130,400 lbs.
Town of Elkton	2	31,800 lbs.	3,200 lbs.
Town of Mt. Crawford	1	0 lbs.	0 lbs.
Town of Timberville	1	6,700 lbs.	18,100 lbs.
TOTAL	44	303,912 lbs.	359,152 lbs.

ESTIMATED LOSSES

As mentioned earlier, the DuPont-Waynesboro mercury release resulted in a settlement exceeding $40 million, though long-term losses to wildlife habitats and recreational fishing remain difficult to quantify. Additionally, since major HazMat disasters are uncommon in Virginia, this section references national incidents to illustrate potential loss scenarios.

The 2023 Norfolk Southern train derailment in East Palestine, Ohio involved 17 HazMat-carrying railcars that contaminated the Ohio River, degraded air quality, and forced 2,000 residents to evacuate. Norfolk Southern estimates total losses exceeding $1 billion, including lawsuit settlements, environmental remediation, penalties, and legal fees. A smaller but relevant incident occurred in April 2020 when a tractor-trailer carrying 10,000 gallons of gasoline overturned near Boston, spilling its contents onto roadways and a nearby marsh. The NTSB estimated losses at $1.1 million for vehicle damage, roadway repairs, cleanup, and product loss.

While the CSPDC region has not experienced disasters of this magnitude, these incidents illustrate the potential financial and environmental impacts from major HazMat releases involving transportation corridors or industrial facilities.

PROBABILITY OF FUTURE OCCURRENCES

Given the broad definition of hazardous material release and the physical context of the CSPDC region, the probability of future occurrences is high and almost certain. The region experiences minor HazMat incidents annually, with the potential for a major incident remaining a constant threat. The potential intensity and range of impact, however, varies depending on several factors.

KEY RISK FACTORS

- **Transportation Corridors:** The region's two major interstate highways (I-81 and I-64) serve as critical commercial freight routes with daily HazMat transportation. I-81, in particular, is a high-volume corridor connecting major distribution centers from the Northeast to the South. The combination of heavy truck traffic, mountainous terrain, and varying weather conditions creates ongoing risk for transportation-related HazMat incidents.
- **Fixed Facility Presence:** The region contains 44 TRI-reporting facilities that collectively released over 800,000 pounds of toxic materials in 2022 (both on-site and off-site). The concentration of facilities in Augusta County (11), Rockingham County (9), and Harrisonburg (6) indicates sustained industrial activity with inherent release risk. While most facilities maintain strong safety protocols, the routine handling, storage, and processing of HazMat increases statistical probability.
- **Rail Transportation:** The CSX rail line traversing the southern portion of the planning district transports various HazMat materials including petroleum products, chemicals, and agricultural products. National trends showing increased rail incidents as infrastructure ages, combined with local freight volumes, suggest continued risk exposure from this transportation mode.
- **Agricultural Operations:** The region's substantial agricultural sector regularly uses and stores fertilizers, pesticides, and other chemicals. While typically involving smaller quantities than industrial facilities, the dispersed nature of agricultural operations creates numerous potential release points, particularly during application seasons or due to improper storage.
- **Environmental Amplification Factors:** The region's karst topography and extensive waterway networks create conditions where HazMat releases can spread rapidly and affect larger areas. Groundwater connectivity through limestone formations means surface spills can quickly contaminate aquifer systems. Development along the South River, South Fork Shenandoah River, and Shenandoah River increases the number of people and critical infrastructure potentially affected by waterborne contamination.

VULNERABILITY

Overall regional vulnerability to HazMat releases is assessed as high, though vulnerability levels vary by location and incident type. Urban areas along I-81 and I-64 face the highest risk due to concentrated populations near daily HazMat transportation routes. Conversely, rural karst areas experience elevated groundwater contamination risk despite lower population density, as surface spills can rapidly infiltrate aquifer systems through limestone formations. The region's economic dependence on agriculture and manufacturing creates inherent vulnerability that demands ongoing risk management and emergency preparedness.



THREAT PROFILE 11

CRITICAL INFRASTRUCTURE FAILURE

DEFINITION

The loss, disruption, or failure of systems that provide essential community services and life safety functions. This includes utility outages (electricity, gas, water), telecommunication and network disruptions, cyber-attacks against critical systems, communication interference from regulatory restrictions, and structural failures of dams.

BACKGROUND

Most instances of infrastructure failure are the result of other hazards causing damage and consequently impacting utilities, roadways, and other lifelines. However, due to aging infrastructure, human error (e.g., maintenance mishaps), or intentional sabotage, failures may also occur as a stand-alone event.

Critical infrastructure in Virginia is constructed and maintained through a complex partnership of federal, state, local, and private entities. At the state level, the Virginia Department of Transportation (VDOT) maintains the third-largest state-maintained highway system in the nation, encompassing approximately 58,000 miles of roadways, over 21,000 bridges and structures, and numerous tunnels and rest areas. Cities maintain their own roadway networks within their boundaries, while utilities are operated by a combination of municipal authorities, regional commissions, and private companies. This decentralized system creates varying levels of investment, maintenance standards, and capacity across different jurisdictions.

Virginia's infrastructure faces mounting pressures from aging systems, deferred maintenance, population growth, and increasing demand. Many water and wastewater systems date to the mid-20th century and are reaching or exceeding their design lifespan. Transportation infrastructure experiences heavy use from both resident and through-traffic, with Virginia serving as a critical corridor along the eastern seaboard. Maintenance funding remains a persistent challenge, with competing priorities and limited resources often resulting in reactive rather than proactive approaches to infrastructure upkeep.

The American Society of Civil Engineers (ASCE) released the 2022 Report Card for Virginia’s infrastructure across 11 categories, with the overarching score receiving a “C,” slightly above the national average of “C-.”

The following scores were provided for the 11 categories (American Society of Civil Engineers, 2022):

Bridges: B	Public Parks: C	Schools: C-	Transit: C-
Dams: C+	Rail: C-	Solid Waste: B-	Wastewater: D+
Drinking Water: C+	Roads: C-	Stormwater: C-	

ASSOCIATED EFFECTS

Although infrastructure failure is often a secondary hazard to another incident such as a hurricane or blizzard, it can also result from poor construction, design flaws, or deteriorating systems. Whether public or private, these failures can cause severe impacts to the day-to-day lives of citizens as the systems are often interconnected and reliant on each other. Secondary effects may include disruptions to essential services, such as utility outages or network failures, which can lead to cascading effects, such as school closures, hospital evacuations, and delays or cancellations in transportation, among others. Infrastructure failure may also pose physical hazards, including fires, explosions, and leaks, depending on the system.

CYBER-ATTACK AGAINST INFRASTRUCTURE

Cybersecurity threats could create significant issues for communities due to a heavy, global dependence on network connectivity to operate complex systems that support our daily services. Officials at CISA warn that cyber-attacks against critical infrastructure and key manufacturing industries have significantly increased in the last decade as technology and Internet-based services continue to expand. From power grids to water systems, commerce to healthcare, cyber-attacks are becoming popular as adversaries do not need to be physically present, attack mechanisms are hard to detect, and they often leave no digital signature to assist investigators in prosecuting those responsible.

All 21 jurisdictions within the planning area have network-enabled critical infrastructure that is considered “desirable” to target by malicious actors, whether part of a ransom-ware scheme, intent to intimidate, or in more severe cases, attempt to incapacitate. Federal government officials in the cybersecurity field warn that cyber-attacks are a regular occurrence, even if it is not seen and/or noticed by end users, even in rural areas such as the Central Shenandoah Valley. According to CISA, state and local government systems experience attempted intrusions daily, with ransomware attacks against municipalities increasing by over 60% nationally between 2019 and 2023.

While there is currently no evidence to suggest that any of the 21 jurisdictions have experienced a successful cyber-attack against critical infrastructure, the threat activity is high and cyberattacks are deployed daily across Virginia and throughout the U.S. The rural nature of the Central Shenandoah region does not provide immunity; in fact, smaller jurisdictions with limited IT security budgets and staff may present more vulnerable targets than larger urban centers with dedicated cybersecurity teams. It is essential for community and business leaders to remain vigilant in their efforts to proactively secure, monitor, and protect networked systems against potential attacks that have the potential to disrupt services, and worse, inflict harm against citizens and visitors.

PROBABILITY

Given the daily occurrence of attempted cyber-attacks nationwide and the increasing sophistication of threat actors, the probability of a successful cyber-attack affecting critical infrastructure in the Central Shenandoah region is assessed as medium to high and increasing annually. While no documented successful attacks have occurred to date in the planning area, the region's interconnected utility systems, reliance on VDOT's networked traffic management along the I-81 corridor, and the presence of water and wastewater treatment facilities controlled by supervisory control and data acquisition (SCADA) systems all present attractive targets. The probability increases with each passing year as the region expands its digital infrastructure without corresponding increases in cybersecurity capacity.

IMPACT

In a hypothetical scenario developed by CISA, economic and insurance impacts from a severe, yet plausible, cyber-attack against the U.S. power grid could reach $240 billion, potentially exceeding $1 trillion. For the Central Shenandoah region specifically, a successful cyber-attack could have devastating cascading effects. An attack on VDOT's traffic management systems could disrupt the I-81 corridor, a critical artery for regional commerce, agricultural distribution, and tourism access to Shenandoah National Park, potentially costing the region millions in daily economic activity. The region's significant agricultural sector, which includes time-sensitive operations such as dairy processing and poultry production, could face catastrophic losses if utility or cold-chain logistics systems were compromised.

A ransomware attack on municipal water or wastewater treatment facilities could leave thousands of residents without safe drinking water or sanitation services for extended periods, with rural areas lacking redundant systems facing the most severe impacts. The region's aging population, including residents dependent on digital health monitoring systems and telemedicine services, would be particularly vulnerable during a prolonged attack affecting healthcare networks. Educational institutions, including James Madison University and numerous K-12 schools, could face disruption to administrative systems, online learning platforms, and campus safety networks. The financial burden of any ransoms paid in effort to expeditiously return operating systems to normal, cost of human life if injuries or deaths are directly linked to the attack, lost revenue for businesses and local governments, emergency response costs, and long-term recovery investments will play a role in overarching costs associated with this hazard. Given the region's limited cybersecurity resources spread across 21 jurisdictions, recovery from a major cyber-attack could be protracted and costly, potentially requiring state and federal assistance.

TELECOMMUNICATION & NETWORK OUTAGE

Given the modern reliance on technology, a telecommunication or network outage can have severe and debilitating effects on a community. In isolated instances where a single service is lost, end users may encounter minor inconveniences or disruptions to their daily routines. However, more substantial outages affecting multiple services or carriers can have crippling impacts on life safety, businesses, transportation,

and other critical services that affect nearly all community members. Hospitals depend on internet services for managing patient records, processing pharmaceuticals, performing surgeries, and controlling environmental systems. Dispatch centers use these services to receive 9-1-1 calls, track and dispatch first responders, and map emergencies. Public transportation systems rely on internet access to maintain schedules, re-route vehicles, and alert customers to service disruptions. From modern conveniences to life-saving medical procedures, communities are becoming increasingly interconnected with and dependent upon communication and network services.

The Central Shenandoah region faces significant broadband connectivity challenges, particularly in its rural counties. According to data from the Virginia Department of Housing and Community Development (DHCD), broadband service gaps vary considerably across the planning district. DHCD defines "broadband" using the Federal Communications Commission's threshold of 25 megabits per second (Mbps) for downloads and 3 Mbps for uploads (this standard was established in February 2015). Locations that do not meet this threshold are considered "unserved."

As shown in Table 4.11.1, the distribution of unserved locations reveals stark disparities between rural and urban jurisdictions. Highland County has 1,969 unserved locations, representing approximately 1.1 people per unserved location, meaning nearly every household lacks adequate broadband access. Bath County follows a similar pattern with 1,650 unserved locations (2.6 people per location). The larger counties show substantial numbers of unserved locations: Rockbridge County has 7,843 unserved locations, Rockingham County has 9,313, and Augusta County has 6,139. By contrast, the region's cities have significantly better coverage, with the City of Waynesboro having only 4 unserved locations (5,662.8 people per unserved location), indicating near-universal broadband availability in urban areas.

Table 4.11.1. Locations Unserved by Broadband (2022)

City/County	# of Locations	Proportion of Population to Unserved Locations
Highland County	1,969	1.1 people per unserved location
Bath County	1,650	2.6 people per unserved location
Rockbridge County	7,843	2.9 people per unserved location
Rockingham County	9,313	9.2 people per unserved location
Augusta County	6,139	12.7 people per unserved location
City of Harrisonburg	742	75.5 people per unserved location
City of Buena Vista	38	171.7 people per unserved location
City of Lexington	26	281.9 people per unserved location
City of Staunton	84	305.6 people per unserved location
City of Waynesboro	4	5,662.8 people per unserved location

Data Source(s): Virginia Department of Housing and Community Development (DHCD), 2022

Recognizing these critical gaps, all five counties in the planning district have applied for state aid through the Virginia Telecommunication Initiative (VATI) to strengthen broadband infrastructure in underserved rural areas. These investments are crucial to the resilience of communication infrastructure and the prevention of widespread service disruptions. Expanding and improving broadband access not only reduces the number of residents affected by outages but also creates redundant pathways that can maintain connectivity when primary systems fail.

PROBABILITY

The Central Shenandoah region experiences telecommunication and network outages with concerning regularity. The region has experienced at least two major documented outages in recent years, including the 2012 high-wind event affecting dispatch services and the June 2024 AT&T outage that prevented 25,000 attempts to reach emergency services. While some jurisdictions are actively working to expand and strengthen communication infrastructure, widespread outages throughout the Central Shenandoah region remain common, particularly during severe weather events. The probability of significant telecommunication outages is assessed as high, with strong correlation to the frequency of severe weather hazards (hurricanes, winter storms, high wind events) addressed elsewhere in this plan. The region's rural topography, aging carrier infrastructure, limited redundant communication pathways, and ongoing gaps in broadband coverage all contribute to elevated outage risk. As severe weather events increase in frequency and intensity due to climate change, the probability of weather-related communication outages will correspondingly increase.

IMPACT

The impacts of telecommunication and network outages on the Central Shenandoah region extend far beyond inconvenience. The June 2024 AT&T outage, which prevented 92 million phone calls nationwide and specifically blocked 25,000 emergency service calls, demonstrates the life-safety implications of these events. In a region served primarily by volunteer fire departments and rescue squads whose members often rely on personal mobile devices for emergency notifications, a major carrier outage can significantly delay response times and potentially cost lives. The 12-hour duration of the AT&T outage illustrates how extended service interruptions can compound these dangers.

The region's substantial agricultural economy faces unique vulnerabilities to communication outages. Modern farming operations depend on internet connectivity for precision agriculture systems, livestock monitoring, irrigation management, and commodity market access. An outage during critical planting or harvesting periods, or during livestock emergencies, could result in significant financial losses for farm operations that form the backbone of the regional economy. The tourism sector, which draws visitors to Shenandoah National Park and surrounding attractions, would be severely impacted as tourists lose access to GPS navigation, online reservations, and the ability to contact emergency services in remote areas.

Educational disruption represents another major impact area. Rural schools throughout the region have increasingly adopted remote and hybrid learning models, and students in underserved areas already struggling with limited connectivity would face complete educational interruption during outages. The data showing Highland County with 1,969 unserved locations (essentially one per

household) illustrates how a telecommunication outage in such areas eliminates not just backup connectivity but primary connectivity for education, telehealth, remote work, and emergency communications. This digital divide disproportionately affects the region's most vulnerable populations and amplifies the consequences of any service disruption.

UTILITY OUTAGE

Outages can occur due to equipment malfunction, misconfiguration, maintenance accident, or because of another hazard, such as hurricane, tornado, or flood. An outage of a single utility in one area has the potential to create cascading effects to other end-users or even other utilities. Other secondary impacts to consider include injury or death. For instance, a power outage impacting the homes of medically compromised persons (e.g. in-home dialysis patients) may require evacuation to area healthcare facilities. Gas outages during winter months could result in freeze-related injuries or hypothermia.

Virginia's electric generation relies heavily on natural gas (54% as of 2022), with nuclear power supplying 31%, renewables providing 11%, and coal and petroleum providing the remainder. Despite this diverse energy portfolio, the state ranks 42nd out of 50 for electric reliability according to U.S. News (with 50 being the worst), and 38th out of 50 for other infrastructure reliability (water, sewage, etc.). While the Central Shenandoah region's rural and suburban characteristics mean lower population density and reduced demand on utility systems, this same rural nature combined with aging infrastructure creates unique vulnerability to prolonged outages and delayed restoration.

PROBABILITY

The Central Shenandoah region has experienced at least four major utility outages in just six years (2018-2024), averaging one significant event every 18 months. These events demonstrate a clear pattern of recurring vulnerability:

- **October 2018:** Hurricane Michael hits the Mid-Atlantic, although the Central Shenandoah region only experienced tropical storm-force winds, resulting in 750,000 without power throughout the State.
- **November 2018:** an ice storm caused a wide-spread power outage across several states, including parts of the planning district, that lasted for several days before restoration was complete; over 6.5 million customers were affected throughout the Mid-Atlantic.
- **October 2022:** Hurricane Ian hits the Mid-Atlantic area, causing wide-spread power outages across the state and the Shenandoah Valley, 211,000 customers were impacted in the state alone.
- **June 2022:** a derecho windstorm caused power outages throughout the state and the planning district and resulted in several heat-related deaths.

This historical frequency, combined with Virginia's 42nd-place ranking for electric reliability and the region's aging infrastructure (with significant portions of electrical grid, water, and wastewater systems exceeding their expected operational lifespan), indicates a high probability of future utility outages. The probability is increasing due to several factors: more frequent and intense severe weather events associated with climate change, continued aging of infrastructure components

without corresponding replacement investments, and growing strain on systems as rural areas experience development pressure. Weather-related outages represent the most common trigger, meaning the probability of utility outages closely tracks the probability of severe weather hazards addressed elsewhere in this plan.

IMPACT

Utility outages produce severe and wide-ranging impacts across the Central Shenandoah region, affecting vulnerable populations, critical economic sectors, and essential services. The region's significant elderly population, many of which may live independently with electrically dependent medical equipment such as oxygen concentrators, CPAP machines, and refrigerated medications, require emergency evacuation to healthcare facilities during prolonged outages, straining hospital capacity and emergency services. The June 2022 derecho's heat-related fatalities underscore the life-safety consequences during temperature extremes.

The agricultural sector faces particularly severe economic impacts. Dairy operations requiring constant refrigeration and milking equipment can lose tens of thousands of dollars in a single day from spoiled products and distressed livestock. Poultry operations dependent on climate control systems can lose entire flocks worth hundreds of thousands of dollars within hours during extreme temperatures. A widespread multi-day outage could produce millions of dollars in direct agricultural losses, with cascading effects on processing facilities, distributors, and related businesses.

Rural residents face compounding challenges as most rely on electric well pumps and septic systems, meaning power outages simultaneously eliminate water and sanitation services. Unlike urban areas, the region's rural geography limits access to cooling or warming centers, leaving isolated residents vulnerable to temperature-related emergencies. The mountainous terrain significantly slows restoration efforts as repair crews face challenging access and longer travel times, extending outages beyond what similar events would require in flatter areas.

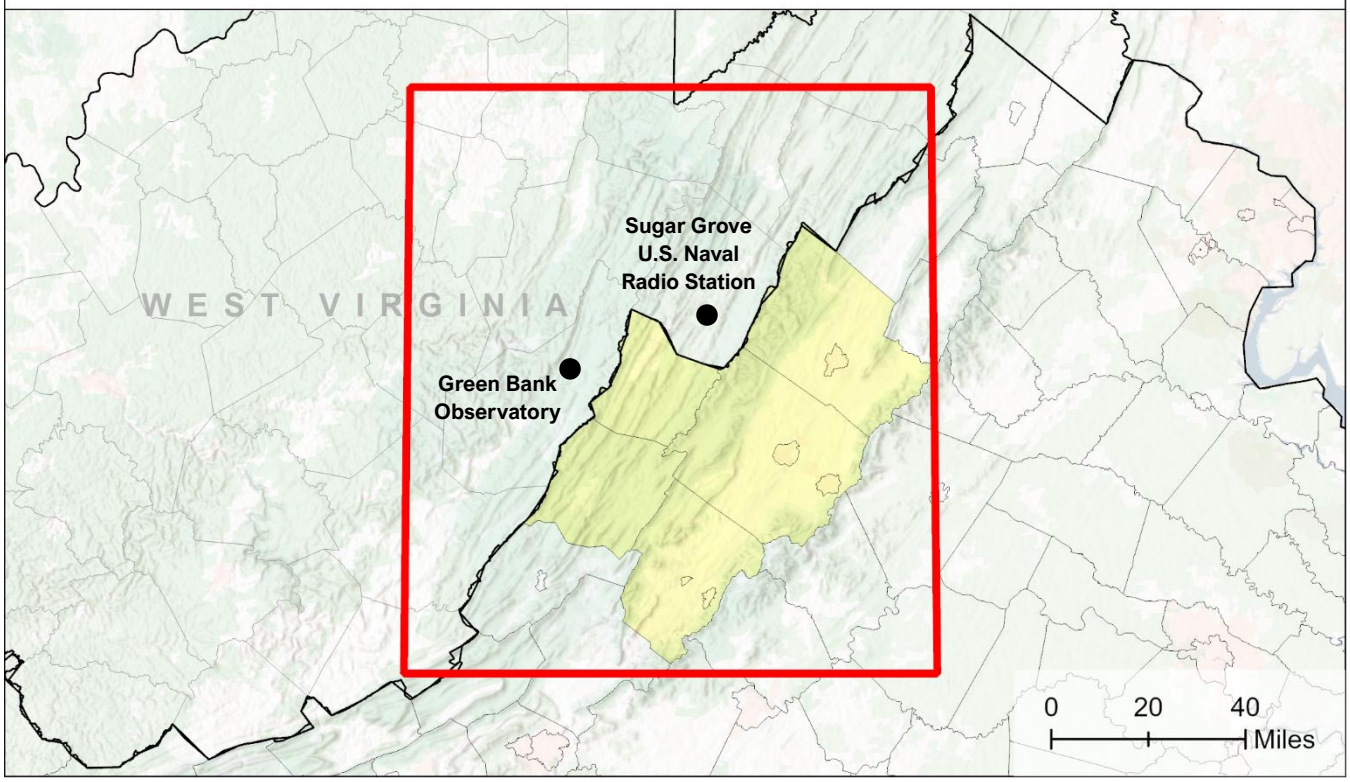
Beyond agriculture, retail establishments lose perishable inventory and transaction capabilities, manufacturing facilities face production shutdowns and equipment damage, and the tourism economy suffers as hotels, restaurants, and attractions cannot serve visitors. When outages affect multiple jurisdictions simultaneously—as occurred in all recent major events—mutual aid resources become severely strained. Economic losses can reach millions of dollars per day during widespread outages, with recovery extending for weeks as businesses rebuild inventory and attempt to recapture lost revenue.

COMMUNICATION SYSTEM INTERFERENCE

The region is within the National Radio Quiet Zone (NRQZ), as shown in Map 4.11.1. The NRQZ was established in 1958 by the Federal Communications Commission (FCC) and the Interdepartment Radio Advisory Committee (IRAC) to minimize possible harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ is bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d 29m 59.2s

W and latitudes of 37d 30m 0.4s N and 39d 15m 0.4s N and encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia (Green Bank Observatory, n.d.).

Map 4.11.1. National Radio Quiet Zone



Source: U.S. National Science Foundation (n.d.)

Being within the National Radio Quiet Zone presents significant challenges, limiting the availability of radio frequencies for emergency responders, healthcare facilities, and police departments. This restriction hampers regional emergency response capabilities, especially in Bath and Highland counties, where localities face unique difficulties in coordinating communication across county and state borders.

PROBABILITY

Unlike episodic hazards that may or may not occur, communication system interference from NRQZ restrictions represents an ongoing and constant vulnerability affecting the region every day. This is not a future probability to assess, but rather a persistent condition that continuously compromises emergency response capabilities and public safety communications. The restrictions are regulatory requirements that will remain in effect indefinitely, meaning the communication limitations are permanent features of the operating environment in affected jurisdictions.

IMPACT

The NRQZ restrictions create severe and unique impacts for emergency response operations, particularly in Bath and Highland counties. Emergency responders must coordinate across vast

geographic areas (Bath County's 540 square miles and Highland County's 416 square miles) with only a fraction of the radio spectrum available to similar rural counties outside the NRQZ. This results in measurably longer response times due to challenges with interagency communication, mutual aid coordination, and maintaining contact across mountainous terrain that already complicates radio transmission.

Healthcare facilities face critical operational constraints since hospital-to-hospital communication, medical helicopter coordination, and ambulance-to-emergency department coordination all depend on reliable radio communications. During mass casualty incidents or regional emergencies requiring coordination across multiple facilities and jurisdictions, these limitations could directly impact patient outcomes and survival rates.

The NRQZ restrictions compound the impacts of other hazards. When telecommunication networks fail during severe weather, areas outside the NRQZ can fall back on radio frequency alternatives, but the region's localities lack these redundant pathways. A telecommunication outage in the NRQZ therefore creates far more severe public safety impacts than the same outage in unrestricted areas, placing the region at disproportionate risk during multi-hazard events.

Mutual aid coordination becomes significantly more complex within the NRQZ. When Bath or Highland counties require assistance from neighboring jurisdictions or state resources during large-scale emergencies, coordinating response across county and state borders requires interoperable communications that NRQZ restrictions complicate, slowing response during time-critical emergencies.

DAM FAILURE

Dams in the region serve several functions including managing floods and stormwater, supplying water, enabling recreational use, supporting agriculture, and generating hydroelectric power. They can be privately owned; owned by local, state, or federal agencies; or owned by political subdivisions of the state such as Soil and Water Conservation Districts (SWCD). The Virginia Soil and Water Conservation Board (VSWCB) is the main regulatory authority for dams in the Commonwealth.

To collect information on dams in the region, the CSPDC contacted the Regional Dam Safety Engineer at the Virginia Department of Conservation and Recreation (DCR) and the four soil and water conservation districts in the region, including: Shenandoah Valley SWCD, Headwaters SWCD, Natural Bridge SWCD, and Mountain SWCD. The districts commonly referred staff to the National Inventory of Dams (NID) and the Virginia Dam Safety Inventory (DSIS), maintained by DCR. According to DSIS, there are nearly 90 documented dams in the region. This number, however, is limited to what DCR tracks. Future updates to this plan should involve additional stakeholder outreach to ensure the plan has the best available data.

All dams in Virginia are subject to the Dam Safety Act and Dam Safety Regulations unless specifically excluded. According to DCR, a dam is excluded if it:

- is less than six feet high;
- has a maximum capacity of less than 50 acre-feet and is less than 25 feet in height;

- has a maximum capacity of less than 15 acre-feet and is more than 25 feet in height;
- is operated primarily for agricultural purposes and has a maximum capacity of less than 100 acre-feet or is less than 25 feet in height (may be subject to regulation if the use or ownership changes);
- is owned or licensed by the federal government;
- is operated for mining purposes under 45.1-222 or 45.1-225.1 of the Code of Virginia; and/or
- is an obstruction in a canal used to raise or lower water levels.

DCR classifies dams into 3 categories based on the hazards that they present: high, significant, and low. Classification is based on a determination of the effects that a dam failure would likely have on people and property in the downstream inundation zone. Safety standards become increasingly more stringent as the potential for adverse impact increases. Classification, however, is not static.

Table 4.11.2. Dam Hazard Potential Classifications

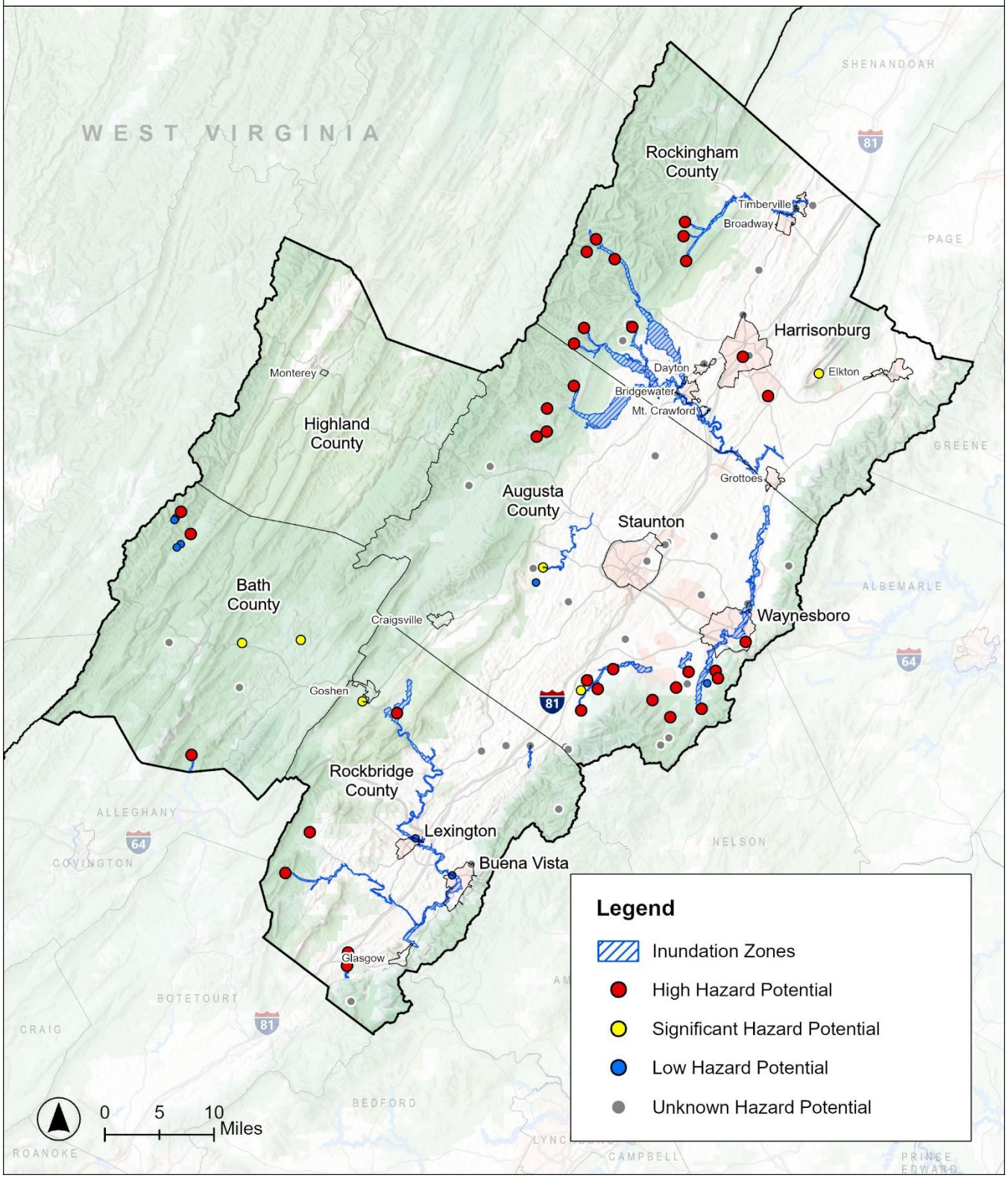
	High	Dams that upon failure would cause probable loss of life or serious economic damage. High Hazard-Potential Dams are required to be inspected by a professional engineer every two years.
	Significant	Dams that upon failure might cause loss of life or appreciable economic damage. Significant Hazard-Potential Dams are required to be inspected by a professional engineer every three years.
	Low	Dams that upon failure would lead to no expected loss of life or significant economic damage. This classification includes dams that upon failure would cause economic damage only to property of the dam owner. Low Hazard-Potential Dams are required to be inspected by a professional engineer every six years.

Data Source(s): Virginia Department of Conservation and Recreation, 2022

The inventory of dams in the region and their hazard potential is shown in Map 4.11.2 and Table 4.11.3. According to this inventory, there are 71 regulated dams. 38 dams have a high hazard potential, and 6 dams have a significant hazard potential. This results in 60% of total regulated dams in the region with a high or significant hazard status.

Map 4.11.2 also shows the existing data on inundation zones, or areas downstream of a dam that would flood if the event of dam failure. Importantly, this information is incomplete for the region. As this information becomes available, it is updated in DSIS and is publicly viewable in the Virginia Dam Safety Map application hosted by DCR. The existing inundation zone data for the region shows the cities of Waynesboro, Lexington, and Buena Vista are downstream of High Hazard Potential Dams (HHPDs). Similarly, areas in western Rockingham County are in inundation zones, particularly areas west of the towns of Dayton, Bridgewater, and Mount Crawford.

Map 4.11.2. Dam Hazard Potential and Dam Inundation Areas



Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Table 4.11.3. CSPDC Dam Inventory and Hazard Potential					
	Dam Name	**Ownership Type**	**Regulation Status**	**Hazard Potential**	
Staunton-Augusta-Waynesboro	Anders Pond Dam (Settling Pond)		Non-Regulated	Unknown	
	Braley Dam		Regulated	Unknown	
	Camp Shenandoah Dam	Private	Regulated	Low	
	Coiner Mill Dam		Non-Regulated	Unknown	
	Coles Run Dam	Local Gov.	Regulated	High	
	Damtown Dam (Krulick Dam)		Non-Regulated	Unknown	
	Elizabeth Hearn Dam	Private	Regulated	Unknown	
	Fauber Dam	Private	Regulated	Unknown	
	Grove Mill Dam		Non-Regulated	Unknown	
	Lower Wallace Dam	Private	Regulated	Unknown	
	Massey Pond Dam	Local Gov.	Non-Regulated	Unknown	
	Mill Place Commerce Park BMP #4	Local Gov.	Non-Regulated	Unknown	
	Morris Glen Dam	Private	Regulated	Unknown	
	Raymax Dam	Private	Regulated	Unknown	
	Scottland Land Dam	Private	Regulated	Unknown	
	Sherando Dam	Private	Regulated	Unknown	
	Smith Dam	Private	Regulated	Unknown	
	Smithleigh Dam	Private	Regulated	Significant	
	South River Dam #10A (Mills Creek)	Local Gov.	Regulated	High	
	South River Dam #11 (Canada Run)	SWCD	Regulated	High	
	South River Dam #19 (Waynesboro Nursery)	SWCD	Regulated	High	
	South River Dam #23 (Robinson Hollow)	SWCD	Regulated	High	
	South River Dam #24 (Happy Hollow)	SWCD	Regulated	Low	
	South River Dam #25 (Toms Branch)	SWCD	Regulated	High	
	South River Dam #26 (Inch Branch)	SWCD	Regulated	High	
	South River Dam #27 (Upper Sherando)	Federal	Regulated	Unknown	
	South River Dam #3 (Poor Creek/Cold Springs)	State	Regulated	Significant	
	South River Dam #4 (Lofton Lake)	SWCD	Regulated	High	
	South River Dam #6 (Sengers Mountain Lake)	SWCD	Regulated	High	
	South River Dam #7 (Wilda)	SWCD	Regulated	High	
	South River Dam #8A (Jones Hollow)	Local Gov.	Regulated	High	
	Staunton Dam	Local Gov.	Regulated	High	
	Staunton City Dam #1	Private	Regulated	Unknown	

	Sugarloaf Farm Dam	Private	Regulated	Unknown	
	Upper North River #76 (Elkhorn Lake)	Local Gov.	Regulated	High	
	Upper North River #77 (Hearthstone Lake Dam)	SWCD	Regulated	High	
	Upper North River Dam #10 (Todd Lake)	SWCD	Regulated	High	
	Upper Wallace Dam	Private	Regulated	High	
	Wood Dam	Private	Regulated	Unknown	
Bath-Highland	Bath Alum Farm Dam	Private	Regulated	Significant	
	Bath Co. Pumped Storage – Lower Dam	Public Utility	Regulated	High	
	Bath Co. Pumped Storage – Lower Recreation Pond	Public Utility	Regulated	High	
	Bath Co. Pumped Storage – Lower Sediment Dam	Public Utility	Regulated	Low	
	Bath Co. Pumped Storage – Middle Sediment Dam	Public Utility	Regulated	Low	
	Bath Co. Pumped Storage – Upper Dam	Public Utility	Regulated	Low	
	Bath Co. Pumped Storage – Upper Recreation Pond	Public Utility	Regulated	Low	
	Bear Loop Hunt Club Dam	Private	Regulated	Unknown	
	Douthat Lake Dam	State	Regulated	High	
	John Lawrence Dam	Private	Regulated	Significant	
	Lake Bacova Dam	Private	Regulated	Unknown	
Harrisonburg-Rockingham	Broadway Town Dam	Local Gov.	Regulated	Unknown	
	JMU Amphitheatre Dam	State	Regulated	Unknown	
	Johnson Dam	Private	Non-Regulated	Unknown	
	Knoll Meadow Dam	Private	Regulated	Unknown	
	Lake Shenandoah Dam	State	Regulated	High	
	Lake Terrace Dam	Private	Non-Regulated	Unknown	
	Lower North River #22B (Dry Run Dam)	SWCD	Regulated	High	
	Lower North River #78 (Briery Branch Dam)	SWCD	Regulated	High	
	Lower North River #80 (Union Springs Dam)	SWCD	Regulated	High	
	Lower North River #81C (Switzer Dam)	State	Regulated	High	
	Lower North River #82 (Dry River Dam)	SWCD	Regulated	High	
	Lower North River #83 (Hone Quarry Dam)	SWCD	Regulated	High	
	Massanutten Dam (Painter's Pond)	Private	Regulated	Significant	
	Newman Lake Dam	State	Regulated	High	
	North Fork Shenandoah River Dam #2	Private	Regulated	Unknown	
	Old Mill Dam	Private	Non-Regulated	Unknown	
	Shoemaker River #1A (Northwoods Lake)	SWCD	Regulated	High	
	Shoemaker River #3B (Hog Pen Dam)	SWCD	Regulated	High	
	Shoemaker River #4C (Slate Lick)	SWCD	Regulated	High	

	Silver Lake Dam	Local Gov.	Non-Regulated	Unknown	
	Union Springs Rd. Dam	Unknown	Unknown	Unknown	
	Zimmerman Dam	Private	Non-Regulated	Unknown	
Lexington-Rockbridge-Buena Vista	Buena Vista City Dam		Non-Regulated	Unknown	
	Cave Mountain Dam		Regulated	Unknown	
	Cold Sulpher Springs Dam	Private	Regulated	Significant	
	Dr. Laurie Landeau Dam	Private	Non-Regulated	Unknown	
	Goshen Dam (Lake Merriweather)	Private	Regulated	High	
	Holbrook Farm Dam	Private	Non-Regulated	Unknown	
	Jordans Point Dam	Local Gov.	Regulated	Low	
	Lake Robertson Dam	State	Regulated	High	
	Moomaws Dam	Private	Regulated	Low	
	Moores Creek Dam (Lexington Reservoir)	Local Gov.	Regulated	High	
	Natural Bridge Dam #1	Private, State	Non-Regulated	Unknown	
	Natural Bridge Dam #2	Private, State	Non-Regulated	Unknown	
	Natural Bridge Dam #3 (Turner Pond Dam)	State	Regulated	High	
	Natural Bridge Dam #4	Private, State	Non-Regulated	Unknown	
	Natural Bridge Dam #5	State	Regulated	High	
	Rockbridge County Dam	Private	Regulated	Unknown	
	Willow Lake Dam (Koogler Dam)	Private	Regulated	Unknown	

Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Dams can fail for numerous reasons related to their construction material, age, and external conditions. Common failure mechanisms include seepage and piping, overtopping, structural deformation, liquefaction, concrete degradation, neglected maintenance, outdated designs, hydraulically inadequate spillways, and damage from vandalism, cyber-attacks, or terrorism (DCR, n.d.). When dam failures occur or appear imminent, Emergency Action Plans (EAPs) are activated. The Virginia Dam Safety Act requires these plans for all dams except those meeting specific exclusion criteria.

Severe weather events represent the most common pathway to dam failure in the region. Extreme precipitation, particularly from tropical systems, atmospheric rivers, or severe thunderstorm complexes, can rapidly overwhelm spillway capacity and cause overtopping, the leading cause of dam failures nationally. Multiple days of heavy rainfall that saturate watersheds can generate runoff volumes exceeding the design specifications of dams built 50+ years ago under different climate conditions and hydrological assumptions.

The region's vulnerability to both drought and flooding creates especially dangerous conditions for dam integrity. Extended droughts produce several compounding effects: reservoir drawdown exposes dam faces to differential drying and cracking, soil consolidation around foundations creates new seepage pathways, and vegetation die-off on earthen dams reduces the stabilizing root systems that help secure embankments.

When droughts end abruptly with intense precipitation, dams face rapid refilling that can exploit weaknesses developed during the dry period.

VULNERABILITY

Predicting the region's vulnerability to dam failures is extremely challenging due to the variety of contributing factors, including structural age, location, and maintenance history. A well-maintained dam classified as a High Hazard structure may pose little risk to downstream community. However, the risk of failure typically increases with age, as many dams were designed for a 50-year operational lifespan. Table 4.11.4 shows the number of High Hazard Potential Dams (HHPDs) in the region by construction period. More than 80% of the region's HHPDs were constructed at least 50 years ago.

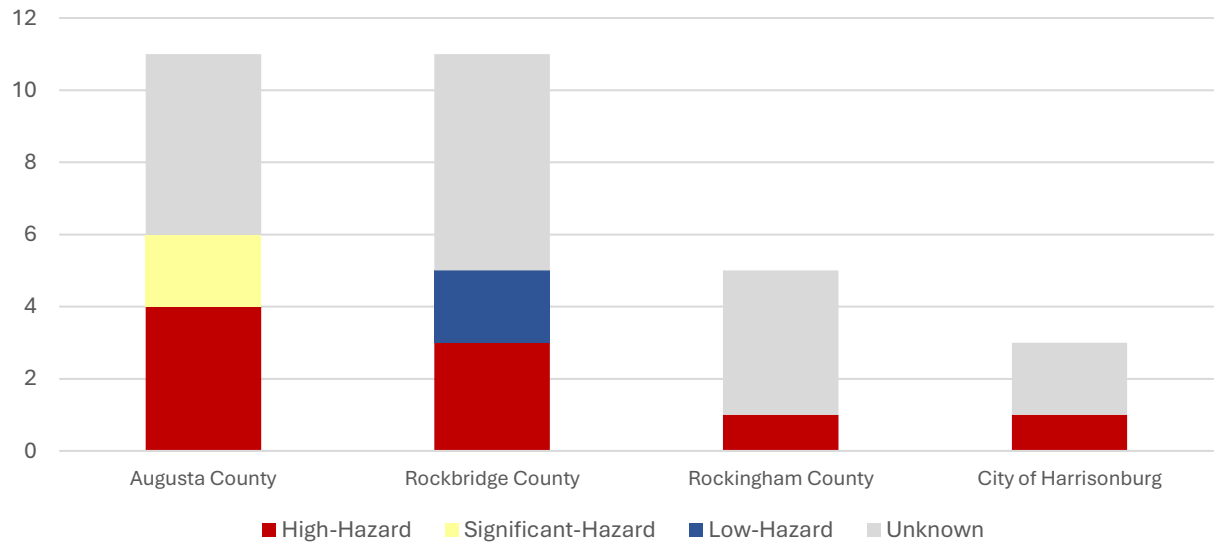
Table 4.11.4. Number of High Hazard Potential Dams by Construction Period

1900-1919	1920-1939	1940-1959	1960-1979	1980-1999	2000-Present
2	3	11	15	7	0

Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Furthermore, a significant amount of the region features karst topography, which is prone to dissolution and sinkhole formation. Like other infrastructure in the area (e.g., roads and bridges), dams are vulnerable to unpredictable sinkhole events. The water impoundment at dam sites compounds this risk by adding weight that presses on the underlying geology, potentially accelerating karstification processes. This concern became reality in 2024 when the City of Lexington discovered that seepage from Moores Creek Dam had caused a sinkhole to form at the dam's base (Haney, 2025). In the Sinkhole hazard profile, Table 4.6.5 details the dams over bedrock susceptible to karst formation. Chart 4.11.1 summarizes that table.

Chart 4.11.1. Number of Dams over Carbonate Bedrock



PROBABILITY

According to a DCR report, 18 dam incidents and failures occurred in Virginia over a 13-month period in 2018. While the Central Shenandoah region does not have a history of dam failure events, the probability of high hazard potential dam failure in the region is a growing concern. More than 80% of the region's high hazard potential dams were constructed at least 50 years ago, meaning many have reached or exceeded their design lifespan. The region faces compounding vulnerabilities from increasingly frequent and intense severe weather events due to climate change, aging infrastructure without corresponding replacement investments, and unique geological risks from karst topography that can accelerate structural deterioration through sinkhole formation. Additionally, the cycle of extended droughts followed by intense precipitation creates particularly dangerous conditions, as droughts weaken dam structures through drying, cracking, and vegetation loss, while subsequent heavy rainfall rapidly refills reservoirs and exploits these newly developed vulnerabilities. While well-maintained dams may pose minimal immediate risk, the combination of structural age, climate-driven weather extremes, and challenging geology suggests the probability of dam failures is increasing and requires sustained investment.

IMPACT

FEMA's Resilience Analysis and Planning Tool (RAPT) estimates that 146,409 people in the region live within 5 miles of a High-Hazard Potential Dam (HHPD). Table 4.11.5 details this for Counties/Cities.

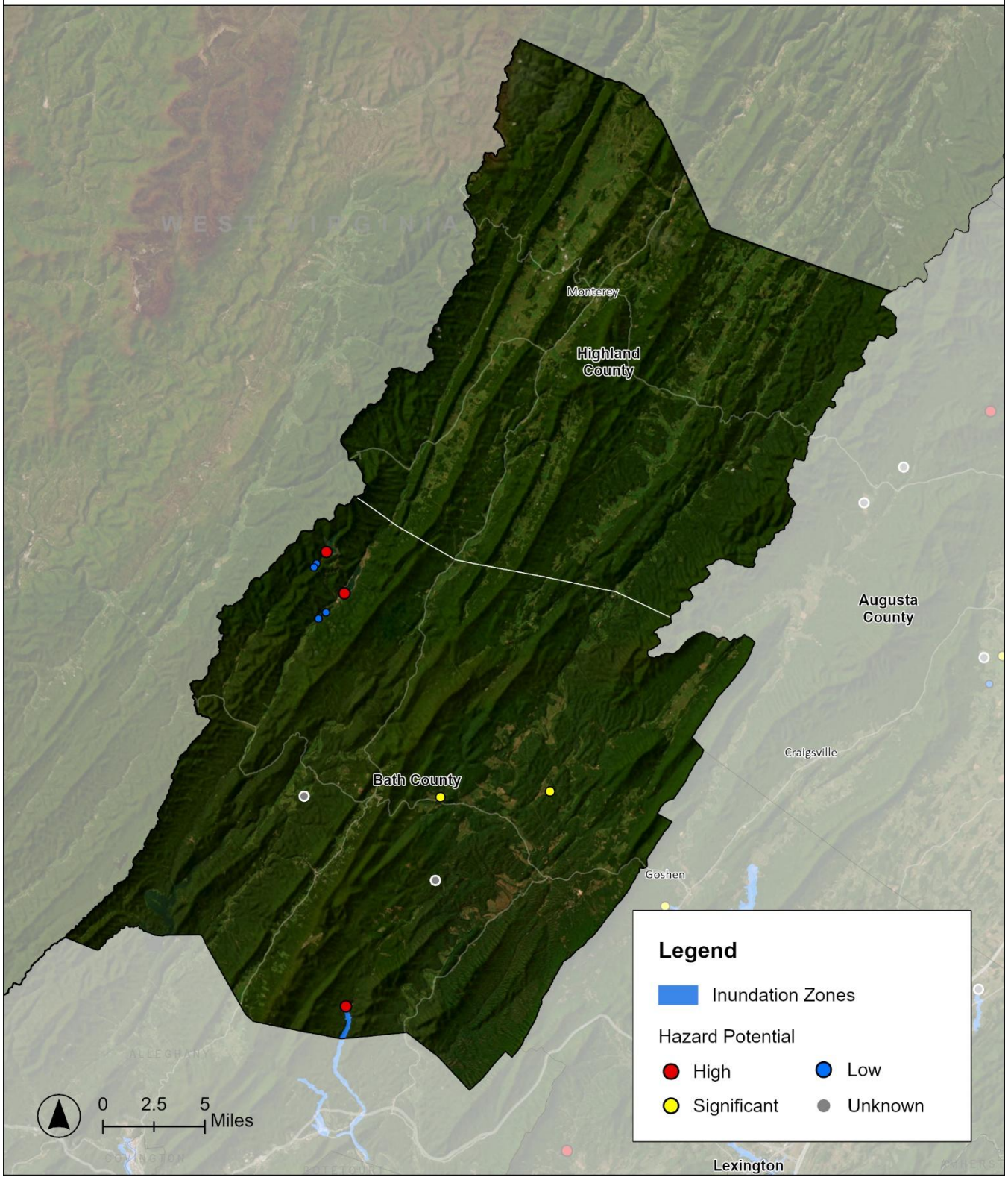
Table 4.11.5. Estimated Population within 5 Miles of HHPDs

Augusta County	29,628	City of Buena Vista	0
Bath County	828	City of Harrisonburg	45,060
Highland County	37	City of Lexington	0
Rockbridge County	7,153	City of Staunton	0
Rockingham County	41,129	City of Waynesboro	22,574

Data Source(s): FEMA Resilience Analysis and Planning Tool (RAPT), 2025

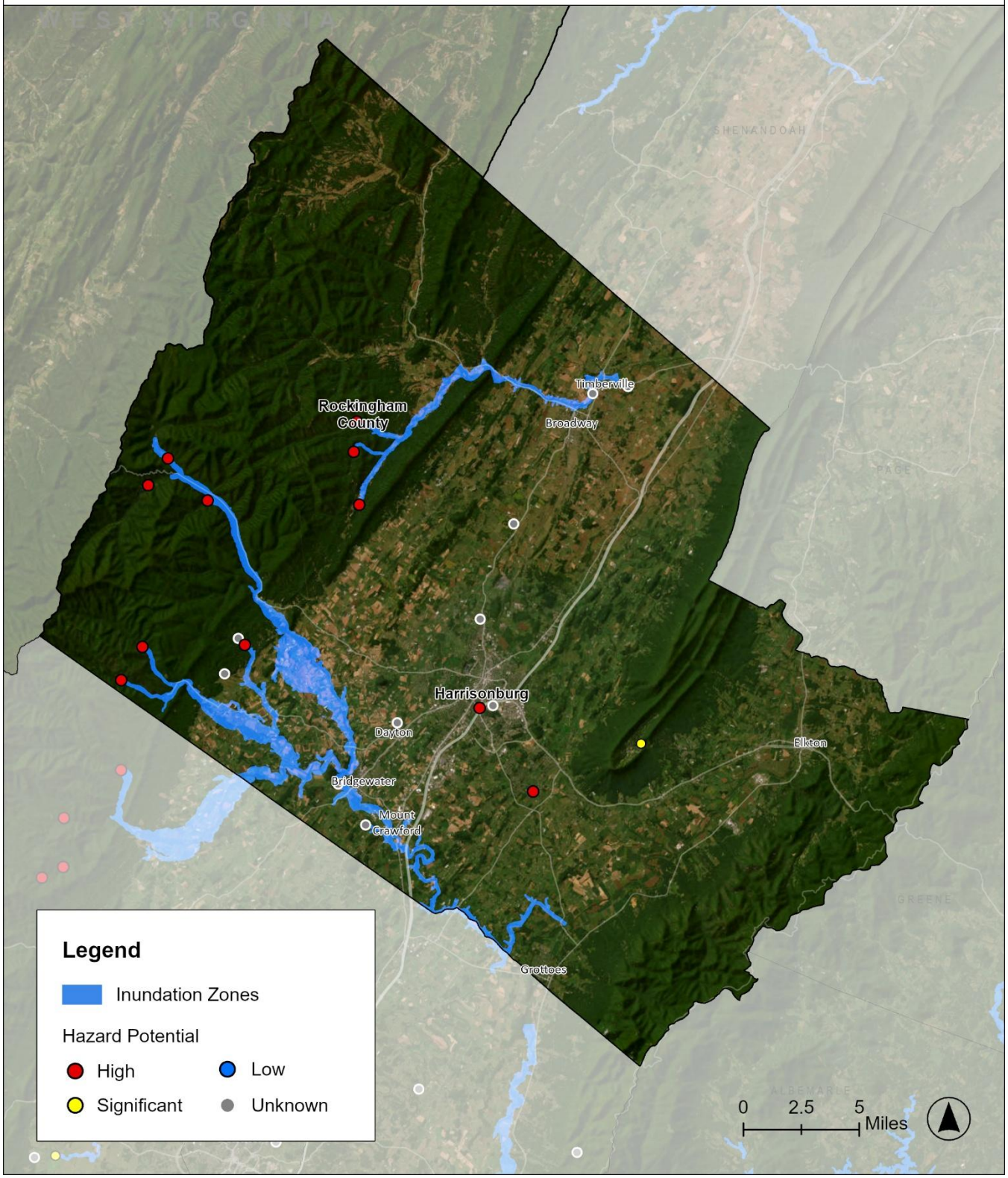
Dam inundation zones, however, often extend beyond 5 miles of a dam. In fact, portions of Buena Vista and Lexington fall within known inundation zones, meaning these cities do have at-risk populations despite showing zero in the 5-mile proximity data. Using DCR inundation zone data (Maps 4.11.3 - 4.11.6), RAPT estimates 8,280 people live within mapped flood inundation zones. This underestimates actual risk because inundation zones have been digitized for only a few dams across the region. Additional data on the potential impact of dam incidents comes from Dam Safety Data Sheets and Emergency Action Plan (EAP) Quick Summaries from DSIS (see Appendix F). Table 4.11.6 summarizes the number of structures and roadways at risk from identified HHPDs in the region. Data was not readily available for some EAP Quick Summaries. Future plan updates should include a comprehensive review and incorporation of newly available data.

Map 4.11.3. Bath-Highland
Existing Dam & Inundation Zone Data



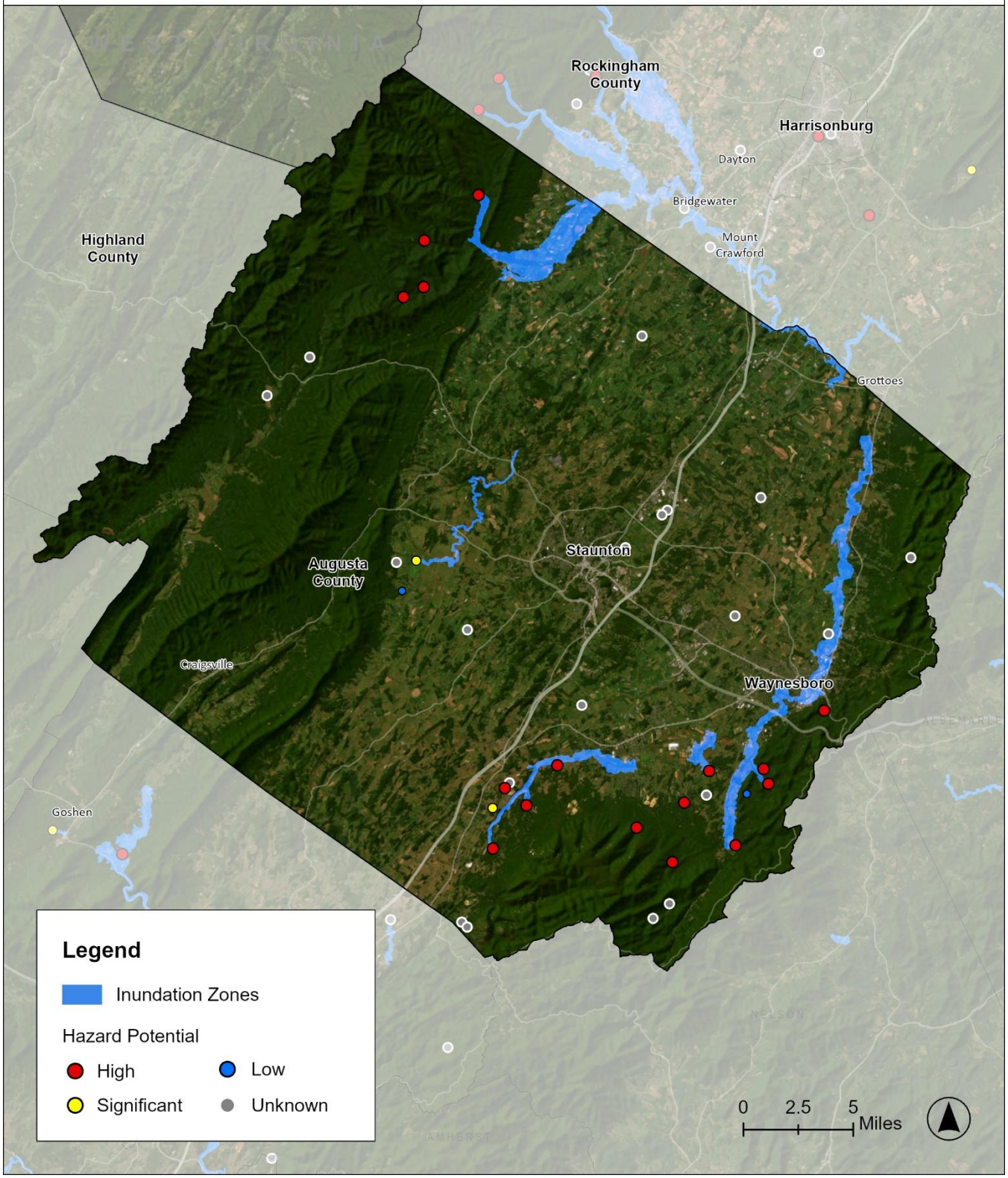
Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Map 4.11.4. Harrisonburg-Rockingham
Existing Dam & Inundation Zone Data



Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

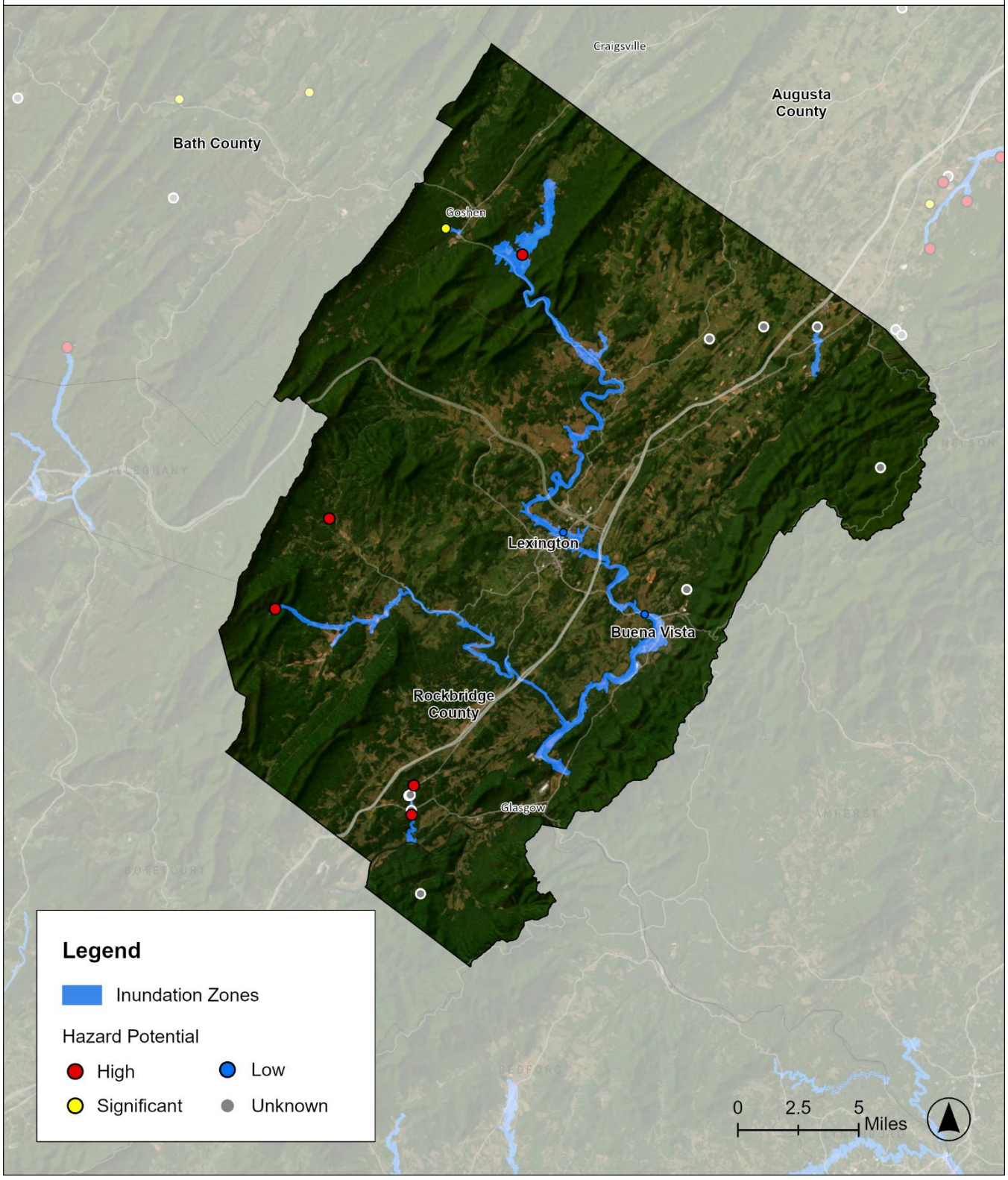
Map 4.11.5. Staunton-Augusta-Waynesboro
Existing Dam & Inundation Zone Data



Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Map 4.11.6. Lexington-Rockbridge-Buena Vista

Existing Dam & Inundation Zone Data



Data Source(s): DCR Virginia Dam Safety Inventory System (DSIS), 2024

Table 4.11.6. Potential Impact of High Hazard Potential Dam (HHPD) Failures											
Area	**HHPD Name**	Homes	Businesses	Schools	Hospitals	Infrastructure	Railroads	Utilities	Parks	Golf Courses	Roadways
Staunton-Augusta-Waynesboro	Coles Run Dam	202	5	0	0	0	0	0	0	0	3
	Elizabeth Hearn Dam	-	-	-	-	-	-	-	-	-	-
	South River Dam #1	35	-	-	-	-	-	-	-	-	3
	South River Dam #4	21	2	0	0	0	5	1	0	0	4
	South River Dam #6	21	1	0	0	0	2	0	0	0	7
	South River Dam #7	8	-	-	-	-	2	-	-	-	2
	South River Dam #8A	250	50	0	0	2	2	5	0	0	2
	South River Dam #10A	324	34	0	0	0	1	3	1	0	2
	South River Dam #19	5	2	0	0	0	2	0	0	0	3
	South River Dam #23	875	193	1	0	2	1	2	5	1	10
	South River Dam #25	46	-	-	-	-	-	-	-	-	2
	South River Dam #26	875	193	1	0	2	1	2	5	1	3
	Staunton Dam	0	0	0	0	0	0	0	1	0	1
	Upper North River Dam #10	-	-	-	-	-	-	-	-	-	2
	Upper North River #76	280	-	-	-	-	-	-	-	-	6
	Upper North River #77	270	15	-	-	-	-	-	-	-	2
	Upper Wallace Dam	35	5	0	0	0	1	0	0	0	3
Bath-Highland	Bath Co. Pumped Storage – Upper Dam	-	-	-	-	-	-	-	-	-	-
	Bath Co. Pumped Storage – Lower Dam	-	-	-	-	-	-	-	-	-	-
	Douthat Lake Dam	564	27	0	0	2	1	1	1	1	3
	Gathright Dam	-	-	-	-	-	-	-	-	-	-
Harrisonburg-Rockingham	Newman Lake Dam	48	0	0	0	0	0	0	1	0	1
	Lake Shenandoah Dam	4	0	0	0	0	0	0	0	0	7
	Lower North River #22B	-	-	-	-	-	-	-	-	-	-
	Lower North River #78	0	0	0	0	0	0	0	0	0	5
	Lower North River #80	200	-	-	-	-	-	-	-	-	4
	Lower North River #81C	-	-	-	-	-	-	-	-	-	3
	Lower North River #82	-	-	-	-	-	-	-	-	-	-
	Lower North River #83	300	-	-	-	-	-	-	-	-	10
	Shoemaker River #1A	-	-	-	-	-	-	-	-	-	-
	Shoemaker River #3B	-	-	-	-	-	-	-	-	-	-
	Shoemaker River #4C	-	-	-	-	-	-	-	-	-	-
LEX-Rockbridge-BV	Goshen Dam	752	86	0	0	12	1	0	0	0	-
	Moores Creek Dam	57	0	0	0	0	0	0	0	0	17
	Natural Bridge Dam #5	-	-	-	-	-	-	-	-	-	-
	Robertson Dam	68	0	1	0	0	0	0	0	0	13
	Tuner Pond Dam	12	5	0	0	0	0	0	0	0	3
	Willow Lake Dam	7	0	0	0	0	0	0	0	0	3

Note: (-) indicates that data was not available in the DSIS Summary Report for the dam.



THREAT PROFILE 12

ACTIVE ASSAILANT

DEFINITION

A physical assault, by 1 or more individuals, with the intent of inflicting serious harm and/or deadly force on others in a confined and/or populated area.

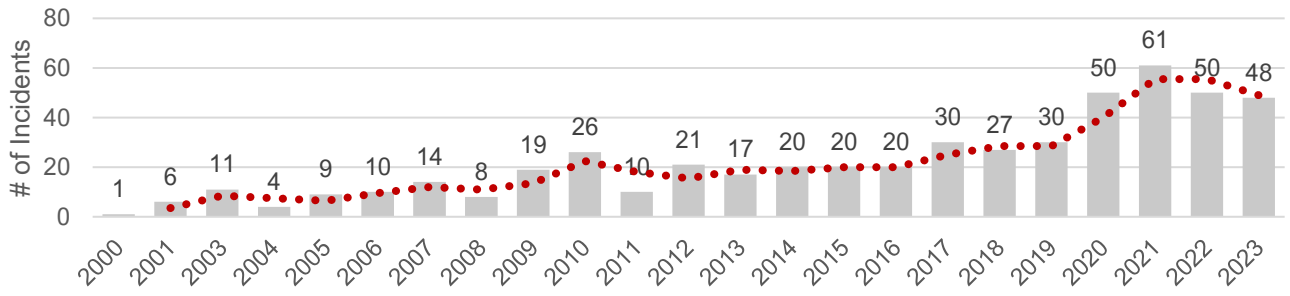
BACKGROUND

Active assailant incidents can have a range of secondary effects in the immediate and long-term aftermath, which can worsen the emergency and result in additional injuries and fatalities. Beyond the potential of a mass casualty event, these incidents can also lead to crowd disturbances, strain on healthcare facilities with limited resources, mental health challenges for both the community and first responders, as well as long-lasting impacts like higher rates of absenteeism in workplaces and schools.

SIGNIFICANT HISTORICAL EVENTS

In 2023 alone, the FBI designated 48 incidents as active shooter incidents, resulting in 244 casualties (105 killed, 139 wounded) in 26 different states (Advanced Law Enforcement Rapid Response Training, 2024). Although no shootings in Virginia in 2023 met the FBI's formal definition of an "active shooter incident," data trends shown in Chart 4.12.1. indicate an increase in these violent events since 2000.

Chart 4.12.1 Active Shooter Incidents Per Year in the United States, 2000-2023



Source: Federal Bureau of Investigation (n.d.)

While not as prevalent, other active assailant events such as vehicle ramming attacks and knife assaults have also increased in frequency in the U.S. These events can occur in a variety of locations, from open-space events such as concert venues to shopping malls, schools, and others. Specifically in the Commonwealth of Virginia, mass shooting and killing events have accounted for hundreds of deaths and many more injuries. The list below highlights some notable incidents, though it is not an exhaustive list.

- **April 16, 2006**: the deadliest mass shooting in U.S. history at the time, a lone assailant at Virginia Polytechnic Institute and State University (Blacksburg) killed 32 people and injured another 17 before committing suicide.
- **June 14, 2017**: at a Congressional baseball game in Alexandria, a shooter injures 6, including Congressman Steve Scalise.
- **August 12, 2017**: a lone driver deliberately drove his vehicle into a crowded, peaceful protest in Charlottesville, killing 1 and injuring 35 others.
- **May 31, 2019**: a city employee killed 12 and injured 4 in Virginia Beach.
- **February 1, 2022**: a shooter on the campus of Bridgewater College (Bridgewater) killed 2 law enforcement officers.
- **November 13, 2022**: a shooter opens fire on a bus at the University of Virginia (Charlottesville), killing 3 and injuring 2 others before being taken into custody by police.
- **November 22, 2022**: a Walmart employee kills 6 coworkers and injures 4 others before committing suicide in Chesapeake.
- **February 17, 2025**: In Crozet, a shooter opens fire in a Harris Teeter parking lot, killing 2 bystanders. An off-duty federal agent shot and killed the assailant, preventing additional crossfire.

In the U.S., active assailant incidents often involve a single type of weapon, such as a firearm. However, there are instances both within the U.S. and internationally where assailants employ a variety of tools and tactics, including both purchased and homemade explosives, to carry out their attacks.

DISASTER DECLARATIONS

There have been no instances of state/federally declared disasters resulting from an active assailant event.

AREAS OF IMPACT

While an active assailant incident can happen at any time within the planning area, only two incidents have occurred within the region, specifically in 2022 with one in Harrisonburg, resulting in 8 injuries, and another in Bridgewater, resulting in 2 deaths. Occurrences like these and others nationwide have significantly influenced preparedness efforts against acts of violence, leading to the development of comprehensive training programs for law enforcement, educational institutions, religious organizations, and other venues that host large events.

Given the serious nature of life safety and security concerns associated with active assailants, each jurisdiction's lead law enforcement agency is encouraged to collaborate with stakeholders in neighboring jurisdictions to prepare for, prevent, and mitigate any potential incidents related to this specific threat. For

security purposes, vulnerability analyses and specific impacted areas within the planning district will not be detailed in this report but can be addressed directly with local authorities.

ESTIMATED LOSSES

Although it is difficult to estimate monetary losses that stem from an active assailant event, "various factors can influence the impact on the organization. Those factors include the scale of the incident, the number of casualties, the response time, and post-incident recovery efforts. Therefore, the greatest indicator for predicting an incident's impact on an organization is having a comprehensive workplace violence prevention program, including pre-incident planning," (Center for Personal Protection and Safety, 2024). The Center for Personal Protection and Safety (CPPS) considers the following:

- **Human cost:** an incident's most devastating cost is the loss of human life, and the physical and emotional harm inflicted upon survivors.
- **Legal and liability expenses:** potential legal consequences from victims, their families, and others who may have been present during the incident.
- **Business disruptions:** temporary or permanent business closings, loss in productivity and/or revenue, potential lost business opportunities, etc.
- **Increased costs for enhanced security:** investments in security measures, preparedness programs, and others to reassure employees and stakeholders of their safety and wellbeing.

Estimated losses are specific to each event and community, as referenced by CPPS above. It is difficult to quantify; however, the losses are often long-term and difficult to overcome.

PROBABILITY OF FUTURE OCCURENCES

The probability of active assailant incidents occurring in the Central Shenandoah region is assessed as low but increasing, consistent with national trends showing a steady rise in such events since 2000. While only two incidents have occurred within the planning area—both in 2022 in Harrisonburg and Bridgewater—the FBI's identification of 48 active shooter incidents nationwide in 2023 alone demonstrates these events are becoming more frequent across the United States.

VULNERABILITY

The Central Shenandoah region's vulnerability to active assailant incidents varies significantly across community settings based on physical characteristics and emergency response capacity. Educational institutions, particularly James Madison University with over 20,000 students and numerous K-12 schools, represent high-risk targets. Rural areas face heightened vulnerability due to longer emergency response times and distances to the nearest Level I or Level II trauma centers, potentially impacting victim survival rates. Numerous soft targets (retail centers, houses of worship, civic events, and tourist destinations) present challenges for prevention and rapid response. The greatest vulnerabilities exist in areas with limited communication infrastructure and during large public gatherings where crowd management and evacuation are critical.