Assessing the Vulnerability of Park System Infrastructure to Impacts from Extreme Weather Events: A Tennessee Application

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To my husband, Dustin; to my parents, Mark and Susan Abkowitz; and to my siblings, Alyssa Cendrowski and Jason Abkowitz

and

To my grandparents, Martin and Davette Abkowitz and Donald and Anne Bergstresser.

Thank you for always believing in me and for providing me with the support and encouragement to continue growing and learning.

I would not have been able to do this without you.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure	Page

Figure **Page**

CHAPTER 1

"Continued emission of greenhouse gases will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems."

—Fifth Assessment Synthesis Report, Intergovernmental Panel on Climate Change

Introduction

According to current Intergovernmental Panel on Climate Change (IPCC) research, recent changes in the earth's climate have resulted in significant and prevalent impacts on human and natural systems (Pachauri, et al., 2014). Such climate change can result in alterations to the frequency, intensity, duration and timing of weather events at specific geographic locations. Characteristics such as temperature, precipitation, sea-level and wind are typically affected, which can spawn extreme weather such as flooding, drought, hurricanes, tornadoes, and excessive heat and cold. In fact, the IPCC has indicated that changes in extreme weather and climate events, such as a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions, have been observed since the middle of the 20th Century (Pachauri, et al., 2014). While climate changes and associated impacts and severity of disruption are specific to geography, the shifting of patterns over time cannot go unnoticed and are not inconsequential.

The impact of extreme weather events regardless of their cause are particularly felt by sectors such as water, agriculture, food security, forestry, health, and tourism (Field, et al., 2012). One type of asset that falls into this domain is state park systems. In Tennessee, these properties are owned and managed by the Tennessee Department of Environment and Conservation (TDEC).

The Tennessee State Parks (TSP) system is comprised of 55 state parks which are visited by an estimated over 32 million people annually. Each park contains a network of operational assets, dining and lodging facilities, recreation activities, hiking trails, and more. Construction, operation, and maintenance of these assets are provided for by a combination of state taxpayer dollars and revenues generated from park services. Central to the park system's existence and attractiveness are Tennessee's abundant natural resources that offer recreational and outdoor opportunities. State park infrastructure has been developed around these important features to facilitate accessibility and enjoyment to visitors.

Tennessee has also experienced extreme weather events that have caused significant impact to a wide range of infrastructure systems, with the impacts incurred by state park assets being no exception. The resulting consequences extend beyond physical damage itself, as such events have involved loss of use, human casualties, and ecological disruption. Also at risk is the direct and indirect economic impact to state park profitability as well as local community tourism and fiscal health.

The TSP system currently has no standardized means for identifying the vulnerability of infrastructure and assets to risks in general, but more specifically, extreme weather events. A process for doing so will enable for more effective management of park system assets and more efficient utilization of public sector resources. Developing such a methodology will also provide a basis for the park system to assess its vulnerability and resilience to various other types of risk, such as financial or operational risk, that may impact individual assets, parks, or the entire park system.

A Spring 2014 review of literature associated with conducting extreme weather vulnerability assessments found that work to date largely addressed more general impacts of climate change (not specifically extreme weather), focused on other types of infrastructure, or concentrated on sea-level rise impacts to coastal areas. By contrast, the TSP system consists of an extensive physical infrastructure that occupies a land-locked region subject to a variety of extreme weather events. While much was learned from these existing climate change and extreme weather vulnerability assessments, in order to further understand potential extreme weather event impacts to Tennessee's or any other state park system infrastructure, a methodology specific to this type of setting is necessary to produce the most effective results. With this in mind, the goal of this dissertation research is to design a method for identifying TSP infrastructure and assets that are the most vulnerable to extreme weather events and apply this methodology to TSP infrastructure as proof-of-concept.

While Tennessee and the infrastructure and assets that are part of the TSP system are the reference point utilized for developing this methodology, the relevance of the concepts outlined in the ensuing discussion are applicable to park systems and public sector assets worldwide and can be adapted to other risk types. In this context, this methodology is meant to be a springboard for further investigation and knowledge exchange that can enhance comprehensive organizational planning to deal with potential impacts to assets of all types from extreme weather events.

This dissertation is organized as three separate but related manuscripts. Background information regarding extreme weather events, impacts, and the need for tools to understand the vulnerability of infrastructure to extreme weather events is incorporated throughout the dissertation. With this in mind, where possible, an attempt to minimize the redundancy of material between the three manuscripts has been made.

Chapter 2, the first manuscript, proposes and executes an approach for identifying which assets are critical to functionality and productive existence of state park system. The analysis performed for this manuscript resulted in identifying 271 critical assets out of more than 1,500 total assets. The second manuscript, Chapter 3, offers and implements a methodology for assessing impacts to particular categories of park system infrastructure from various extreme weather event types. This exercise resulted in impact scores for various park infrastructure type and weather event scenarios. Chapter 4, the final manuscript, proposes a methodology for assessing the vulnerability of particular park infrastructure assets based on location to extreme weather events utilizing historic and projected future extreme weather events. As part of Chapter 4, the methodology is employed using the 271 critical assets identified in the first manuscript. The final chapter, Chapter 5, provides a summary of research contributions from this work and identifies possible areas for additional research.

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CHAPTER 2

Defining Criticality[1] for Park System Infrastructure: A Tennessee Application

This chapter has been submitted for publication to the Journal of Park and Recreation Administration.

Introduction

The TSP system currently has no standardized means for characterizing assets in terms of their relative importance to a given park or to the park system as a whole. A process for doing so will enable TDEC to more effectively manage park system assets, while also utilizing public sector resources more efficiently, and further, will provide a basis for TSP to assess their vulnerability and resilience to various types of risk (e.g., financial, operational, natural hazards) that may impact individual assets, parks, or the entire park system.

The TSP system is an attractive candidate for employing this methodology due to the geographic dispersion of parks across the state and further variation with respect to infrastructure asset types, age, revenue generating ability, and historical or ecological significance. While the assets that are part of the TSP system are the reference point utilized for developing this methodology, the concepts embedded in the approach are relevant and may be applicable to park systems and other public sector assets elsewhere.

Defining Critical Infrastructure: State of the Practice

In exploring how critical infrastructure might be defined in a state park system, prior definitions for critical infrastructure were considered. While no existing approaches for assessing criticality of public park system infrastructure could be found, several important insights were gained from a review of the literature.

There does not appear to be an agreed-upon definition of what constitutes critical infrastructure, as it has been characterized in physical, utility, organizational, technological and/or business terms depending upon the system under consideration (Egan, 2007). The term infrastructure, itself, can be any system with characteristics of "capital intensiveness and high public investment at all levels of government" (Moteff, 2003). Given the various potential definitions of infrastructure, it is perhaps not surprising to learn that critical infrastructure has taken on similar situational interpretations.

While numerous studies have provided examples of systems that might be considered critical, a formal definition of critical infrastructure is typically lacking (Egan, 2007). However, following the September 11 terrorist attacks and formation of the Department of Homeland Security, critical infrastructure has been

[1] What constitutes critical infrastructure is to some extent dependent upon the specific scope and environment under consideration. In this application, the term "critical" and all contexts in which it is used should be understood as components deemed essential to system functionality and the benefits derived from normal operations, specifically to a public state park system. The methodology included within presents an approach catered towards the TSP system and its values for determining criticality.

loosely defined as any structure at which an attack might cause substantial loss of life or significant societal disruption.

There are two temporal phases that are closely related to understanding an object's criticality: (1) normal operating characteristics and (2) characteristics in case of failure (Fekete, 2011). These characteristics fall into three broad categories: (1) proportion (e.g., capacity for preparedness; number of services; spatial extent or redundancies), (2) time (e.g., duration of outage; time for repair), and (3) quality (e.g., impacts to quality of service, product, or image; social significance). A comprehensive criticality assessment captures the effects of all three categories.

Some researchers have attempted to define critical infrastructure through process-oriented mechanisms, such as supply of routine functions, along operational paths essential for regular system function, with no readily available substitutes and dysfunction that causes serious harm, or entrenchment in integrated systems (Demchak, 2006). The field of facilities management has taken a similar approach to determining criticality, defining characteristics of business attributes deemed central to operations, such as: (1) mission impact, (2) safety and environmental impact, (3) ability to isolate single point failures, (4) preventative and corrective maintenance histories, (5) asset replacement value, and (6) utilization rate (Wikoff, 2014). Other considerations have included fatalities, repair costs, recuperation time, and environmental damage (McGill, 2007).

It is apparent from this review that what constitutes critical infrastructure is a subjective judgment based on the specific scope and environment under study. Most importantly, the criteria used to make that judgment must be defined such that they represent what is truly important to system functionality and the benefits derived from maintaining normal operations.

Accordingly, the methodology for determining park infrastructure criticality consists of a series of three sequential steps: (1) define asset types and develop asset categories, (2) establish asset criticality criteria, and (3) apply the criteria to the assets to identify those deemed as critical park infrastructure. The following discussion introduces the methodology as applied to the TSP system.

Developing a Tennessee State Parks Asset Inventory

Building an asset inventory for a park system requires a holistic and systematic process to ensure that no potentially critical asset is omitted from the inventory. An asset is defined as any facility, structure, or other park component deemed of value, regardless of its insured amount. Value could also refer to non-monetary worth that is received through a service or experience provided to an interested party.[2] This definition was intentionally aligned with key elements of several statutes that pertain to the establishment and operation of state parks in Tennessee State Law.[3]

Since the most comprehensive database of physical facilities within the state park system, is maintained by the Tennessee Department of Treasury, Division of Risk Management (DRM), it was selected as the

[2] Examples include preservation of natural and historic resources, recreational activities, lodging, dining, and local economic development.

[3] *Tennessee Code Annotated* § 11-3-101 and § 11-3-305.

basis for building the asset inventory. This database includes any insured asset owned by TDEC. As Tennessee's property insurance policy has a deductible of $25,000, it can be assumed that any item included in the database has a minimum value equal to that amount. Each asset contains information describing its approximate physical address, building square footage, year built, building value, contents value, and county location.

Additionally, certain types of park infrastructure are not included in this database, such as dams or utilities infrastructure, as well as other facilities that may not meet the monetary threshold or do not have a distinct monetary value for the purposes of being insured. It should also be noted that reporting accuracy relies on input from owning agencies and is dependent on the inventory updating schedule.

The State of Tennessee procures insurance policies annually through a competitive bidding process administered by its insurance broker. Aggregate deductibles[4] are maintained for various types of events, but in general, the State is not self-insured against any type of property-related loss. New construction is insured at actual construction contract costs, with insurance of building purchases based on real estate evaluation reports adjusted to fill gaps between market value and replacement value. Additions or value-added renovations to existing facilities require submission of T-100 Property Reports, autocad or perimeter drawings, and photos. Premiums are determined for each structure by multiplying building and contents values by insurance rates based on risk factors.[5] All agencies are required to review entire property schedules twice per year and report changes. Any changes in the status of insured properties are to be reported immediately to DRM so that they can be reflected in the insurance policy.

DRM claims to provide tools and resources for agencies to use in assessing building and content value for the purposes of the insurance database. However conversations with TSP facilities management indicate that despite multiple requests for access to assistance, DRM has not provided any guidelines or standards for conducting facilities assessments. Therefore, facilities management utilizes recent, scaled renovation or construction costs for similar facilities or applies an inflation rate to the building value as a means of estimating or updating building value information within the DRM database. This process occurs on an inconsistent basis between parks and facilities. Further, TSP facilities management indicates that there is no standard or process for updating building content information.

Shortly after learning of this database, it was discovered that the Tennessee Emergency Management Agency (TEMA), DRM, and the Office of Information Resources (OIR), had received grant funding to map, in a geographic information systems (GIS) format, all of the state's insured assets for the purpose of updating flood mapping records and disaster response procedures. With a total of over 1,500 insured assets located within the various state parks and due to the level of detail required for mapping assets,

[4] $5 million for earthquake and flood; $5 million for all other perils; buildings risk insurance requires a separate $2.5 million aggregate de3ductivle for earthquake and flood, and $1 million for all other perils.

[5] Risk factors include: location, occupancy, type of construction, sprinkler protection, fire protection classification, and exposure hazards.

staff intimately involved in the day-to-day operations at each park were asked to locate assets as part of this effort.[6]

To help fill information gaps in the DRM database, the TSP Facilities Management division was asked to identify items which may not be insured by the State of Tennessee but still deemed central to the operation of state parks, as well as those assets that may impact public safety within parks. This resulted in the inclusion of dams at each park as part of the asset inventory.

With the inventory assembled, an effort to identify general building use categories and specific building types ensued. This list is presented in Table 2.1; a more detailed description appears in Appendix A.

Building Types (from GIS Mapping Project)		
Administration	Golf cart shed	Recreation center
Amphitheater	Golf pro shop	Residence
Barn/pole barn	Historic structure	Restaurant/cafeteria
Bathhouse	Inn	Restrooms
Boat dock/dock	Lodge	Salt bin
Boat house	Maintenance	Shelter
Boat slips	Marina	Shop
Cabin/villa	Monument	Storage – heavy equipment
Classrooms	Museum	Storage – other
Concession/vending	Nature center	Store
Conference center	Office	Tower – radio/communications
Dam	Other	Training center
Dining hall	Physical plant	Treatment facility
Dorm/student housing	Platform	Warehouse
Fishing pier	Pool/pool house	Water control structure
Garage	Pump house	Welcome center/visitor center
Building Use Categories[7] (Added by TDEC)		
Dining	Other	Recreation
Lodging	Park Staff Residence	Retail
Operations	Public Health/Safety	

Table 2.1. Tennessee State Parks Building Types and Use Categories

Asset Criticality Criteria

In consultation with TSP Operations and Facilities Management, characteristics for state parks and particular assets were utilized to define criteria for determining asset criticality. Criteria selection focused on three considerations: (1) public safety, (2) financial stability, and (3) land preservation. These considerations were intentionally selected due to their alignment with the current mission and values espoused by State government (i.e., health and wellness of the citizens of Tennessee and visitors,

[6] As of when TDEC received inventory records from OIR's GIS project, the export contained incomplete records for Henry Horton State Park. Multiple requests to receive an updated version were requested, but not received within the timeline required for this research.
[7] In cases where a building could be categorized for more than one use, a combined category was assigned (e.g., Recreation/Retail).

financial efficiency, customer service/value to Tennesseans) and/or the park system (i.e., conservation and recreational opportunities financial solvency). Table 2.2 lists the characteristics and associated metrics that were used in determining criticality.

					Applicability	
Category	Characteristic	Definition	Data Source	Metric Type	Park-Level	Asset-Level
Financial	Park Revenue Generation	2-year average annual revenue generation at each park (mean of FY12/13 and FY14/15)	Park financial reports	Numeric	X	
Financial	Asset Revenue Generating Capability	The extent to which an individual asset is capable of generating significant revenue[8]	Park financial reports	Descriptive (Significant /Negligible)		X
Financial	Insured Structure Value	The insured monetary value assigned to a particular asset (or grouping of contiguous assets).	Risk management insurance database; only applicable to insured structures (typically those exceeding $25,000 in value)	Numeric		X
Financial	Insured Contents Value	The insured monetary value assigned to the contents of an asset (or grouping of contiguous assets).	Risk management insurance database; only applicable to insured structures (typically those exceeding $25,000 in value)	Numeric		X
Public Safety	Necessity to Park Functioning	A qualitative indicator of an asset's relation to the basic functioning of a park	Based on building use categories	Descriptive (High/ Medium/ Low/ Negligible)		X
Public Safety	Annual Visitation	FY13/14 Annual Visitation	Park visitation reports	Numeric	X	
Public Safety	Number of employees	FY13/14 full- and part-time staff employed at a particular park.	TDEC payroll reports	Numeric	X	
Land	Trail Miles	Number of accessible trail miles maintained within a given park's property.	Parks central office reports	Numeric	X	
Land	Number of rare species	Number of different rare species identified in each park.	Division of Natural Areas Custom Report	Numeric	X	
Land	Maintained Acreage	Total property acreage managed by a particular park.	Parks central office reports	Numeric	X	

Table 2.2. Characteristics for Determining Park Asset Criticality

[8] Assets capable of having significant revenue-generating ability (e.g., park inn or restaurant) were distinguished from those that do not have significant revenue-generating ability (e.g., shelter or park staff residence).

Public Safety Criteria

Protection of the individuals who visit and work in TSP is paramount and could have serious implications with respect to liabilities while on-site and the overall welfare and operation of the park system. Three criticality criteria were included to represent this consideration, all of which were applied at the park level.

1. Necessity to Park Functioning—Input from TSP Facilities Management and Operations indicated that certain structures are deemed necessary to the functioning of the park. The building use category assigned to each asset was used as a proxy measure. Any asset categorized as Public Health/Safety was assigned a High rating, those categorized as Operations or Park Staff Residence received a Medium rating, and the remaining assets (Retail, Dining, Lodging, Recreation, Other) were given a Low rating.
2. Annual Visitation—Park visitation is calculated on a monthly basis. "Drive-over" counters are located at park entrances, and tally the number of vehicles that enter and exit parks. For all parks in the system, park management calculates the number of visitors by taking the total drive-over count and dividing it in half as each car that enters the park must also exit the park. This car count is then multiplied by 3.2, to represent the average number of passengers per vehicle.[9] Parks that draw more visitors could be deemed more important to the overall park system; this metric also provides a basis for comparing the number of individuals that might be present within a given park should an extreme weather event occur. Annual visitations of each park were applied to each asset within the respective park.
3. Number of Employees—A report indicating the number of employees on payroll at each park during fiscal year 2013/2014 was obtained from TDEC's Division of Fiscal Services. This metric was used to identify those parks that have more on-site staff, which serves as an indication of size of park operational activities and the availability of immediate assistance in the event of an emergency. Staff size associated with each park was applied to each asset within the respective park.

Financial Criteria

Four criticality criteria were developed to represent financial considerations. One criterion was employed at the park level, while the remaining three criteria were applied at the individual asset level.

1. Park Revenue Generation—At the end of each fiscal year, TDEC's Division of Fiscal Services reports the annual revenue generation at each park. This metric can be used to compare parks based on their ability to contribute to the economic sustainability of the overall park system. To account for abnormalities in revenue generation that may be specific to particular economic or weather circumstances within a given year, the two most recent years of annual park revenue

[9] This methodology has consistently been utilized by TSP for quantifying park visitation. According to TSP leadership, the methodology was informed by peer state and federal agency practices at the time. Potential revision of this this methodology is currently being discussed.

were averaged to compute a mean annual revenue generation for each park. This metric was applied to each asset within its respective park.

2. Asset Revenue Generating Capability—TDEC's Division of Fiscal Services also reports revenue generation for its various hospitality operations across the park system as well as at each individual park. Hospitality operations are classified separately for marinas, campgrounds, golf courses, cabins, gift shops, restaurants and inns. However, each of these hospitality operations is not clearly delineated in the DRM database by a particular asset. Therefore, in lieu of trying to estimate which particular asset is tied to which particular hospitality operation at each park, a qualitative metric (significant or negligible) was used to represent the extent to which each particular asset is capable of generating significant revenue based on its building category. This criterion can be used to compare park assets based on their individual potential to contribute to revenue generation. It differs from park revenue generation in its scale (asset level instead of park level) and representation (actual revenue vs. potential revenue). In theory, assets capable of generating revenue play a more critical role in ensuring park financial solvency.
3. Insured Structure Value—As noted earlier, properties owned by the State of Tennessee are eligible for insurance through the State's property insurance plan, which has a $25,000 deductible. The property insurance database contains the insured structure value of each state park asset. This enables one to compare structures of different types and categories across parks and within an individual park. An asset with a higher insured structure value would be deemed more valuable than an asset with a lower insured structure value on this basis.
4. Insured Contents Value—Another metric reported for each insured state park asset is insured contents value. Similar to insured structure value, insured contents value can be used to compare structures of different types and categories across parks and within an individual park. An asset with a higher insured content value would be deemed more critical to a park system or individual park than one with a lower insured content value.

Land Criteria

Preservation of natural resources and provision of recreational and outdoor experiences are central to the mission of TSP. Three criticality criteria were defined to represent this consideration.

1. Trail Miles—TDEC keeps track of the number of trails and total trail miles maintained within each park. A park with more trail miles would be viewed as providing greater recreational value than one with fewer trail miles. This metric was applied to each asset within each respective park.
2. Number of Rare Species—TDEC's Division of Natural Areas is responsible for maintaining databases that identify rare species throughout Tennessee. This metric is intended to be representative of the natural resources value and biodiversity that is provided through preservation of land. A park that is home to a greater number of rare species would be deemed as providing greater value to the park system and an individual park than one with fewer rare species. This metric was applied to each asset within a given park.
3. Park Acres Maintained—Each park is responsible for maintaining and preserving the area within its geographic boundaries, as well as significant parcels of land that are contained within State

Natural Areas located adjacent to or near state parks. Total park acreage and State Natural Area acreage maintained by each park was obtained from TDEC's Real Property Manager. This criterion was applied to each asset within a given park. This metric is intended to representative of the preservation value of natural resources that the park system provides to Tennessee.

Assigning Criticality Metrics to Park Assets

The criticality metrics were subsequently applied to each state park or particular asset in the inventory database. This process involved three steps: (1) determining how criticality metrics would be quantified within each characteristic to normalize their values, (2) assigning weights to each criticality metric to differentiate their relative importance, and (3) combining the normalized criticality metrics and relative weights to determine an overall criticality score for each asset.

Normalizing Criticality Metrics

As various measurement units were utilized in defining criticality criteria, it was necessary to normalize them to a common scale. For numeric metrics, the range of values for each criticality characteristic was divided into quartiles, with a score of 0, 1, 2 or 3 assigned to each respective quartile. This scoring approach is illustrated in Table 2.3 and an example of an application to a specific criticality characteristic is shown in Table 2.4. Quartile scoring ranges for all numeric criticality characteristics are provided in Appendix B.

Criticality Characteristic Ranges		
Min	**Max**	**Rank Score**
Minimum Value	1st Quartile	0
1st Quartile	2nd Quartile	1
2nd Quartile	3rd Quartile	2
3rd Quartile	Maximum Value	3

Table 2.3. Criticality Characteristic Quartile Scoring Approach for Numeric Metrics

Park Revenue Ranges		
Min	**Max**	**Rank Score**
$0	$14,825	0
$14,826	$147,511	1
$147,512	$471,721	2
$471,722	$5,278,505	3

Table 2.4. Park Revenue Criticality Characteristic Quartile Scoring Ranges

Descriptive metrics, were translated into normalized scores by assigning scores ranging from 0 to 3 for each descriptor. For the Asset Revenue criterion, significant revenue generating capability was assigned a score of 3, while negligible revenue generating capability was given a value of 0. For the Necessity to Park Functioning criterion, Public Health/Safety assets were assigned a score of 3, Operations or Park Staff Residence assets received a value of 2, Retail, Dining, and Lodging assets were given a 1, and Recreation or Other assets were valued at 0.

Weighing Criticality Metrics

In consultation with TSP Operations and Facilities Management, a consensus approach was utilized to assign weights to signify the importance of each characteristic. These weights were they applied to derive an overall criticality score.

- Tier I: 13% weight to: (1) necessity to park functioning. This characteristic is deemed most connected to criticality due to its representation of centrality to operations. This amounted to a 13% total weight to Tier I.
- Tier II: 11% weight, respectively, to: (1) building value, (2) content value, (3) employees, (4) park revenue, (5) asset revenue generation capability and (6) visitation. These characteristics are connected to criticality due to their representation of operational significance, park popularity, facility structure and content value, park financial sustainability and the potential to influence financial sustainability. This amounted to a 66% total weight to Tier II.
- Tier III: 7% weight, respectively, to: (1) rare species, (2) trails, and (3) acreage managed. These characteristics are the least tied to criticality in this context due to their focus on conservation and preservation of natural resources rather than facilities and structures. This amounted to a 21% total weight to Tier III.

Determining an Overall Criticality Score

The overall criticality score equation therefore becomes:

Overall Criticality Score = [(Necessity Score x 0.13) + (Building Value Score x 0.11) + (Contents Value Score x 0.11) + (Employees Score x 0.11) + (Park Revenue Score x 0.11) + (Visits Score x 0.11) + (Asset Revenue Generation Capability Score x 0.11) + (Rare Species Score x 0.07) + (Trails Score x 0.07) + (Acreage Managed Score x 0.07)]

Characteristics pertaining to the overall criticality scores for the inventory of assets contained within the database are described in Table 2.5.

Criticality Score Characteristics	
Count	1,584
Range	0.00 – 2.74
Mean	1.67
Median	1.73
Standard Deviation	0.52

Table 2.5. Criticality Score Characteristics for Tennessee State Parks Asset Inventory

The overall criticality scores for each asset were sorted from highest to lowest. To determine which subset of assets qualify as meeting the critical asset standard, a threshold was set at one standard deviation, 0.52, above the mean overall criticality score, 1.67. This threshold was set at this level because it effectively served to represent the top sixth most critical subset of assets. Additionally, it reduced the number of assets utilized within the analysis to a manageable number. Therefore, any asset with a criticality score equal to or higher than 2.19 was deemed critical, producing a list of 249 assets. In consultation with TSP Facilities Management, the decision was made to include any dams in the list of critical assets. Therefore, an additional 24 assets were added to the list of critical asset infrastructure, for a grand total of 273 critical assets. A full listing of all critical assets can be found in Appendix C.

Findings and Implications

Of the 273 critical assets that were identified using the aforementioned methodology, 146, or 53%, were lodging facilities. A total of 45 critical assets, or 17%, were public health/safety facilities and 36, or 13%, were operational assets. The remaining 46 assets were retail/dining, recreation, recreation/retail, park staff residence, retail, or dining structures. Figure 2.1 illustrates critical asset count and percentage by building category.

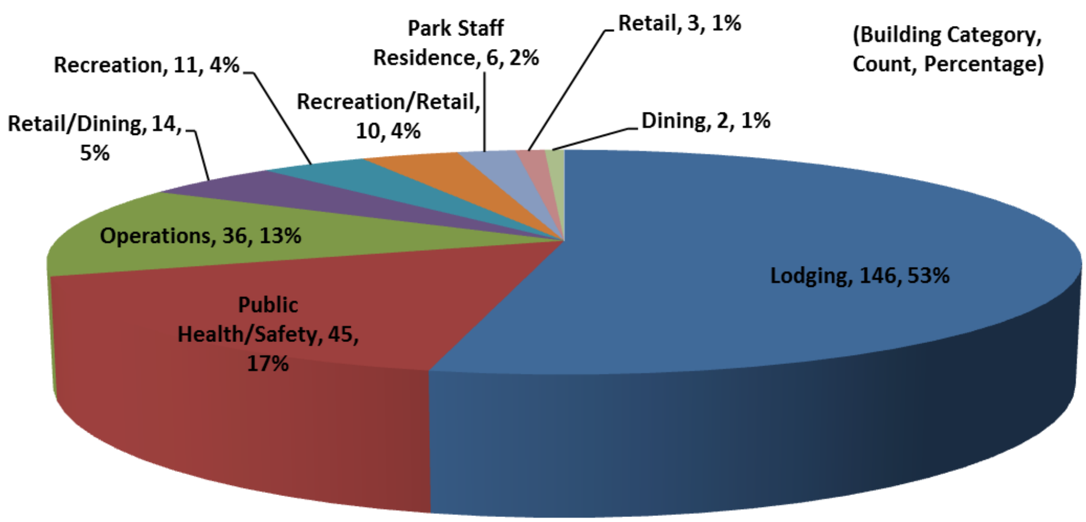

Figure 2.1. Critical Asset Count and Percentage by Building Category

The results of the criticality assessment indicate that when compared by building category, lodging, public health/safety assets, and operational assets are the most critical facilities compared to other categories. Conversely recreation, dining, retail, and park staff residence assets are deemed less critical. While high criticality ranking for public/health safety and operational assets would be somewhat expected due to their centrality to park functioning, the author was surprised that so many lodging facilities were included in the listing of critical assets, specifically cabins/villas. This in part may be explained by certain individual criticality metrics, such as building value, content value, potential revenue generation capability or necessity to park functioning, being more influential in determining overall criticality score than others due to the weighting assigned to each metric. Of those buildings that were not included in the listing of critical assets, assets tended to be located in parks with low revenue generation and low visitation and were deemed noncritical to park functioning.

A total of 28 different parks, or about half of the parks in the entire park system, were represented as having one or more critical assets onsite. Figure 1.2 illustrates critical asset county by park for all assets deemed critical using the described methodology. The five parks containing the greatest number of critical assets include: Fall Creek Falls (78), Natchez Trace (49), Montgomery Bell (40), Tims Ford (28), and Meeman-Shelby Forest (21).

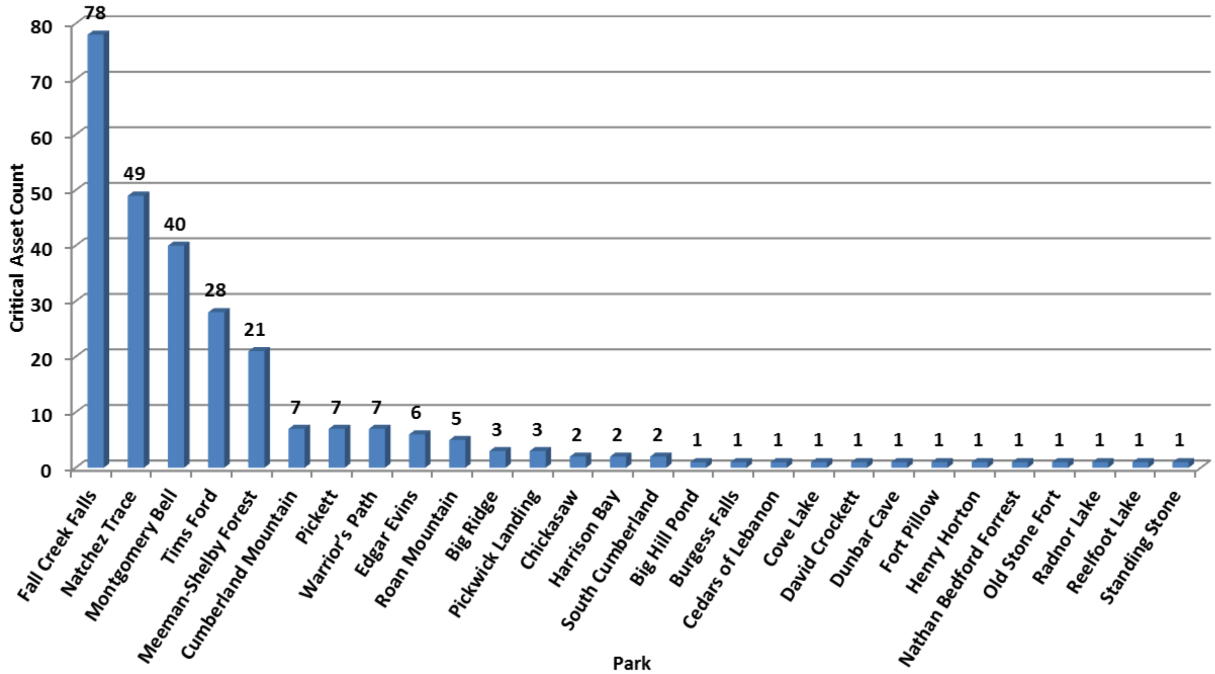

Figure 2.2. Critical Asset Count by Park

It would be expected that parks with historic and potential revenue generating capabilities and those with high visitation numbers would be ranked as more critical than others. Therefore, it was predicted that resort parks[10] would be prominently featured within the listing of critical assets. Five of the six resort parks were included in the listing of critical assets. Further, all six of the non-resort parks with hospitality centers had at least one critical asset onsite. This implies that there is a relationship between historic and potential revenue generation, and parks visitation. However, building and content value, trails, acreage, and rare species should not be discredited in their importance either.[11]

Concluding Remarks

This study has presented and applied a methodology by which park systems can assess the criticality of individual assets within their jurisdiction taking into consideration agency priorities, values, and asset-

[10] Resort parks are generally understood as those with hospitality operations such as: resort inns/cabins, dining facilities, convention complexes, golf courses, gift shops, swimming pools, and marinas.

[11] In consultation with park leadership, the objective of this particular research was to examine critical *built* infrastructure, and was designed such that criteria as indicated in this methodology were more heavily weighted if indicative of public safety and financial criteria. This should not be interpreted to suggest that land criteria are not important. Rather, for the purposes of this study they are *less directly related* to the functioning park built infrastructure.

specific characteristics expressed in both quantitative and qualitative terms. Building this methodology can be challenging due to the fact that necessary information can be expected to reside in many different state agencies and divisions within the same agency. The outcome of this process is also heavily dependent on the selection of criticality criteria, how each criterion is measured and subsequently normalized in the scoring process, and the importance rating assigned to each criterion.

In this particular application, it was determined that the majority of critical assets are of three building category types (lodging, health/safety, and operations) and located in five different parks (Fall Creek Falls, Natchez Trace, Montgomery Bell, Tims Ford, and Meeman-Shelby Forest State Parks). Generally, these parks tend to have comparatively more revenue generating opportunities and historically higher visitation. Areas for future and further research and analysis include understanding the relationship between park asset geographic location and criticality, critical asset performance during particular weather events, and interaction of critical asset performance and future weather event scenarios.

Beyond applicability to park systems, this approach can be tailored to other entities based on their particular preferences. This becomes an especially important tool for public agencies who may have limited resources with which to manage various types of risk threatening its assets. The approach described herein provides flexibility in terms of what factors to consider and their relative importance in contributing to system operability. By deploying methodologies of this sort, decision-makers can determine how best to prioritize and plan for operational and capital improvements. This, in turn, enhances the quality of life for individuals as well as society in general.

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CHAPTER 3

Assessing Impacts to Tennessee State Parks Infrastructure Caused by Extreme Weather Events

This chapter has been submitted for publication to the Journal of Facilities Management.

Introduction

Tennessee is home to 55 state parks, each of which contains a network of operational assets, including dining and lodging structures, recreational facilities, and hiking trails. Construction, operation and maintenance of these assets are provided for by a combination of state taxpayer dollars and revenues generated from park services. Central to the park system's existence and attractiveness are Tennessee's abundant natural resources that offer recreational and outdoor opportunities. State park infrastructure has been developed around these important features to facilitate visitor accessibility and enjoyment.

Tennessee has also experienced extreme weather events that have caused significant impact to a wide range of infrastructure systems, with the impacts incurred by state park assets being no exception. The resulting consequences extend beyond physical damage itself, as such events have involved loss of use, human casualties, and ecological disruption. Also at risk is the direct and indirect economic impact to state park profitability as well as local community tourism and fiscal health. A 2009 study conducted by the University of Tennessee, Department of Agricultural Economics found that total direct expenditures by visitors at TSP amounted to $725 million annually. Taking additional economic activity into consideration, direct and indirect impact of TSP to the state's economy totaled $1.5 billion (Fly, 2009). These estimates do not reflect the fact that visitation has increased by more than 12 percent[12] since the study was completed.

While the overall impact of the park system on the state's economy has been studied, less is known about the extent to which consequential impacts of extreme weather events can affect this outcome. With concerns being expressed about the potential for more frequent and severe extreme weather events, it therefore becomes important to better understand this relationship; hence the motivation for the work described herein. What follows is a description of this effort.

Approaches for Measuring Extreme Weather Event Impacts on Infrastructure Assets

Extreme weather vulnerability assessments have traditionally relied on damage and loss estimates compiled in the aftermath of significant weather events. These approaches, however, have encountered difficulty in accurately estimating the economic impacts (Smith, 2013). Problems include underreporting in less populated areas, and damage/loss reports are often limited to impacts that align with information sought by federal, state or local government assistance programs. To overcome these limitations, this research utilized input from park service subject matter experts from which a numerical scale was derived to identify damage and loss to different types of park assets from extreme weather

[12] FY 2009/2010 visitation was 28,404,662 and FY 2013/2014 was 32,063,130.

events experienced in the state. When combined with the likelihood of occurrence of these extreme weather events in Tennessee, asset vulnerability can be determined. The results of this exercise can be used in making decisions involving future infrastructure planning and operations.

Historic Extreme Weather Events in Tennessee

A comprehensive study of historic extreme weather events in Tennessee was recently completed by the Tennessee Department of Transportation (TDOT), focused on transportation assets within the state (3 Sigma Consultants, 2015). Because these weather events cover the same geographical extent as the Tennessee parks system, the data from that study was obtained and used in this initiative. A brief overview of the treatment of historic extreme weather events in Tennessee utilized by the TDOT study is provided in this section. For further details regarding this research, the reader is directed to the full study.

The National Weather Service (NWS), a part of the National Oceanic and Atmospheric Administration (NOAA), is the U.S. entity responsible for collection of weather and climate data. Since 1950, NWS has been collecting information regarding extreme weather events as part of its storm events database. Events included in this database are those with sufficient intensity to cause death, injuries, significant property damage, or disruption of commerce. It also includes other significant meteorological events associated with unusual weather occurrences.[13] Records within the storm events database are organized by the state and county in which the weather event occurred and according to storm event type. For the first four years of the database's existence (1950-1954), only tornado events were recorded. From 1955 and through 1995, thunderstorm wind and hail events were included in the database in addition to tornadoes. Beginning in 1996, 45 additional extreme weather event types were included in the database. Therefore, at the present time, a total of 48 types of extreme weather events are being monitored (NOAA, 2015).

Tennessee has experienced 26 of the 48 types of extreme weather events since database inception, resulting in over 27,000 records in the NWS database. However, three event types, tropical depressions, tropical storms, and wildfires, have been so rare that they were removed from consideration as part of this analysis. NWS definitions for the remaining 23 extreme weather event types are described in Appendix D.

In some instances, NWS definitions for weather event types depend on regional thresholds. For example, NWS defines heavy snow as: "Snow accumulation meeting or exceeding locally/regionally defined 12 and/or 24 hour warning criteria, on a widespread or localized basis. This could mean such values as 4, 6, or 8 inches or more in 12 hours or less; or 6, 8, or 10 inches in 24 hours or less" (NWS, 2007). To apply the appropriate threshold for Tennessee, local Tennessee weather forecast offices were contacted. For example, the Memphis Weather Forecast Office has created such definitions for public notification in advance of and during extreme weather events as described in Appendix E.

[13] It is worth noting that these criteria lend themselves to a higher likelihood that an extreme weather event would meet NWS criteria in more populated areas, given that more people and infrastructure are potentially exposed during an extreme event. However, state parks in Tennessee tend to be located in less urbanized areas.

In examining the descriptions of each of the 23 extreme weather event types, it became clear that some of these represent gradations of the severity of certain weather forms. For this reason, the 23 event types in Tennessee were combined into 9 aggregate event categories based on their similarities. For example, the NWS event types of funnel cloud, dust devil, and tornado, all of which represent circular wind rotation, were aggregated into a single category – Twister. The NWS event types of cold/wind chill and extreme cold/wind chill, both which indicate exposure to low temperatures, were also aggregated into a single category – Cold. Table 3.1 shows the connection between NWS event types and corresponding aggregate extreme weather categories.

Aggregate Weather Event Type	National Weather Service Event Type
Cold	Cold/wind chill
	Extreme cold/wind chill
Heat	Heat
	Excessive heat
Wind	Strong wind
	High wind
	Thunderstorm wind
Twister	Funnel cloud
	Dust devil
	Tornado
Hydrologic	Heavy rain
	Flash flood
	Flood
Lightning	Lightning
Hail	Hail
Drought	Drought
Winter	Winter weather
	Sleet
	Freezing fog
	Frost freeze
	Heavy snow
	Winter storm
	Ice storm

Table 3.1. Aggregated Weather Event Types
(3 Sigma Consultants, 2015)

Assessing Damage and Disruption to Park Service Assets Caused by Extreme Weather Events

Park service asset categories were defined in earlier research by the author and were grouped into four general categories as shown in Table 3.2. The reader is referred to Chapter 2 for a detailed description of the process employed to define and rate the importance of Tennessee State Parks assets.

Infrastructure Category	Asset Types
Dining & Lodging	Restaurants, cabins, inns, group lodges, conference centers, park staff residences
Camping & Outdoor Recreation	Campgrounds, group camps, picnic shelters, trails, playgrounds, stables, swimming pools, marinas, docks, amphitheaters
Operations	Pumphouses, dams, maintenance sheds/buildings, bathhouses, restrooms, water or propane tanks, park offices or welcome centers, treatment plants
Retail	Camp stores, gift shops, Laundromats, snack bars, pro shops

Table 3.2. Tennessee State Parks Infrastructure Categories and Asset Types

To assess the impacts on these assets when exposed to extreme weather events experienced in Tennessee, an electronic questionnaire was developed and administered wherein respondents were asked to evaluate damage to assets and disruption to services that would be expected to occur for each combination of infrastructure category and extreme weather event scenario.[14] Respondents were asked to assign the appropriate damage/loss to each combination according to the following scale: Nominal (≤ $25,000), Moderate ($25,000 ≤ $100,000), Significant ($100,000 ≤ $500,00), and Catastrophic (≥ $500,000). Respondents were also provided a Not Applicable/Unsure option, along with an opportunity to provide any comments. The questionnaire, which can be referenced in Appendix F, was designed such that recipients were only asked to respond to infrastructure categories for which they felt sufficiently knowledgeable to assign an impact score.

The questionnaire was distributed by TSP leadership to state park employees deemed intimately familiar with park infrastructure and past performance during extreme weather events; this included park rangers and maintenance staff.[15] The questionnaire was sent to 62 TSP staff members and 53 responses were received, a response rate of approximately 85%. The number of survey responses by category is provided in Table 3.3.[16]

Infrastructure Category	Number of Responses
Dining & Lodging	43
Camping & Outdoor Recreation	47
Operations	47
Retail	36

Table 3.3 Survey Responses by Infrastructure Category

Developing Impact Scores

The damage/loss scale was converted to an impact score by assigning values as follows: Nominal = 1, Moderate = 2, Significant = 3, and Catastrophic = 4. For each weather event and infrastructure category combination, an average impact score was calculated by dividing the sum of the individual impact scores

[14] Combinations for which impacts to assets within an infrastructure category were deemed insignificant such that they would not qualify as causing considerable damage were eliminated from consideration.

[15] While there was a desire to distribute the questionnaire more widely to peer park system staff in other states as well as at the national level, an effective mechanism and appropriate contact list for doing so could not be identified.

[16] The total number of responses in Table 3.3 exceeds the number of survey respondents as many respondents felt capable of answering questions pertaining to more than one infrastructure category.

by the number of responses received. Average overall event and infrastructure impact scores were also derived. These results appear in Table 3.4. Appendix G provides similar information at the disaggregate weather event level.

Event	Dining & Lodging	Camping & Outdoor Recreation	Operations	Retail	Event Average
Twister	3.37	3.06	2.96	2.88	3.07
Lightning	1.86	1.70	1.91	1.73	1.80
Hydrologic	1.86	1.72	1.76	1.75	1.77
Wind	1.74	1.63	1.53	1.56	1.62
Hail	1.71	1.49	1.53	1.61	1.58
Winter	1.75	1.49	1.48	1.54	1.57
Cold	1.45	1.39	1.45	1.43	1.43
Heat	1.20	1.16	1.20	1.32	1.22
Drought		1.20	1.09		1.22
Infrastructure Average	1.87	1.65	1.66	1.73	

Table 3.4. Impact Scores by Infrastructure Category and Aggregate Weather Event

Impact Score Results

The results indicate that with the exception of twister events, respondents consider all other extreme weather events to have a nominal (≤ $25,000) to moderate ($25,000 ≤ $100,000) impact on TSP infrastructure, regardless of infrastructure category. According to respondents, twister events have the most significant impact on TSP assets ($100,000 ≤ $500,00), followed by lightning events. Hydrologic, wind, and hail events have similar levels of impact (nominal to moderate) on infrastructure, followed by winter and cold events. Drought and heat are considered to have the least significant impacts on infrastructure for all infrastructure categories.

When considering impacts to infrastructure categories, respondents generally indicated that camping and outdoor recreation and operations infrastructure are impacted to a lesser extent from extreme weather events than other infrastructure categories. Retail infrastructure is impacted slightly more severely by extreme weather events than camping and outdoor recreation and operations infrastructure, but to a lesser extent than the most significantly impacted infrastructure category across all event types, dining and lodging. This relationship could be explained by the fact that building structure and contents associated with dining and lodging infrastructure, such as inns, lodges and conference centers, tend to be valued more highly than other assets, such as swimming pools, bathhouses, maintenance sheds, hiking trails, picnic shelters, or campgrounds.

Further Discussion

As previously noted, respondents were given an opportunity to provide comments regarding their assessment of impacts caused by extreme weather events to various different types of infrastructure categories. In reviewing these comments, the following themes emerged:

- Evaluation of impacts to infrastructure, even within a specific infrastructure category, is location-specific given that structures are often scattered across parks and impact could be concentrated in a subset of the park or could be more widespread. This makes it difficult to precisely identify damage/loss.
- Many park structures are located in heavily wooded areas, and consequently tree fall is a common occurrence for multiple types of extreme weather events (e.g., thunderstorms, tornadoes, lightning).
- It is difficult to evaluate impacts to infrastructure from drought or heat conditions in particular, as impacts from these types of events may not be realized until 12-18 months following an event.
- Within the operations infrastructure category, most significant concerns were those pertaining to flooding of wastewater treatment plants and freezing/bursting of pipes.

Concluding Remarks

This study has presented and applied a methodology by which park systems can assess the damage to infrastructure and service disruption that result from the occurrence of extreme weather events. Using this approach, a park or park system can identify which types of extreme weather events are likely to cause the most significant damage, and which infrastructure categories are most vulnerable. When combined with future forecasts of the likelihood of occurrence of these events in particular geographic regions, the vulnerability of park assets located in those areas can be assessed. This, in turn, enables park managers to allocate resources for implementing adaptation strategies where the need is greatest.

The methodology utilized for creating impact scores for weather event scenario and infrastructure combinations is conceptually appealing and relatively straightforward to implement. However, potential challenges can arise since the impact assessment is dependent upon a sufficiently high level of participation from subject matter experts. Moreover, there is considerable discretion in how weather event types, infrastructure categories, and damage/loss thresholds are defined.

In this application, it was found that twister events can be expected to have the most significant impact on TSP infrastructure ($100,000 ≤ $500,00 of damage/loss), and drought and heat events are considered to have the least effect (≤ $25,000 of damage/loss), regardless of infrastructure category type in both situations. Additionally, it was observed that dining and lodging is the infrastructure category type within TSP that will incur the most significant damage/loss when exposed to extreme weather, with camping and outdoor recreation and operations infrastructure considered to incur the least amount of damage/loss. This conclusion could be explained by the comparatively higher content and structure value typically associated with dining and lodging infrastructure.

While this methodology was developed and applied within the context of extreme weather events and park system infrastructure, it could be adapted to other risk types and entities. For public agencies in particular, who often operate under constrained resources in employing risk-based asset management, a simple and cost effective approach for evaluating potential infrastructure impacts is desirable. The framework described herein offers the flexibility to accomplish this objective.

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CHAPTER 4

Evaluating Vulnerability of Critical State Park Infrastructure Caused by Extreme Weather Events: A Tennessee Application

This chapter has been submitted for publication to the journal Risk Management.

Introduction

Tennessee's experience with extreme weather events have caused significant impact to a wide range of infrastructure systems, with the impacts incurred by state park assets being no exception. The resulting consequences extend beyond physical damage itself, as such events have involved loss of use, human casualties, and ecological disruption. Also at risk is the direct and indirect economic impact to state park profitability as well as local community tourism and fiscal health.

The TSP system currently has no standardized means for identifying the vulnerability of infrastructure and assets to risks in general, but more specifically, extreme weather events. Developing such a methodology will enable for more effective management of park system assets and more efficient utilization of public sector resources, and will provide a mechanism for the park system to assess its vulnerability and resilience to various types of risk, included but not limited to financial, operational, security, or physical risk, that may impact individual assets, parks, or the entire park system.

In an effort to more clearly understand the impacts of extreme weather events on TSP system infrastructure that has been deemed to be most important to park system functioning, a methodology for evaluating the vulnerability of critical park building infrastructure to extreme weather events is provided in the following discussion.

Historic and Future Extreme Weather Events in Tennessee

As briefly mentioned in Chapter 3, a comprehensive study of historic and projected future extreme weather events in Tennessee was recently completed by TDOT, focused on transportation assets within the state (3 Sigma Consultants, 2015). Because these weather events cover the same geographical extent as the TSP system, the data from that study was obtained and used in this initiative. A general overview of these weather data as relevant to this chapter provided below.

Using the NWS database and aggregate weather event types discussed in Chapter 3 and specified in Table 3.1, the annual average number of recorded events was calculated for each of Tennessee's 95 counties. While the TDOT study had normalized for number of years for which each type of weather event had been recorded, in this research the data was further normalized by the county size. This removed any bias that could be attributed to differences in the geographical area associated with each county. A map showing the locations of Tennessee's counties appears in Figure 4.1, while the annual average number of recorded events for the sum of all extreme weather types by county is displayed in Figure 4.2. Counties having the highest number of recorded extreme weather events include Putnam, Carter, Lake, Shelby, Hamblen, Trousdale, Unicoi, Davidson, and Moore. Maps showing the annual average number of recorded events for each weather event type for each county are contained in Appendix H.

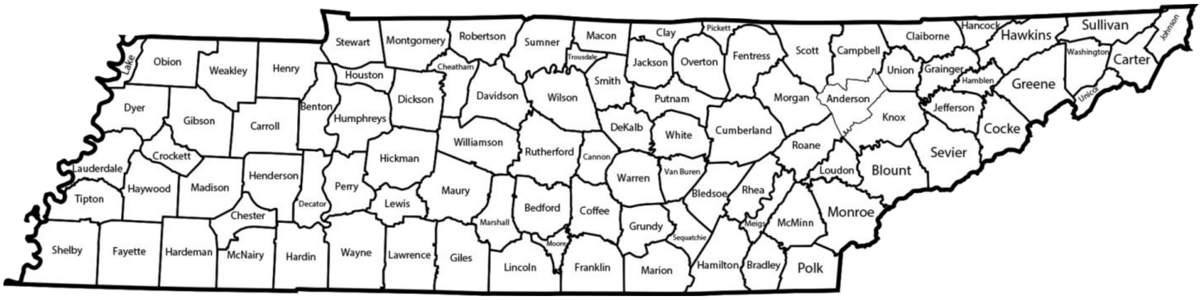

Figure 4.1. Tennessee County Map

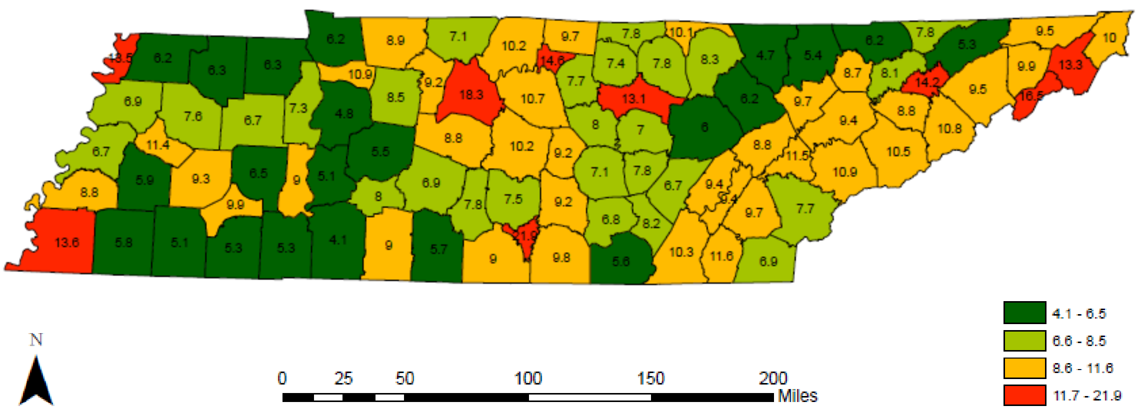

Figure 4.2. Average Annual Extreme Weather Events by County

The TDOT study also utilized climate modeling and trend analyses to estimate the frequency of future weather events (3 Sigma Consultants, 2015). The World Climate Research Programme's Coupled Model Intercomparison Project (CMIP) tool was selected due to its inclusiveness of multiple climate modeling group data inputs and use by the IPCC to complete its research. The project utilized CMIP3 data generated by the University of Georgia to develop projections of monthly averages of precipitation and temperature for each Tennessee county for the period of 2035-2045. Observed precipitation and temperature data for each Tennessee county for 2000-2010 were used as a basis of comparison. To understand the change in temperature and precipitation lows and highs that each county could experience in the future compared to current occurrences, the top 90th percentile and the bottom 10th percentile values were selected from each county for both total monthly precipitation and average monthly temperature for the 2035-2045 time period as well as the 2000-2010 time period. Expected percent change in temperature and precipitation were calculated; the results of this exercise are included in Appendix I.

While climate forecast models projecting future temperature and precipitation increases were utilized, similar applications for other types of extreme weather (e.g., tornado, hail, lightning, winter storm, thunderstorm winds) were not available. Due to their increasing occurrences in recent years, the TDOT study attempted to project the frequency of future tornadoes and thunderstorm winds using regression analysis.[17] Appendix J displays the results of these efforts.[18] For the remainder of extreme weather event categories (hail, lightning, and winter storms), no means of projection was performed; therefore, only historic occurrences are available as a basis for assessing vulnerability.

The TDOT modeling should not be interpreted as presentation of a certain predictor of future extreme weather events. Instead, it should be viewed as an illustration of what could happen. That is, it presents several possible scenarios for future extreme weather occurrences, but not the only possible future within each extreme weather event category. This is an important consideration given that research indicates that CMIP3 data prediction within portions of the United States could be improved.[19]

Assessing Vulnerability of Critical Park Assets

The final step in this vulnerability assessment process consisted of calculating a vulnerability "score" for combinations of extreme weather event types and infrastructure categories on a county-by-county basis. Formulas were developed to account for historic trends and future projections of occurrences of weather event types and their corresponding impacts on infrastructure categories (see Table 4.1).[20] Generally, the annual expected frequency of each type of extreme weather event was multiplied by its respective impact score according to the type of infrastructure being exposed that was generated during previous phases of research (see Chapters 2 and 3). For future weather events dependent on temperature and precipitation fluctuations (i.e., cold, heat, drought, and hydrologic events), a multiplier equivalent in magnitude to the percent change was utilized to account for respective increases or decreases in precipitation or temperature. Each formula was applied to each of the four TSP infrastructure categories for each county in Tennessee.

Event Type	Vulnerability Score Type	Formula
Twister	Historic[21]	Vulnerability Score = Twister Impact Score for Infrastructure Category 'X' * Average Annual Twister Events in County 'Y'
Lightning	Historic	Vulnerability Score = Lightning Impact Score for Infrastructure Category 'X' * Average Annual Lightning Events in County 'Y'
Hydrologic	Projected	Vulnerability Score = Hydrologic Impact Score for Infrastructure Category 'X' * Average Annual Hydrologic Events in County 'Y' * Projected Percent Change in High Precipitation in County 'Y'

[17] The most severe events over 50 years of recorded data in each respective aggregate weather category were used. Sample sizes were too small to support county-level analysis.
[18] Increases in thunderstorm wind and tornado trends reported are likely measurement artifacts and not increases in the actual number of severe storms. See NOAA research "Historical Records and Trends" and "Monitoring and Understanding Trends in Extreme Storms."
[19] See Knutson, T.R. Zeng, F., and Wittenberg, A.T. (2013) "Multimodel Assessment of Regional Surface Temperature Trends: CMIP3 and CMIP5 Twentieth-Century Simulations." *Journal of Climate*, 26, 8709–8743.
[20] Because future projections are available for some weather event types but not others, formulas differ depending on accessibility of information.
[21] While a regression analysis was completed for the TDOT report, the R^2 value was 0.42, indicating that the precision of the line of best fit is relatively unreliable. Therefore, this research utilized a historic illustration of the data.

Thunderstorm Wind	Projected[22]	Vulnerability Score = Wind Impact Score for Infrastructure Category 'X' * Average Annual Thunderstorm Wind Events in County 'Y' * Projected Increase in Thunderstorm Wind Events
Hail	Historic	Vulnerability Score = Hail Impact Score for Infrastructure Category 'X' * Average Annual Hail Events in County 'Y'
Winter	Historic	Vulnerability Score = Winter Event Impact Score for Infrastructure Category 'X' * Average Annual Winter Events in County 'Y'
Cold	Projected	Vulnerability Score = Cold Event Impact Score for Infrastructure Category 'X' * Average Annual Cold Events in County 'Y' * Projected Percent Change in Low Temperature in County 'Y'
Drought	Projected	Vulnerability Score = Drought Event Impact Score for Infrastructure Category 'X' * Average Annual Drought Events in County 'Y' * Projected Percent Change in Low Precipitation in County 'Y'
Heat	Projected	Vulnerability Score = Heat Event Impact Score for Infrastructure Category 'X' * Average Annual Heat Events in County 'Y' * Projected Percent Change in High Temperature in County 'Y'

Table 4.1. Vulnerability Score Formulas

Once vulnerability scores had been calculated for each weather event-infrastructure type combination, the scores were superimposed over a map depicting the physical location for TSP system assets that had been identified as critical. This effectively allows for the depiction of park assets that are more vulnerable to impacts from potential extreme weather events in the future. Maps for each weather event-infrastructure type combination are presented in Appendix K. Figure 4.3 provides an example of a map displaying future vulnerability for critically-identified dining and lodging infrastructure to a hydrologic event. It indicates that the locations with the greatest vulnerability to critically-identified dining and lodging infrastructure from a hydrologic event are in Shelby County at Meeman-Shelby Forest State Park (vacation cabins and group bunkhouses) and in Wilson County at Cedars of Lebanon State Park (group lodge). This result makes sense given that geography within Shelby and Wilson Counties is relatively flat and any flow of water from higher elevations tends to collect in these areas.

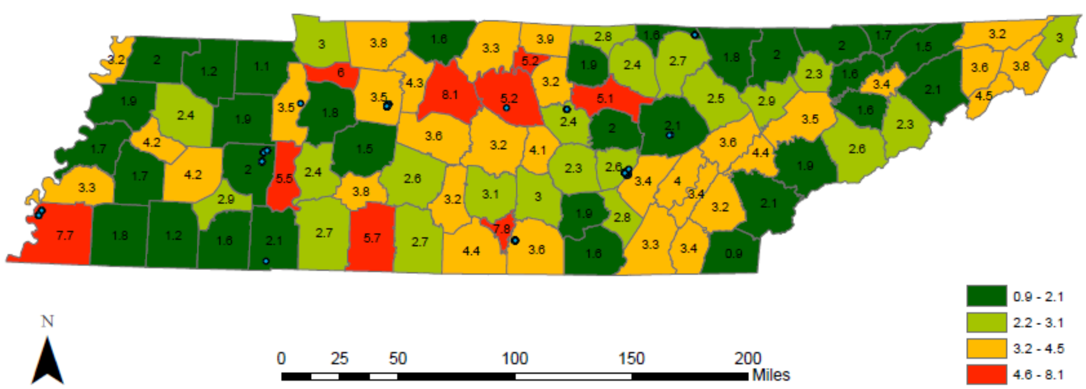

Figure 4.3. Vulnerability of Critical Dining/Lodging Infrastructure to Hydrologic Events by County – 2035

22 The R^2 value for the thunderstorm wind regression analysis, 0.72, was considered sufficient for inclusion of this future factor in the analysis. Therefore, the author opted to use a 12% rate of increase based on the slope of the regression.

Vulnerability Score Results

In reviewing the results, it is apparent that vulnerability scores can vary significantly among counties by weather event and infrastructure category (see Table 4.2). Accordingly, it made sense to establish a "threshold" score for recognizing locations that warrant more serious consideration as having critical assets with high vulnerability to extreme weather. A vulnerability score threshold of 4 was established for this purpose; however, scores falling very close to this threshold were also considered on a case-by-case basis.

	Value
Minimum	0
Maximum	15.3
Mean	1.71
Median	1.17
Standard Deviation	1.89

Table 4.2. **Vulnerability Score Range for Critical State Park Infrastructure and Extreme Weather Events**

Table 4.3 lists critical assets determined as being particularly vulnerable, according to their county location and the extreme weather event of interest. It should not go unnoticed that only four of the nine extreme weather categories are represented on the list of most significant concerns. This is due to either the low expected frequency of occurrence of the other five types of extreme weather events or the comparatively small damage or disruption to infrastructure categories anticipated from exposure to particular extreme weather events.

Extreme hydrologic weather events (i.e., heavy precipitation and flooding) appear to be of greatest concern for critical park infrastructure of all types within Shelby County. Individual critical infrastructure types are also vulnerable to hydrologic events in Wilson, Davidson, Putnam, and Lawrence counties. Strong thunderstorm winds appear to be problematic for various critical park infrastructure categories in multiple locations across the state, including Shelby, Wilson, Dickson, Franklin, Pickett, Hamilton, Sullivan, Carter, Union, Coffee, and Putnam counties. This may be indicative of damage and disruption to various types of park infrastructure, including indoor and outdoor facilities, which result from tree fall, dispersal of debris, and downed power lines. With regard to winter weather and storms, critical park infrastructure of various types in Carter and Pickett counties, both located in the northern portion of Tennessee, appear to be the most vulnerable to damage and disruption, followed closely by various types of park infrastructure in Franklin, Van Buren, Lake and Putnam counties. Finally, drought is of concern for critical camping and outdoor recreation and operations infrastructure in Shelby county and operations infrastructure in Davidson county.

Infrastructure Category	**Hydrologic**	**Thunderstorm Winds**	**Winter Storms**	**Drought**
Dining & Lodging	Shelby (Meeman-Shelby Forest) Wilson (Cedars of Lebanon)	Shelby (Meeman-Shelby Forest) Wilson (Cedars of Lebanon) Dickson (Montgomery	Pickett (Pickett) Franklin (Tims Ford) Van Buren (Fall Creek Falls)	

Infrastructure Category	Hydrologic	Thunderstorm Winds	Winter Storms	Drought
		Bell) Franklin (Tims Ford) Pickett (Pickett)		
Camping & Outdoor Recreation	Shelby (Meeman-Shelby Forest)	Shelby (Meeman-Shelby Forest) Hamilton (Harrison Bay) Sullivan (Warrior's Path) Carter (Roan Mountain)	Carter (Roan Mountain) Franklin (Tims Ford)	Shelby (Meeman-Shelby Forest)
Operations[23]	Davidson (Radnor Lake) Shelby (Meeman-Shelby Forest) Putnam (Burgess Falls) Lawrence (David Crockett)	Davidson (Radnor Lake) Shelby (Meeman-Shelby Forest) Hamilton (Harrison Bay) Sullivan (Warrior's Path) Carter (Roan Mountain) Dickson (Montgomery Bell) Union (Big Ridge) Coffee (Old Stone Fort) Putnam (Burgess Falls)	Carter (Roan Mountain) Lake (Reelfoot Lake) Pickett (Pickett) Putnam (Burgess Falls) Franklin (Tims Ford)	Davidson (Radnor Lake) Shelby (Meeman-Shelby Forest)
Retail	Shelby (Meeman-Shelby Forest)	Shelby (Meeman-Shelby Forest) Hamilton (Harrison Bay) Union (Big Ridge) Sullivan (Warrior's Path) Carter (Roan Mountain)	Carter (Roan Mountain) Pickett (Pickett) Franklin (Tims Ford)	

Table 4.3. **TSP Locations of Most Vulnerable Critical Infrastructure by Weather Event Category**

Concluding Remarks

This study has presented and applied a methodology by which park systems can perform an assessment of the vulnerability of particular infrastructure types to the occurrence of extreme weather events. As applied to the TSP system, it was determined that hydrologic events, strong thunderstorm winds, winter weather, and in a few instances, drought, present the greatest concern for critically-identified TSP infrastructure in various locations across the state. While the combination of other infrastructure components and extreme weather event types in certain locations may be of concern and warrant additional examination, this initial screening process has resulted in the identification of vulnerabilities of most significant consideration.

However, these results should be interpreted with caution, as historic extreme weather event occurrence tends to be over-reported in highly urbanized areas, future extreme weather event predictions by their very nature are not exact, and extreme weather event impact scoring can be highly subjective based on respondent participation, as it is the subjectivity of the analyst's determination of a vulnerability threshold. Rather, this approach should be viewed as a tool capable of providing

[23] Radnor Lake, Meeman-Shelby Forest, Burgess Falls, Montgomery Bell, Big Ridge, Old Stone Fort, David Crockett Reelfoot Lake and Pickett have one or more dams onsite, which were not included in the GIS mapping effort but have been determined to be critical operations infrastructure.

knowledge and awareness for leadership to consider ways to reduce park system infrastructure vulnerabilities to extreme weather events, and to incorporate asset criticality and extreme weather event vulnerability assessment into planning processes.

While this methodology was developed and applied within the context of extreme weather events and park system infrastructure, it could be adapted to other risk types and assets. For public agencies in particular, who often operate under constrained resources in employing risk-based asset management, a simple and cost effective approach for evaluating potential infrastructure vulnerability is desirable. The framework described herein offers flexibility to consider different asset categories and threat types, and their comparative importance in contributing to system functionality. Employing methodologies of this nature offer an important opportunity to make more informed decisions regarding a critical and emerging problem.

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CHAPTER 5

Research Contributions and Opportunities for Further Research

This research was performed with the intent of furthering understanding of the vulnerabilities of infrastructure to damages and disruption posed by impacts resulting from extreme weather events. While this endeavor and its outcomes resulted in an opportunity for the TSP system to focus its infrastructure resilience needs in response to extreme weather events, numerous opportunities for future research and action were identified. This chapter summarizes contributions made by this dissertation to the state of the practice and outlines additional areas for further investigation.

Research Contributions

This research developed a methodology for state parks, and particularly the TSP system, to use in (1) identifying critical infrastructure within the park system, (2) evaluating damage and disruption to park assets caused by impacts from extreme weather events, and (3) assessing the vulnerabilities of park infrastructure types to extreme weather events for the purpose of identifying those assets of utmost concern (see Figure 5.1).

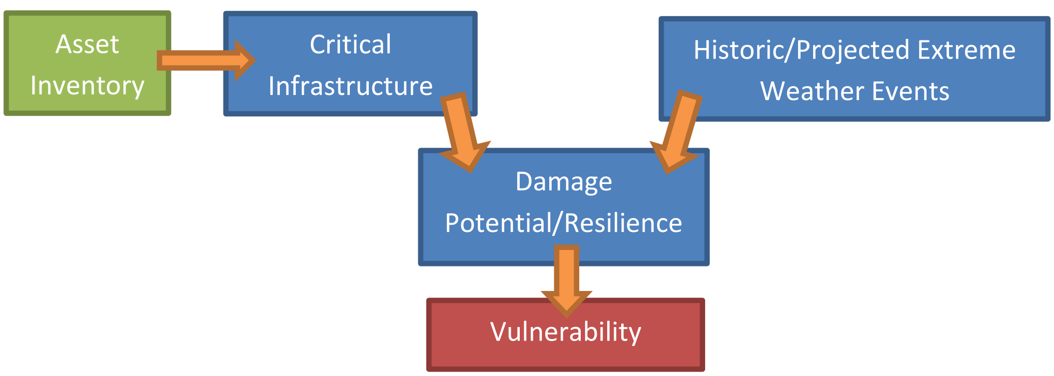

Figure 5.1 TSP Vulnerability Assessment Methodological Approach

Several important observations and work products have been realized through this research:

- A standardized approach for identifying, valuing, and categorizing state park assets is lacking.
- A means of identifying which facilities within the state park system are deemed critical to the overall enterprise has been created. Moreover, this methodology can be modified and/or adopted to represented different value streams and infrastructure systems.
- A mechanism for understanding potential impacts to park infrastructure categories that result from different types of extreme weather events has been developed.
- Finally, critical assets that are deemed of utmost concern in terms of being the most vulnerable to various types of extreme weather events throughout the state have been identified. This approach/final output can be modified to meet the needs of various organizations.
- Specifically, within state parks, three extreme weather event types – thunderstorm winds, hydrologic events, and winter storms – present the most significant concerns with regard to

resulting in damage and disruption for specific types of state park infrastructure in 14 parks (counties) across the state.

TSP now has access to a vulnerability assessment tool that can be utilized for evaluating park infrastructure as its assets evolve over time. This knowledge can be utilized to inform TSP strategic and operational planning processes, policies, and decision-making, laying the ground work for enhancing the effectiveness of existing activities such as:

- Individual park and TSP system-wide business and management plans[24]
- State recreation plans
- Legislative reports
- Facilities management operations, maintenance procedures, and planning
- Capital project siting and design[25]
- Budgeting documents
- Emergency response plans
- Individual job planning documents
- Division and department strategic plans

Incorporating information pertaining to vulnerabilities of infrastructure to extreme weather events will allow TSP to further its mission of protecting and improving the quality of Tennessee's air, land and water resources and provision of quality outdoor recreation experiences.

Opportunities for Future Research and Action

Completion of an extreme weather event vulnerability assessment is the TSP system's first step in preparing for impacts from future extreme weather events. While this methodology serves as a screening tool to identify the subset of assets deemed most vulnerable to impacts from extreme weather events, it would be prudent for TSP leadership to select specific assets from this subset for completion of a "deep-dive" into asset-specific characteristics that may cause a particular facility to be more or less vulnerable to extreme weather events. Tools that are more precise with respect to future weather impacts on specific locations are available, but were determined to be impractical for use during this application involving an area the size of an entire state. These location-specific deep-dives would pave the way for development and implementation of cost-effective adaptation strategies to increase resilience of particular sites.

This research used a prior analysis performed by TDOT to understand the frequency of historic and future projected extreme weather events on a county-by-county basis. However, it was noted that the

[24] *Tennessee Code Annotated* § 11-3-120 requires that TDEC formulate a long-range "management plan" for each state park including goals and projections for the next 10 years regarding topics relevant to this research including facilities preservation, maintenance and utilization; preservation, development and expansion of existing and new park resources and facilities; and land acquisition. These park management plans are to be updated every 5 years.
[25] *Tennessee Code Annotated* § 11-3-120 requires that TDEC receive approval by the state building commission for new capital projects with costs in excess of $100,000 and requires that these capital projects be reflected in park management plans. Further, State Building Commission (SBC) policy and procedures bolster this requirement.

TDOT data produced by the CMIP3 suite represents possible scenarios for future extreme weather events—not the future that will occur with certainty. Utilization of additional future extreme weather event modeling suites would allow for analysis of added, unique model outputs, and therefore further illustrate impacts from potential extreme weather event scenarios. The park system could then have more potential “futures” that could be modeled and effectively used for planning purposes. In essence, this would allow for a greater breadth of extreme weather event occurrences and resulting impacts to facilities infrastructure.

This research opted to scale individual criticality scores and utilized a consensus approach to assign weights to the various characteristics and criteria used to determine overall criticality scores. While this approach made sense given the tools and resources available to complete this effort, the outputs of this particular phase of the research, as well as the entire vulnerability assessment framework, would benefit from further analysis of the weights assigned to factors and the methodology employed through more advanced statistical approaches. For example, performance of sensitivity analysis would capture the extent to which the results produced by the criticality scoring approach are dependent on the input criticality criteria and their respective uncertainty and potential variation. Multivariate analysis would have identified correlations and interactions among the various criticality criteria and could have allowed for further refinement of the model to better capture the influence of criticality criteria within the overall scoring approach. Additionally, as indicated by responses within the damage/impact questionnaire, respondents noted the difficulties associated with evaluating damage/impact to infrastructure resulting from a specific extreme weather event due to either the time delay between event and detection of damages or the location-specific nature of potential damages from particular extreme weather events. In this instance, statistical approaches that may prove beneficial to this research include Bayesian hierarchical modeling or interpretive structure modeling. Incorporating this next level of analysis would allow for further informed understanding and interpretation of the results produced within the context of the research.

Compilation of a park system asset inventory and further mapping these assets utilizing GIS technology proved to be a complex and time-intensive process. While a significant contribution to creating a dynamic and comprehensive inventory, the criteria utilized for inclusion in DRM’s list of insured assets excluded potential TSP assets of interest. While there is a clear need to develop a more exhaustive inventory, the inventory created for this research lays the groundwork for data attributes that might be beneficial in characterizing this future “all-assets inventory.”

This research enhanced a prior analysis performed by TDOT to understand the frequency of historic and future projected extreme weather events on a county-by-county basis. The analysis results present an opportunity for TDEC and the TSP system to interact with local stakeholders by sharing information regarding the likelihood and consequences of extreme weather events at a community level throughout the state. Such outreach and sharing of knowledge and awareness aligns with the important role that park sites already play in enhancing the livelihood of communities across Tennessee.

Beyond TDEC and the TSP system, the completion of this research can help prepare other agencies responsible for managing park assets in planning for and responding to extreme weather events. While applied to the TSP system, the decision-support tools created were designed with the flexibility for other organizations to customize the tool for diverse types of asset systems and a broad range of risk types. Specifically, these tools were developed with the intent of providing affordable vulnerability assessment approaches for use by public sector entities at the local, state, and federal level, who are often faced with limited budgets for risk management planning. The relatively simplistic design of this approach provides an entity with the opportunity to customize its data and method for employing such vulnerability assessments.

Completion of this research also leads to several broader opportunities for vulnerability assessment application and further research such as:

- Development of a vulnerability assessment template or workbook that automates the tools and methodology associated with this research. This would allow users to streamline the upload or input of assets and their associated characteristics into the tool that further processes outputs according to user specifications and purposes. This would also allow individuals with varying levels of technological expertise and comfort to utilize this resource.
- Development of extreme weather event communication tools that can be utilized by parties responsible for emergency response, as well as the general public.
- Application of the vulnerability assessment methodology within states or regions that are external to Tennessee. This could uncover areas of opportunity for improvement within the tool based on factors that are not specific to the Tennessee context. It would also gauge the effectiveness and applicability of the tool on a broader scale.
- Incorporation of Light Detection and Ranging (LIDAR) data and most current Federal Emergency Management Agency (FEMA) flood mapping and associated information to further enhance the estimation accuracy of the vulnerability assessment tool to extreme weather events, specifically heavy precipitation events.
- Investigation and analysis of circumstances under which and frequency for which wastewater treatment plants in Tennessee experience overflow events necessitating bypass, and correlations with occurrences of extreme weather events.

Appendix A - Tennessee State Parks Building Types and Use Categories

Use	Facility/Asset Type	Definition
Dining	Restaurant	Full-service, enclosed dining and kitchen facilities; often attached to or located nearby park office, inn and conference center spaces; may also be referred to as a mess hall or cafeteria.
Lodging	Cabin	A small detached house or cottage structure with sleeping and bathing accommodations; may also be referred to as a cottage, villa, or chateau.
Lodging	Campground	An outdoor area utilized for camping; may be equipped with water and electricity hookups and located near bathhouse facilities.
Lodging	Group Lodges	A detached, enclosed facility with sleeping, bathing, kitchen and dining hall accommodations for groups of varying sizes; may also be referred to as a group lodge, group cabin, or retreat center.
Lodging	Group Camps	Clusters of small cabins equipped with dining hall, bunk beds, and toilet facilities capable of accommodating 6 to 8 people.
Lodging	Inn	A single facility providing individual rooms for sleeping and bathing accommodations; often connected to restaurant and conference center facilities; may also be referred to as a hotel, lodge, etc.
Lodging/ Operations	Park Staff Residence	On-site residential homes or living quarters for park employees; includes ranger residences, superintendent homes, and other staff dwellings.
Operations	Dam	A physical barrier engineered to hold back water for the purposes of creating water supply or preventing water flow.
Operations	Maintenance Building/Shed	An enclosed facility utilized for storage of maintenance supplies, operation equipment, tools, etc.; includes craft shops, maintenance sheds, paint shops, tool rooms, etc.; may also be referred to as a shed.
Operations	Park Office/Welcome Center	An enclosed space utilized for provision of information to park visitors and/or park operations; includes park offices, welcome centers, rental offices, and other miscellaneous office and administrative spaces; may be attached to welcome or visitor center or inn or detached as independent space.
Operations	Tank	A large receptacle or storage chamber typically used for holding water or propane; most tanks are metal; may be located within an enclosed or covered facility or located below ground.
Operations	Treatment Plant	A wastewater treatment plant is a system designed to remove biological or chemical waste products from water, which permits the treated water to be used for other purposes; may also be referred to as a sewer treatment plant or system.
Operations	Pump house	An enclosed facility containing pumps for the operation of an irrigation system; often located near golf course operations.
Public Health	Bathhouse	A enclosed facility with access to showers, bathrooms, and changing facilities; may also be referred to as a washhouse.
Public Health	Restroom	A publicly accessible space or structure with a toilet and oftentimes, a washbowl or sink; may also be referred to as a bathroom, lavatory, washroom, or water closet.
Recreation	Amphitheater	A round, unroofed structure with spectator seating around a central space for events or presentations; often but not always outdoors.
Recreation	Dock	An outdoor structure extending alongshore or out from the shore into a body of water, to which boats may be attached or fishing and other recreational activities may occur; may also be referred to as a pier.

Use	Facility/Asset Type	Definition
Recreation	Historic Site	A location where political, military, natural or social history have been preserved; includes houses, landmarks, monuments, museums, etc.
Recreation	Marina	An outdoor dock or similar structure providing secure moorings for boats and often offering supply, repair, and storage functions for boats.
Recreation	Picnic Shelter	A covered structure or pavilion intended to provide protection to the public for individuals or a group of individuals who may be gathering; includes picnic shelters, golf shelters, and hiking shelters, etc.
Recreation	Playground	An outdoor play area provided for children often with structures such as slides, monkey bars, swings, etc.
Recreation	Recreation Center	A building designed to hold or coordinate recreational or sports activities and opportunities for the public.
Recreation	Stable	A covered structure utilized for keeping horses; may be referred to as a barn.
Recreation	Swimming Pool	A large, outdoor, in-ground structure filled with water and that is used for swimming.
Retail	Camp Store	A small, enclosed retail establishment offering camping supplies for purchase; typically located near campgrounds as detached facility.
Retail	Gift Shop	A small, enclosed retail establishment offering retail goods and souvenir items for purchase; typically located within welcome or visitor centers, inn, or restaurant facilities.
Retail	Laundromat	An enclosed facility with washing machines and dryers for public use; typically located within inn or near lodging facilities.
Retail	Snack Bar	A small facility, station, or hut where snacks and other concessions are sold; typically enclosed and may or may not be connected to other facilities.
Retail/ Dining/ Recreation	Conference Center	An enclosed structure capable of accommodating special events, meetings and other assemblies of people; typically located near inn or restaurant and may or may not include its own kitchen and catering space.
Retail/ Recreation	Golf Pro Shop	A small, enclosed retail establishment offering tee times, cart rental, light food and beverage, and golf equipment, clothing, and supplies operated in connection with a golf course.
Recreation	Trail	A passable travel way established and marked for recreational use.

Appendix B – Quartile Scoring Ranges for all Numeric Criticality Characteristics

Building Value Ranges		
Min	**Max**	**Rank Score**
$0	$125,000	0
$125,001	$200,000	1
$200,001	$300,000	2
$300,001	$20,691,000	3

Table B1. Building Value Criticality Characteristic Quartile Scoring Ranges

Content Value Ranges		
Min	**Max**	**Rank Score**
$0	$1,000	0
$1,001	$5,500	1
$5,501	$20,000	2
$20,001	$2,406,000	3

Table B2. Content Value Criticality Characteristic Quartile Scoring Ranges

Employee Ranges		
Min	**Max**	**Rank Score**
0	7	0
8	16	1
17	35	2
36	162	3

Table B3. Employee Criticality Characteristic Quartile Scoring Ranges

Rare Species Ranges		
Min	**Max**	**Rank Score**
0	1	0
2	3	1
4	9	2
10	57	3

Table B4. Rare Species Criticality Characteristic Quartile Scoring Ranges

Trails Ranges		
Min	**Max**	**Rank Score**
0.3	5.0	0
5.1	10.5	1
10.6	24.8	2
24.9	176.8	3

Table B5. Trails Criticality Characteristic Quartile Scoring Ranges

Visits Ranges		
Min	Max	Rank Score
15,758	250,803	0
250,804	494,273	1
494,274	846,429	2
846,430	1,958,137	3

Table B6. Visits Criticality Characteristic Quartile Scoring Ranges

Acreage Ranges		
Min	Max	Rank Score
11	352	0
353	1,172	1
1,173	2,474	2
2,475	28,170	3

Table B7. Acreage Criticality Characteristic Quartile Scoring Ranges

Park Revenue Ranges		
Min	Max	Rank Score
$0	$14,825	0
$14,826	$147,511	1
$147,512	$471,721	2
$471,722	$5,278,505	3

Table B8. Park Revenue Criticality Characteristic Quartile Scoring Ranges

Appendix C – Tennessee State Parks Assets Determined to be Critical Infrastructure

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Fall Crk Falls	GROUP CAMP 2 - MESS HALL	2.74	dining hall	Retail/Dining
Fall Crk Falls	GOLF PRO SHOP	2.74	golf pro shop	Recreation/Retail
Fall Crk Falls	NEW GUEST LODGE	2.74	inn	Lodging
Fall Crk Falls	RESORT LODGE/CONFERENCE CENTER	2.74	inn	Lodging
Fall Crk Falls	GROUP LODGE	2.74	lodge	Lodging
Fall Crk Falls	GROUP LODGE	2.74	lodge	Lodging
Natchez Trace	PARK INN - PIN OAK RESTAURANT & CONFERENCE CENTER	2.67	conference center	Retail/Dining
Natchez Trace	ADMINISTRATION AND DINING HALL - GROUP LODGE	2.67	lodge	Lodging
Fall Crk Falls	VILLAGE AREA - WALK-UP SNACK BAR	2.63	restaurant / cafeteria	Retail/Dining
Fall Crk Falls	RESORT LODGE - SWIMMING & WADING POOLS (INCL FILTER HO)	2.61	pool / pool house	Recreation
Fall Crk Falls	VILLAGE AREA - SWIMMING & WADING POOLS (INCL FILTER HO)	2.61	pool / pool house	Recreation
Fall Crk Falls	RECREATION BLDG	2.61	recreation center	Recreation
Natchez Trace	RENTAL CABIN # 8 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #1 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #10 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #2 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #3 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #4 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #5 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #6 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #7 (VILLAS)	2.56	cabin / villa	Lodging
Natchez Trace	RENTAL CABIN #9 (VILLAS)	2.56	cabin / villa	Lodging
Montgomery Bell	INN AND CONFERENCE CENTER (INCLUDING SWIMMING POOLS)	2.56	conference center	Retail/Dining
Natchez Trace	CUB LAKE LODGE	2.56	lodge	Lodging
Fall Crk Falls	SEWAGE TREATMENT PLT (INCL PUMP HO)	2.56	other	Public Health/Safety
Montgomery Bell	GROUP #1 DINING HALL	2.56	other	Dining
Montgomery Bell	NEW GOLF PRO SHOP	2.56	other	Retail
Fall Crk Falls	PARK HEADQUARTERS	2.54	office - single agency	Operations
Fall Crk Falls	GOLF MAINT BLDG	2.54	shop	Operations
Fall Crk Falls	NEW MAINTENANCE SUPPLY STORAGE SHED	2.54	storage - other	Operations
Fall Crk Falls	NATURE CENTER	2.54	welcome center / visitor center	Operations
Tims Ford	BEAR TRACE PRO SHOP	2.53	golf pro shop	Recreation/Retail
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 311	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 312	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 313	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 314	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 315	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 316	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 317	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 318	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 319	2.52	cabin / villa	Lodging
Fall Crk Falls	FISHERMAN'S VILLAGE CABIN 320	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CABIN 321	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CABIN 330	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 322	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 323	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 324	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 325	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 326	2.52	cabin / villa	Lodging

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Fall Crk Falls	LANDSIDE CBN 327	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 328	2.52	cabin / villa	Lodging
Fall Crk Falls	LANDSIDE CBN 329	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 331	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 332	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 333	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 334	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 335	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 336	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 337	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 338	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 339	2.52	cabin / villa	Lodging
Fall Crk Falls	VILLA 340	2.52	cabin / villa	Lodging
Meeman-Shelby Fst	GROUP CAMP ASSEMBLY BLDG	2.52	dining hall	Retail/Dining
Fall Crk Falls	GROUP CAMP 1 - DINING HALL	2.52	other	Dining
Natchez Trace	WRANGLER CAMP GROUND - LARGE BATH HOUSE & SHELTER	2.49	bathhouse	Public Health/Safety
Roan Mountain	CONVENTION CENTER	2.49	conference center	Retail/Dining
Natchez Trace	REGIONAL WHSE PARK MAINT. SHOP	2.47	maintenance	Operations
Natchez Trace	VISITOR'S CENTER - & - PARK OFFICE	2.47	welcome center / visitor center	Operations
Natchez Trace	PARK MAINTENANCE REPAIR SHOP	2.47		Operations
Montgomery Bell	VILLA 151	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 152	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 153	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 154	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 155	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 156	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 157	2.45	cabin / villa	Lodging
Montgomery Bell	VILLA 158	2.45	cabin / villa	Lodging
Meeman-Shelby Fst	SEWAGE TREATMENT PLANT	2.45	water treatment / sewage	Public Health/Safety
Natchez Trace	GROUP LODGE #2	2.45	lodge	Lodging
Natchez Trace	GROUP LODGE #3	2.45	lodge	Lodging
Natchez Trace	GROUP LODGE #4	2.45	lodge	Lodging
Natchez Trace	GROUP LODGE #5	2.45	lodge	Lodging
Natchez Trace	RENTAL COTTAGE - GROUP LODGE # 1	2.45	lodge	Lodging
Natchez Trace	GROCERY STORE	2.45	store	Retail
Fall Crk Falls	GOLF CART SHED	2.43	other	Operations
Fall Crk Falls	VISITOR'S LOUNGE & REST ROOMS	2.43	other	Operations
Henry Horton	GOLF PRO SHOP	2.42	golf pro shop	Recreation/Retail
Fall Crk Falls	LODGE 2-A	2.41	lodge	Lodging
Fall Crk Falls	LODGE 2-B	2.41	lodge	Lodging
Fall Crk Falls	MARINA	2.41	marina	Recreation/Retail
Fall Crk Falls	GENERAL STORE	2.41	store	Retail
Meeman-Shelby Fst	GROUP CAMP BUNKHOUSE A	2.41	dorm / student housing	Lodging
Meeman-Shelby Fst	GROUP CAMP BUNKHOUSE B	2.41	dorm / student housing	Lodging
Meeman-Shelby Fst	GROUP CAMP BUNKHOUSE C	2.41	dorm / student housing	Lodging
Meeman-Shelby Fst	GROUP CAMP BUNKHOUSE D	2.41	dorm / student housing	Lodging
Meeman-Shelby Fst	RECREATION BLDG	2.41	lodge	Lodging
Warrior's Path	RECREATION BLDG	2.39	conference center	Retail/Dining
Warrior's Path	PRO SHOP & CART SHED	2.39	golf pro shop	Recreation/Retail
Warrior's Path	MARINA	2.39	marina	Recreation/Retail
Meeman-Shelby Fst	POOL BATH HOUSE	2.39	pool / pool house	Recreation
Roan Mountain	RESTAURANT	2.38	restaurant / cafeteria	Retail/Dining
Roan Mountain	SWIMMING POOL (INCL FILTER HSE)	2.36	pool / pool house	Recreation
Natchez Trace	STORAGE SHED #1 MAINTENANCE AREA	2.36	storage - heavy equipment	Operations

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Montgomery Bell	REGIONAL WHSE	2.36	office - single agency	Operations
Montgomery Bell	EQUIPMENT BUILDING	2.36	storage - heavy equipment	Operations
Montgomery Bell	GOLF MAINTENANCE SHOP	2.36	storage - heavy equipment	Operations
Montgomery Bell	PARK MAINTENANCE SHOP	2.36	storage - heavy equipment	Operations
Montgomery Bell	WOOD SHOP	2.36	storage - other	Operations
Montgomery Bell	WAREHOUSE - MAINTENANCE BUILDING	2.36	warehouse	Operations
Montgomery Bell	VISITOR'S CENTER	2.36	welcome center / visitor center	Operations
Tims Ford	BATHHOUSE & DECK	2.35	bathhouse	Public Health/Safety
Cumberland Mtn	MILL HOUSE LODGE	2.35	cabin / villa	Lodging
Cumberland Mtn	BEAR TRACE PRO SHOP	2.35	golf pro shop	Recreation/Retail
Cumberland Mtn	RESTAURANT	2.35	restaurant / cafeteria	Retail/Dining
Edgar Evins	4 UNITS - CABIN 6 (A)	2.34	cabin / villa	Lodging
Edgar Evins	6 UNITS - CABIN 1 (B)	2.34	cabin / villa	Lodging
Edgar Evins	6 UNITS - CABIN 2 (C)	2.34	cabin / villa	Lodging
Edgar Evins	6 UNITS - CABIN 3 (D)	2.34	cabin / villa	Lodging
Edgar Evins	6 UNITS - CABIN 4 (E)	2.34	cabin / villa	Lodging
Edgar Evins	6 UNITS - CABIN 5 (F)	2.34	cabin / villa	Lodging
Fall Crk Falls	IRRIGATION PUMP HOUSE	2.34	pump house	Public Health/Safety
Natchez Trace	DUPLEX VACATION COTTAGE #7	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #1	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #10	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #11	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #12	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #13	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #14	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #15	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #16	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #17	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #2	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #3	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #4	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #5	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #6	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #8	2.34	cabin / villa	Lodging
Natchez Trace	VAC COTTAGE #9	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1 - DOUBLE CABINS #16-18-19-20-21-22- 25-27	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS # 31-32-33-34-36-37- 38-42	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS #2-3-4-5-7-10-11 13	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS #2-3-4-5-7-10-11 13	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS #2-3-4-5-7-10-11 13	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS #2-3-4-5-7-10-11 13	2.34	cabin / villa	Lodging
Montgomery Bell	GROUP CAMP #1-DOUBLE CABINS #2-3-4-5-7-10-11 13	2.34	cabin / villa	Lodging
Natchez Trace	BUNKHOUSE IN GROUP LODGE	2.34	lodge	Lodging
Tims Ford	BEAR TRACE MAINTENACE BUILDING	2.33	maintenance	Operations
Tims Ford	EQUIPMENT SHED	2.33	maintenance	Operations
Tims Ford	MAINTENANCE BLDG	2.33	maintenance	Operations
Tims Ford	NEW VISITORS CENTER	2.33	welcome center / visitor center	Operations
Pickwick Landing	GOLF PRO SHOP	2.32	golf pro shop	Recreation/Retail
Pickwick Landing	INN & CONFERENCE CENTER	2.32	inn	Lodging
Meeman-Shelby Fst	MAINTENANCE SHOP AND EQUIPMENT SHED	2.32	maintenance	Operations
Pickwick Landing	MARINA	2.32	marina	Recreation/Retail
Fall Crk Falls	GROUP CAMP 2 - RECREATION BLDG & OFFICE	2.32	other	Operations
Warrior's Path	BATH HOUSE	2.32	restrooms	Public Health/Safety
Fall Crk Falls	WAREHOUSE & TOOL WORKSHOP (OLD MAINT AREA)	2.32	shop	Operations
Fall Crk Falls	EQUIPMENT SHED	2.32	warehouse	Operations
Meeman-Shelby Fst	VISITOR CENTER/PARK OFFICE	2.32	welcome center / visitor center	Operations
Natchez Trace	CUB LAKE BOAT DOCK AND RENTAL HOUSE	2.32	boat house	Recreation
Natchez Trace	EQUESTRIAN CENTER	2.32	other	Recreation
Pickett	ASSEMBLY HALL	2.30	conference center	Retail/Dining
Tims Ford	ACTIVITIES BLDG	2.29	recreation center	Recreation
Roan Mountain	MAINTENANCE BLD	2.29	shop	Operations
Roan Mountain	VISITORS CENTER	2.29	welcome center / visitor center	Operations
Cumberland Mtn	SWIMMING POOL BATHHOUSE (NEW)	2.28	restrooms	Public Health/Safety
Meeman-Shelby Fst	MISSISSIPPI RIVER GROUP CAMP DINING HALL	2.28	historic structure	Recreation
Natchez Trace	BATH HOUSE #1 (PIN OAK R.V. CAMP)	2.27	bathhouse	Public Health/Safety
Natchez Trace	BATH HOUSE #2 (PIN OAK R.V. CAMP)	2.27	bathhouse	Public Health/Safety
Natchez Trace	200,000-GALLON STEEL STANDPIPE TANK (PENNY TRAIL)	2.27	water control structure	Public Health/Safety
Warrior's Path	SWIMMING POOL	2.26	pool / pool house	Recreation
Harrison Bay	BEAR TRACE PRO SHOP	2.25	golf pro shop	Recreation/Retail
Harrison Bay	MARINA & REST	2.25	restaurant / cafeteria	Retail/Dining
Cumberland Mtn	COON HOLLOW CABIN	2.24	cabin / villa	Lodging
Fall Crk Falls	CAMPGROUND B - WASH HOUSE #1	2.23	bathhouse	Public Health/Safety
Fall Crk Falls	CAMPGROUND B - WASH HOUSE #2	2.23	bathhouse	Public Health/Safety
Fall Crk Falls	CAMPGROUND B - WASH HOUSE #3	2.23	bathhouse	Public Health/Safety
Big Ridge	GROUP CAMP DINING HALL	2.23	conference center	Retail/Dining
Big Ridge	RECREATION HALL & LAUNDRY ROOM	2.23	conference center	Retail/Dining
Natchez Trace	HORSE BARN - CORINTH ROAD	2.23	lodge	Lodging
Fall Crk Falls	GROUP CAMP 2 - STANDPIPE #2	2.23	other	Public Health/Safety
Fall Crk Falls	STABLES AREA - STANDPIPE #1	2.23	other	Public Health/Safety
Fall Crk Falls	PUMPING STATION @ FISHERMAN'S VILLAGE	2.23	pump house	Public Health/Safety
Fall Crk Falls	PUMPING STATION @ MARINA	2.23	pump house	Public Health/Safety

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Fall Crk Falls	PUMPING STATION @ RESORT LODGE	2.23	pump house	Public Health/Safety
Fall Crk Falls	CAMPGROUND A - BATH HOUSE	2.23	restrooms	Public Health/Safety
Fall Crk Falls	CAMPGROUND C - BATH HOUSE	2.23	restrooms	Public Health/Safety
Fall Crk Falls	MARINA COMFORT STATION	2.23	restrooms	Public Health/Safety
Cumberland Mtn	RECREATION PAV	2.22	recreation center	Recreation
Fall Crk Falls	ICE HOUSE	2.21	other	Operations
Fall Crk Falls	MAINTENANCE AREA - PERMANENT STAFF DWG #2	2.21	residence	Park Staff Res
Fall Crk Falls	MAINTENANCE AREA - PERMANENT STAFF DWG #3	2.21	residence	Park Staff Res
Fall Crk Falls	MAINTENANCE AREA - PERMANENT STAFF DWG #4	2.21	residence	Park Staff Res
Fall Crk Falls	NORTH ENTRANCE - PERMANENT STAFF DWG #1	2.21	residence	Park Staff Res
Fall Crk Falls	RANGER'S DWG (FMLY SUPT)	2.21	residence	Park Staff Res
Fall Crk Falls	TENT CAMP AREA - PERMANENT STAFF DWG #5	2.21	residence	Park Staff Res
Fall Crk Falls	MAINT SHOP	2.21	shop	Operations
Fall Crk Falls	STORAGE BLDG & PLANNER ROOM (OLD MAINT AREA)	2.21	shop	Operations
Fall Crk Falls	EQUIPMENT STORAGE BUILDING	2.21	storage - other	Operations
Meeman-Shelby Fst	NEW RIDING STABLE	2.21	storage - other	Operations
Meeman-Shelby Fst	STORAGE BUILDING (INCLUDING RADIO ANTENNA & REPEATER)	2.21	storage - other	Operations
Tims Ford	CABIN #1	2.20	cabin / villa	Lodging
Tims Ford	CABIN #10	2.20	cabin / villa	Lodging
Tims Ford	CABIN #11	2.20	cabin / villa	Lodging
Tims Ford	CABIN #12	2.20	cabin / villa	Lodging
Tims Ford	CABIN #13	2.20	cabin / villa	Lodging
Tims Ford	CABIN #14	2.20	cabin / villa	Lodging
Tims Ford	CABIN #15	2.20	cabin / villa	Lodging
Tims Ford	CABIN #16	2.20	cabin / villa	Lodging
Tims Ford	CABIN #17	2.20	cabin / villa	Lodging
Tims Ford	CABIN #18	2.20	cabin / villa	Lodging
Tims Ford	CABIN #19	2.20	cabin / villa	Lodging
Tims Ford	CABIN #2	2.20	cabin / villa	Lodging
Tims Ford	CABIN #20	2.20	cabin / villa	Lodging
Tims Ford	CABIN #3	2.20	cabin / villa	Lodging
Tims Ford	CABIN #4	2.20	cabin / villa	Lodging
Tims Ford	CABIN #5	2.20	cabin / villa	Lodging
Tims Ford	CABIN #6	2.20	cabin / villa	Lodging
Tims Ford	CABIN #7	2.20	cabin / villa	Lodging
Tims Ford	CABIN #8	2.20	cabin / villa	Lodging
Tims Ford	CABIN #9	2.20	cabin / villa	Lodging
Tims Ford	BAIT SHOP	2.20	concession / vending	Retail/Dining
Nathan Bedford Fst	GROUP LODGE	2.20	lodge	Lodging
Cedars of Lebanon	GROUP LODGE	2.20	lodge	Lodging
Meeman-Shelby Fst	VACATION CBN #1	2.19	cabin / villa	Lodging
Meeman-Shelby Fst	VACATION CBN #2	2.19	cabin / villa	Lodging
Meeman-Shelby Fst	VACATION CBN #3	2.19	cabin / villa	Lodging
Meeman-Shelby Fst	VACATION CBN #4	2.19	cabin / villa	Lodging
Meeman-Shelby Fst	VACATION CBN #5	2.19	cabin / villa	Lodging
Meeman-Shelby Fst	VACATION CBN #6	2.19	cabin / villa	Lodging
Pickett	CABIN 16	2.19	cabin / villa	Lodging
Pickett	CABIN 17	2.19	cabin / villa	Lodging
Pickett	CABIN 18	2.19	cabin / villa	Lodging
Pickett	CABIN 19	2.19	cabin / villa	Lodging
Pickett	CABIN 20	2.19	cabin / villa	Lodging
Warrior's Path	GOLF COURSE MAINT BUILDING	2.19	shop	Operations
Warrior's Path	PARK MAINTANENCE	2.19	shop	Operations

PARK	NAME	CRITICALITY SCORE	BUILDING TYPE	BUILDING CATEGORY
Fall Crk Falls	DAM	2.01	dam	Public Health/Safety
Natchez Trace	DAM	1.94	dam	Public Health/Safety
Montgomery Bell	DAM	1.83	dam	Public Health/Safety
Montgomery Bell	DAM	1.83	dam	Public Health/Safety
Montgomery Bell	DAM	1.83	dam	Public Health/Safety
Meeman-Shelby Fst	DAM	1.79	dam	Public Health/Safety
Meeman-Shelby Fst	DAM	1.79	dam	Public Health/Safety
Cumberland Mtn	DAM	1.62	dam	Public Health/Safety
Big Ridge	DAM	1.61	dam	Public Health/Safety
Pickett	DAM	1.57	dam	Public Health/Safety
Reelfoot Lake	DAM	1.44	dam	Public Health/Safety
David Crockett	DAM	1.41	dam	Public Health/Safety
Radnor Lake	DAM	1.40	dam	Public Health/Safety
South Cumberland	DAM	1.35	dam	Public Health/Safety
South Cumberland	DAM	1.35	dam	Public Health/Safety
Cove Lake	DAM	1.26	dam	Public Health/Safety
Chickasaw	DAM	1.22	dam	Public Health/Safety
Chickasaw	DAM	1.22	dam	Public Health/Safety
Standing Stone	DAM	1.22	dam	Public Health/Safety
Big Hill Pond	DAM	1.06	dam	Public Health/Safety
Fort Pillow	DAM	1.03	dam	Public Health/Safety
Old Stone Ft	DAM	1.00	dam	Public Health/Safety
Dunbar Cave	DAM	0.75	dam	Public Health/Safety
Burgess Falls	DAM	0.39	dam	Public Health/Safety

Appendix D – NWS Definitions of Extreme Weather Event Types for Tennessee Park Systems

Cold/Wind Chill: Period of low temperatures or wind chill temperatures reaching or exceeding locally/regionally defined advisory (typical value is -18°F or colder) conditions, on a widespread or localized basis. There can be situations where advisory criteria are not met, but the combination of seasonably cold temperatures and low wind chill values (roughly 15°F below normal) must result in a fatality.

Drought: Drought is a deficiency of moisture that results in adverse impacts on people, animals, or vegetation over a sizeable area. Conceptually, drought is a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield.

Dust Devil: A ground-based, rotating column of air, not in contact with a cloud base, usually of short duration, rendered visible by dust, sand, or other debris picked up from the ground, resulting in a fatality, injury, or damage.

Excessive Heat: Excessive Heat results from a combination of high temperatures (well above normal) and high humidity. An Excessive Heat event occurs and is reported in Storm Data whenever heat index values meet or exceed locally/regionally established excessive heat warning thresholds, on a widespread or localized basis.

Extreme Cold/Wind Chill: A period of extremely low temperatures or wind chill temperatures reaching or exceeding locally/regionally defined warning criteria (typical value around -35°F or colder), on a widespread or localized basis.

Flash Flood: A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam-related), on a widespread or localized basis. Ongoing flooding can intensify to flash flooding in cases where intense rainfall results in a rapid surge of rising flood waters. Flash floods do not exist for two or three consecutive days.

Flood: Any high flow, overflow, or inundation by water which causes or threatens damage. In general, this would mean the inundation of a normally dry area caused by an increased water level in an established watercourse, or ponding of water, generally occurring more than 6 hours after the causative event, and posing a threat to life or property. This can be on a widespread or localized basis.

Freezing Fog: Fog which freezes on contact with exposed objects and forms a coating of rime and/or glaze, on a widespread or localized basis, resulting in an impact on transportation, commerce, or individuals. Freezing fog can occur with any visibility of 6 miles or less.

Frost/Freeze: A surface air temperature of 32°F or lower, or the formation of ice crystals on the ground or other surfaces, over a widespread or localized area for a period of time long enough to cause human or economic impact, during the locally defined growing season.

Funnel Cloud: A rotating, visible, extension of a cloud pendant from a convective cloud with circulation not reaching the ground. This would include cold-air funnels which typically form in a shallow, cool air mass behind a cold front. The funnel cloud should be large, noteworthy, or create strong public interest.

Hail: Frozen precipitation in the form of balls or irregular lumps of ice. Hail ¾ of an inch or larger in diameter or hail accumulations of smaller size which cause property and/or crop damage, or casualties.

Heat: A period of heat resulting from the combination of high temperatures (above normal) and relative humidity during which heat index values meet or exceed locally/regionally established advisory thresholds.

Heavy Rain: Unusually large amount of rain which does not cause a flash flood or flood, but causes damage, e.g., roof collapse or other human/economic impact.

Heavy Snow: Snow accumulation meeting or exceeding locally/regionally defined 12 and/or 24 hour warning criteria, on a widespread or localized basis. This could mean such values as 4, 6, or 8 inches or more in 12 hours or less; or 6, 8, or 10 inches in 24 hours or less.

High Wind: Sustained non-convective winds of 35 knots (40 mph) or greater lasting for 1 hour or longer or winds (sustained or gusts) of 50 knots (58 mph) for any duration (or otherwise locally/regionally defined), on a widespread or localized basis.

Ice Storm: Ice accretion meeting or exceeding locally/regionally defined warning criteria (typical value is ¼ or ½ inch or more), on a widespread or localized basis.

Lightning: A sudden electrical discharge from a thunderstorm, resulting in a fatality, injury, and/or damage.

Sleet: Sleet accumulations meeting or exceeding locally/regionally defined warning criteria (typical value is ½ inch or more).

Strong Wind: Non-convective winds gusting less than 50 knots (58 mph), or sustained winds less than 35 knots (40 mph), resulting in a fatality, injury, or damage.

Thunderstorm Wind: Winds, arising from convection (occurring within 30 minutes of lightning being observed or detected), with speeds of at least 50 knots (58 mph), or winds of any speed (non-severe thunderstorm winds below 50 knots) producing a fatality, injury, or damage.

Tornado: A violently rotating column of air, extending to or from a cumuliform cloud or underneath a cumuliform cloud, to the ground, and often (but not always) visible as a condensation funnel. Literally, in order for a vortex to be classified as a tornado, it must be in contact with the ground and extend to/from the cloud base, and there should be some semblance of ground-based visual effects such as dust/dirt rotational markings/swirls, or structural or vegetative damage or disturbance.

Winter Storm: A winter weather event which has more than one significant hazard (i.e., heavy snow and blowing snow; snow and ice; snow and sleet; sleet and ice; or snow, sleet and ice) and meets or exceeds locally/regionally defined 12 and/or 24 hour warning criteria for at least one of the precipitation elements, on a widespread or localized basis. Normally, a winter storm would pose a threat to life or property.

Winter Weather: A winter precipitation event that causes a death, injury, or a significant impact to commerce or transportation but does not meet locally/regionally defined warning criteria. A Winter Weather event could result from one or more winter precipitation types (snow, or blowing/drifting snow, or freezing rain/drizzle), on a widespread or localized basis.

Appendix E – NWS Memphis Forecast Office Extreme Weather Notification Thresholds (NWS, 2011)[26]

CONVECTIVE		
Headline	**Issuance Criteria**	**Typical Leadtime**
Severe Thunderstorm Watch	Conditions are favorable for thunderstorms containing 1 inch or larger hail and/or wind gusts of at least 58 mph (50 knots).	6 to 8 hours
Particularly Dangerous Situation (PDS) Severe Thunderstorm Watch	Conditions are favorable for thunderstorms containing 1 inch or larger hail and/or wind gusts of at least 80 mph (64 knots). Typically issued for widespread, significant non-tornadic severe weather events.	6 to 8 hours
Tornado Watch	Conditions are favorable for thunderstorms producing tornadoes. Hail and strong winds are also possible.	6 to 8 hours
PDS Tornado Watch	Conditions are favorable for thunderstorms producing tornadoes. Hail and strong winds are also possible. Typically issued when there is a likelihood of multiple strong (damage of EF2 or EF3) or violent (damage of EF4 or EF5) tornadoes.	6 to 8 hours
Severe Thunderstorm Warning	A thunderstorm producing 1 inch or larger hail and/or wind gusts of at least 58 mph (50 knots) are occurring or imminent.	20 to 60 minutes
Tornado Warning	A tornado has been reported or is highly likely to occur due to Doppler radar signatures.	15 to 45 minutes
Significant Weather Advisory	Issued under the Special Weather Statement product for strong thunderstorms producing winds between 40 and 57 mph, and/or hail less than 1 inch in diameter, and/or frequent or continuous lightning, and/or funnel clouds or cold air funnels.	Up to 1 hour
HYDROLOGY		
Headline	**Issuance Criteria**	**Typical Leadtime**
Flash Flood Watch	Rapidly developing and life-threatening flooding is possible due to a hydrologic event (e.g., heavy rain) or dam or levee failure.	6 to 48 hours
Flood Watch	Flood Watch (Areal): Flooding of land and/or rivers and streams is possible. Flood Watch (Forecast Point): Flooding is possible at a particular point on a river or stream.	6 to 48 hours
Flash Flood Warning	Flash flooding is reported; and/or a dam or levee failure is imminent or occurring; and/or a sudden failure of a naturally-caused stream obstruction (including debris slide, avalanche, or ice jam) is imminent or occurring; and/or precipitation capable of causing flash flooding is indicated by radar, rain gages, and/or satellite; and/or precipitation as indicated by radar, rain gages, satellite and/or other guidance is capable of causing debris flows, particularly (but not only) in burn areas; and/or local monitoring and prediction tools indicate flash flooding is likely; and/or a hydrologic model indicates flash flooding for locations on small streams.	30 minutes to 6 hours
Flood Warning	Flood Warning (Areal): Issued for any high flow, overflow, or inundation in a geographic area which threatens life and property and is not appropriately covered by a flash flood warning or flood warning for forecast points. Flood Warning (Forecast Point): Issued for any high flow, overflow, or inundation event threatening life and/or property which can be quantified or indexed at specific locations and is not accounted for in areal flood or flash flood warning products. Flood warnings for forecast points usually include information on upstream and/or downstream locations which are impacted.	3+ hours
Flood Advisory	Flood Advisory (Areal/Forecast Point/Urban and Small Stream): Issued when flooding is expected to be of inconvenience, but not necessarily life-threatening.	30 minutes to 6 hours
Non-Precipitation		
Headline	**Issuance Criteria**	**Typical Leadtime**

[26] Listing of headlines has been excerpted such that it only reflects those events which have occurred within Tennessee and indicated within the NWS storm events database.

Excessive Heat	Conditions favorable for heat indices to reach 110°F due to a combination of heat and humidity.	24 to 72 hours
Freeze Watch	Minimum shelter temperatures below 32°F are possible during the growing season which poses a threat to plants and crops.	18 to 48 hours
Hard Freeze Watch	Minimum shelter temperatures may drop to 28°F or lower during the growing season which poses an especially high risk plants and crops.	18 to 48 hours
High Wind Watch	Conditions are favorable for sustained winds of at least 40 mph for one hour or longer, or wind gusts of at least 58 mph of any duration.	18 to 48 hours
Excessive Heat Warning	Heat index values of 110°F or higher during the day with low temperatures ≥ 75°F at night are occurring or imminent.	12 to 48 hours
Freeze Warning	Minimum shelter temperatures below 32°F are expected during the growing season which poses a threat to plants and crops.	12 to 36 hours
Hard Freeze Warning	Minimum shelter temperatures are expected to drop to 28°F or lower during the growing season which poses an especially high risk to plants and crops.	12 to 36 hours
High Wind Warning	Sustained winds of at least 40 mph for one hour or longer, or wind gusts of at least 58 mph of any duration are expected.	12 to 36 hours
Dense Fog Advisory	Widespread or localized fog reducing visibilities to ¼ mile or less.	6 to 36 hours
Freezing Fog Advisory	Very light ice accumulation resulting from freezing fog (no visibility requirement).	6 to 36 hours
Frost Advisory	Minimum shelter temperature forecast to be 33 to 36°F during the growing season on nights with good raditational cooling making conditions conducive for frost formation (e.g., light winds, clear skies, high humidity.)	12 to 36 hours
Heat Advisory	The combination of heat and humidity making for heat indices between 105°F to 109°F.	12 to 36 hours
Wind Advisory	Sustained wind speeds of 25 to 39 mph lasting for 1 hour or longer.	12 to 36 hours
	WINTER	
Headline	**Issuance Criteria**	**Typical Leadtime**
Blizzard watch	Possibility of sustained winds or wind gusts above 35 mph causing falling and/or blowing snow to reduce visibilities below ¼ mile for 3 hours or longer	12 to 48 hours
Wind Chill Watch	Possibility of very cold temperatures and brisk winds causing dangerously cold wind chills of -18°F or colder.	12 to 48 hours
Winter Storm Watch	Possibility of accumulating snow, sleet, and/or freezing rain causing significant impacts to society and commerce.	12 to 48 hours
Blizzard Warning	Sustained winds or frequent gusts of 35 mph or higher causing falling and/or blowing snow to reduce visibilities below ¼ mile for 3 hours or longer are imminent or occurring.	8 to 36 hours
Ice Storm Warning	Heavy ice accumulation of ¼ inch or greater due to freezing rain is imminent or occurring.	8 to 36 hours
Wind Chill Warning	Very cold air temperatures and brisk winds causing dangerously cold wind chills of -18°F or colder are imminent or occurring. Hypothermia, frost bite, or death is likely if proper precautions are not taken.	8 to 36 hours
Winter Storm Warning	Heavy snow and/or sleet and ice accumulations are imminent or occurring. Society and commerce is expected to be greatly impacted. Precipitation may be accompanied by gusty wind. For a mixture of snow, sleet or freezing rain, only two inches of snow is required.	8 to 36 hours
Freezing Rain Advisory	Ice accumulation less than ¼ inch due to freezing rain is imminent or occurring.	8 to 24 hours
Wind Chill Advisory	Cold temperatures and brisk wind causing hazardous wind chills of 0 to -17°F are imminent or occurring. Hypothermia and frost bite are possible if proper precautions are not taken.	8 to 24 hours
Winter Weather Advisory	Snow and/or sleet and ice accumulations causing an inconvenient to society and commerce are imminent or occurring.	8 to 24 hours

Appendix F – Tennessee State Parks Infrastructure Damage Survey

Introduction

This survey is part of a project that Tennessee State Parks has undertaken to evaluate and identify critical state park assets that may be vulnerable to future extreme weather events. As part of the project, we need to identify the extent to which different forms of extreme weather would cause damages or disruption to individual state park structures and assets, as well as to the entire park system as a whole using input from experts like you.

Your responses to the following questions, which should only take a few minutes to complete, will greatly benefit the project. If you are unsure of a response to a particular field, indicate as such within the comments field on each page. Please read each question and all response choices carefully. There are opportunities throughout the survey to provide comments or qualifying statements on your responses to further provide input into this process.

Thanks in advance for your assistance!

1. Please provide your zip code. This is to ensure that we have responses represented from a variety of geographic areas. ___________________________________

Asset Categories

This questionnaire refers to four categories of infrastructure:

- Dining & Lodging (restaurants, cabins, inns, group lodges, conference center, park staff residences)
- Camping & Outdoor Recreation (campgrounds, group camps, picnic shelters, trails, playgrounds, stables, swimming pools, marinas, docks, amphitheaters)
- Operations (pumphouses, dams, maintenance sheds/buildings, bathhouses, restrooms, water or propane tanks, park office or welcome center, treatment plants)
- Retail (camp stores, gift shops, Laundromats, snack bars, pro shops)

Even if you only feel comfortable commenting on one type of infrastructure within each category (for example staff residences within dining & lodging), please still provide a response for that category.

2. Do you feel knowledgeable about and comfortable with assessing the impacts of weather conditions to Dining & Lodging infrastructure (restaurants, cabins, inns, group lodges, conference center, park staff residences)?
   - ☐ Yes (If yes, respondent directed to question 4.)
   - ☐ No (If no, respondent directed to question 5.)
3. Please indicate the extent to which you feel damages and disruption would occur to Dining & Lodging infrastructure (restaurants, cabins, inns, group lodges, conference center, park staff residences) due to each weather condition listed below. (One response per row.)

Condition	Not Applicable/ Unsure	Nominal (≤ $25,000 of damage)	Moderate ($25,000 ≤ $100,000 damage)	Significant ($100,000 ≤ $500,000 damage)	Catastrophic (≥ $500,000)
Excessive Heat – Heat index of at least 110°F or higher for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
High Wind – Sustained non-convective winds of 40 mph or greater lasting for one hour or longer; or winds of 58 mph for any duration.					
Lightning – Strike associated with a sudden electrical discharge.					
Flash Flood – A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure).					
Flood – Any high flow, overflow, or inundation by water.					
Heavy Rain – An unusually large amount of rain which does not cause a Flash Flood or Flood.					
Cold/Wind Chill – Low temperatures or wind chill temperatures of zero to -17°F.					
Extreme Cold/Wind Chill – Low temperatures or wind chill temperatures of -18°F or colder.					
Ice Storm – Ice accretion meeting or exceeding ¼''.					
Hail – Frozen precipitation in the form of balls or irregular lumps of ice that are ≥ ¾''.					
Heavy Snow – Snow accumulation meeting or exceeding 4'' or more in 12 hours or less; or 6'' or more in 24 hours or less.					
Tornado – Rotating column of air extending to the ground with winds up to 157 mph (up to F2 level); damage typically includes roofs torn off frame houses, mobile homes destroyed, large trees snapped or uprooted, cars lifted off ground.					
Severe Tornado – Rotating column of air extending to the ground with winds exceeding 158 mph (F3 or greater); damage typically includes leveling of well-constructed homes, structures with weak foundations blown away a fair distance; cars thrown.					
Severe Thunderstorm – Thunderstorms containing 1 inch diameter or larger hail and/or wind gusts of at least 58 mph.					

Comments:

4. Do you feel knowledgeable about and comfortable with assessing the impacts of weather conditions to Camping & Outdoor Recreation infrastructure (campgrounds, group camps, picnic shelters, trails, playgrounds, stables, swimming pools, marinas, docks, amphitheaters)?
   - ☐ Yes (If yes, respondent directed to question 6.)
   - ☐ No (If no, respondent directed to question 7.)

5. Please indicate the extent to which you feel damages and disruption would occur to Camping & Outdoor Recreation (campgrounds, group camps, picnic shelters, trails, playgrounds, stables, swimming pools, marinas, docks, amphitheaters) due to each weather condition listed below.

Condition	Not Applicable/ Unsure	Nominal (≤ $25,000 of damage)	Moderate ($25,000 ≤ $100,000 damage)	Significant ($100,000 ≤ $500,000 damage)	Catastrophic (≥ $500,000)
Excessive Heat – Heat index of at least 110°F or higher for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
Heat – Heat indices between 105-109°F for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
Drought – Two or more months of deficient precipitation that results in adverse impacts over a sizeable area.					
High Wind – Sustained non-convective winds of 40 mph or greater lasting for one hour or longer; or winds of 58 mph for any duration.					
Lightning – Strike associated with a sudden electrical discharge.					
Flash Flood – A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure).					
Flood – Any high flow, overflow, or inundation by water.					
Heavy Rain – An unusually large amount of rain which does not cause a Flash Flood or Flood.					
Cold/Wind Chill – Low temperatures or wind chill temperatures of zero to -17°F.					
Extreme Cold/Wind Chill – Low temperatures or wind chill temperatures of -18°F or colder.					
Frost/Freeze – A surface air temperature of 32°F or lower, or the formation of ice crystals on the ground or other surfaces.					
Ice Storm – Ice accretion meeting or exceeding ¼''.					
Hail – Frozen precipitation in the form of balls or irregular lumps of ice that are ≥ ¾''.					
Heavy Snow – Snow accumulation meeting or exceeding 4'' or more in 12 hours or less; or 6'' or more in 24 hours or less.					
Tornado – Rotating column of air extending to the ground with winds up to 157 mph (up to F2 level); damage typically includes roofs torn off frame houses, mobile homes destroyed, large trees snapped or uprooted, cars lifted off ground.					
Severe Tornado – Rotating column of air extending to the ground with winds exceeding 158 mph (F3 or greater); damage typically includes leveling of well-constructed homes, structures with weak foundations blown away a fair distance; cars					

thrown.					
Severe Thunderstorm – Thunderstorms containing 1 inch diameter or larger hail and/or wind gusts of at least 58 mph.					

Comments:

6. Do you feel knowledgeable about and comfortable with assessing the impacts of weather conditions to Operations infrastructure (pumphouses, dams, maintenance sheds/buildings, bathhouses, restrooms, water or propane tanks, park office or welcome center, treatment plants)?
   - ☐ Yes (If yes, respondent directed to question 8.)
   - ☐ No (If no, respondent directed to question 9.)
7. Please indicate the extent to which you feel damages and disruption would occur to Operations (pumphouses, dams, maintenance sheds/buildings, bathhouses, restrooms, water or propane tanks, park office or welcome center, treatment plants) due to each weather condition listed below.

Condition	Not Applicable/ Unsure	Nominal (≤ $25,000 of damage)	Moderate ($25,000 ≤ $100,000 damage)	Significant ($100,000 ≤ $500,000 damage)	Catastrophic (≥ $500,000)
Excessive Heat – Heat index of at least 110°F or higher for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
Heat – Heat indices between 105-109°F for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
Drought – Two or more months of deficient precipitation that results in adverse impacts over a sizeable area.					
High Wind – Sustained non-convective winds of 40 mph or greater lasting for one hour or longer; or winds of 58 mph for any duration.					
Lightning – Strike associated with a sudden electrical discharge.					
Flash Flood – A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure).					
Flood – Any high flow, overflow, or inundation by water.					
Heavy Rain – An unusually large amount of rain which does not cause a Flash Flood or Flood.					
Cold/Wind Chill – Low temperatures or wind chill temperatures of zero to -17°F.					
Extreme Cold/Wind Chill – Low temperatures or wind chill temperatures of -18°F or colder.					
Frost/Freeze – A surface air temperature of 32°F or lower, or the formation of ice crystals on the ground or other surfaces.					
Ice Storm – Ice accretion meeting or exceeding ¼’’.					
Hail – Frozen precipitation in the form of balls or irregular lumps of ice that are ≥ ¾’’.					
Heavy Snow – Snow accumulation meeting or					

exceeding 4'' or more in 12 hours or less; or 6'' or more in 24 hours or less.					
Tornado – Rotating column of air extending to the ground with winds up to 157 mph (up to F2 level); damage typically includes roofs torn off frame houses, mobile homes destroyed, large trees snapped or uprooted, cars lifted off ground.					
Severe Tornado – Rotating column of air extending to the ground with winds exceeding 158 mph (F3 or greater); damage typically includes leveling of well-constructed homes, structures with weak foundations blown away a fair distance; cars thrown.					
Severe Thunderstorm – Thunderstorms containing 1 inch diameter or larger hail and/or wind gusts of at least 58 mph.					

Comments:

8. Do you feel knowledgeable about and comfortable with assessing the impacts of weather conditions to Retail infrastructure (camp stores, gift shops, Laundromats, snack bars, pro shops)?
   - ☐ Yes (If yes, respondent directed to question 10.)
   - ☐ No (If no, respondent directed to end of survey.)
9. Please indicate the extent to which you feel damages and disruption would occur to Retail infrastructure (camp stores, gift shops, Laundromats, snack bars, pro shops) due to each weather condition listed below.

Condition	Not Applicable/ Unsure	Nominal (≤ $25,000 of damage)	Moderate ($25,000 ≤ $100,000 damage)	Significant ($100,000 ≤ $500,000 damage)	Catastrophic (≥ $500,000)
Excessive Heat – Heat index of at least 110°F or higher for more than 3 hours per day and nighttime low temperatures of 75°F or higher for at least 2 days.					
High Wind – Sustained non-convective winds of 40 mph or greater lasting for one hour or longer; or winds of 58 mph for any duration.					
Lightning – Strike associated with a sudden electrical discharge.					
Flash Flood – A rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within 6 hours of the causative event (e.g., intense rainfall, dam failure).					
Flood – Any high flow, overflow, or inundation by water.					
Heavy Rain – An unusually large amount of rain which does not cause a Flash Flood or Flood.					
Cold/Wind Chill – Low temperatures or wind chill temperatures of zero to -17°F.					
Extreme Cold/Wind Chill – Low temperatures or wind chill temperatures of -18°F or colder.					
Frost/Freeze – A surface air temperature of 32°F or lower, or the formation of ice crystals on the ground or other surfaces.					

Ice Storm – Ice accretion meeting or exceeding ¼''.					
Hail – Frozen precipitation in the form of balls or irregular lumps of ice that are ≥ ¾''.					
Heavy Snow – Snow accumulation meeting or exceeding 4'' or more in 12 hours or less; or 6'' or more in 24 hours or less.					
Tornado – Rotating column of air extending to the ground with winds up to 157 mph (up to F2 level); damage typically includes roofs torn off frame houses, mobile homes destroyed, large trees snapped or uprooted, cars lifted off ground.					
Severe Tornado – Rotating column of air extending to the ground with winds exceeding 158 mph (F3 or greater); damage typically includes leveling of well-constructed homes, structures with weak foundations blown away a fair distance; cars thrown.					
Severe Thunderstorm – Thunderstorms containing 1 inch diameter or larger hail and/or wind gusts of at least 58 mph.					

Comments:

Thank you for your response to this questionnaire!

Appendix G – Impact Scores by Infrastructure Type and Weather Event

	Dining & Lodging	Camping & Outdoor Recreation	Operations	Retail Infrastructure
Excessive Heat	1.20	1.19	1.23	1.32
Heat	[redacted]	1.13	1.18	[redacted]
Drought	[redacted]	1.20	1.09	[redacted]
High Wind	1.63	1.52	1.49	1.35
Lightning	1.86	1.70	1.91	1.73
Flash Flood	2.22	1.81	1.93	2.04
Flood	2.13	1.93	2.07	1.88
Heavy Rain	1.21	1.41	1.29	1.33
Cold/Wind Chill	1.34	1.30	1.37	1.38
Extreme Cold/Wind Chill	1.55	1.48	1.52	1.48
Frost/Freeze	[redacted]	1.24	1.21	1.19
Ice Storm	1.90	1.67	1.80	1.86
Hail	1.71	1.49	1.53	1.61
Heavy Snow	1.60	1.55	1.43	1.58
Tornado	3.17	2.87	2.72	2.67
Severe Tornado	3.57	3.26	3.19	3.09
Severe Thunderstorm	1.85	1.74	1.58	1.77

Appendix H – Average Annual Historic Extreme Weather by Event Type and County

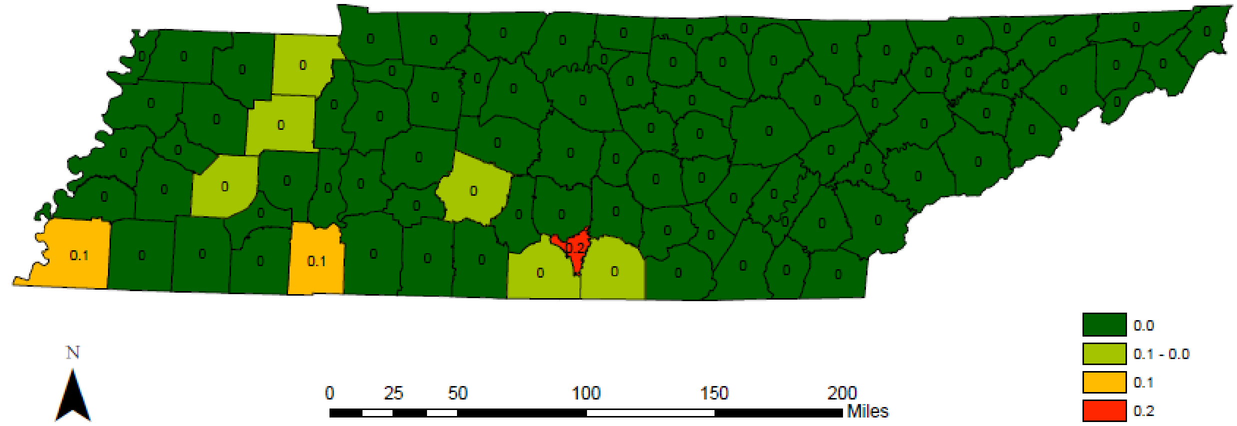

Figure H1. **Average Annual Historic Cold Events by County**

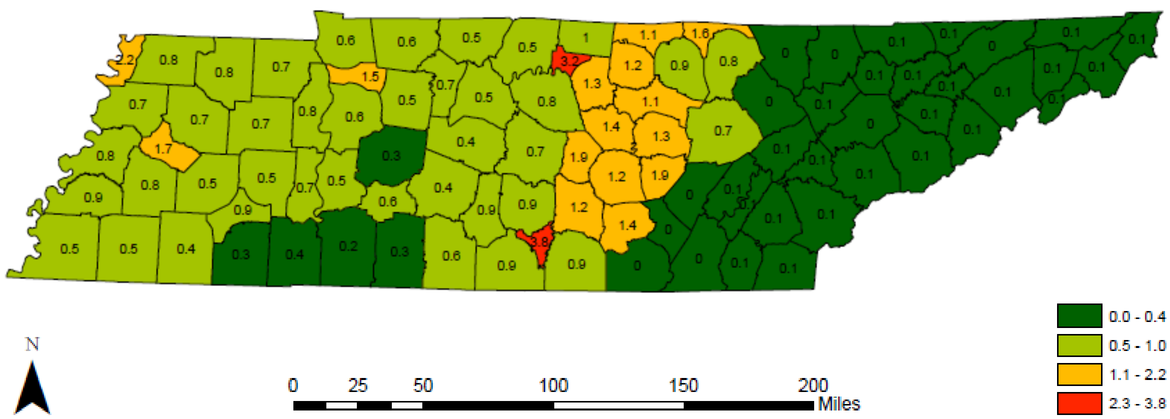

Figure H2. **Average Annual Historic Drought Events by County**

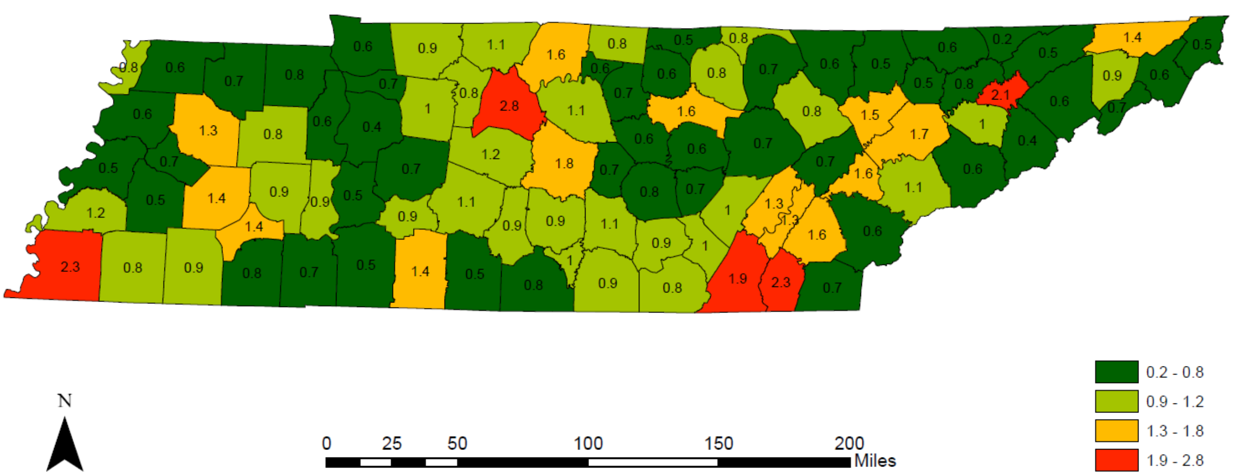

Figure H3. **Average Annual Historic Hail Events by County**

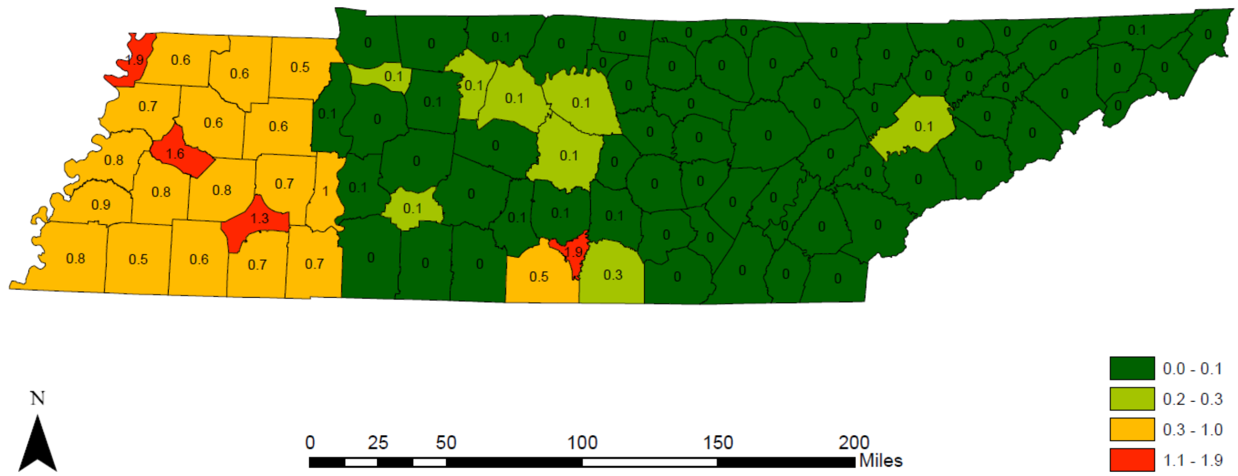

Figure H4. Average Annual Historic Heat Events by County

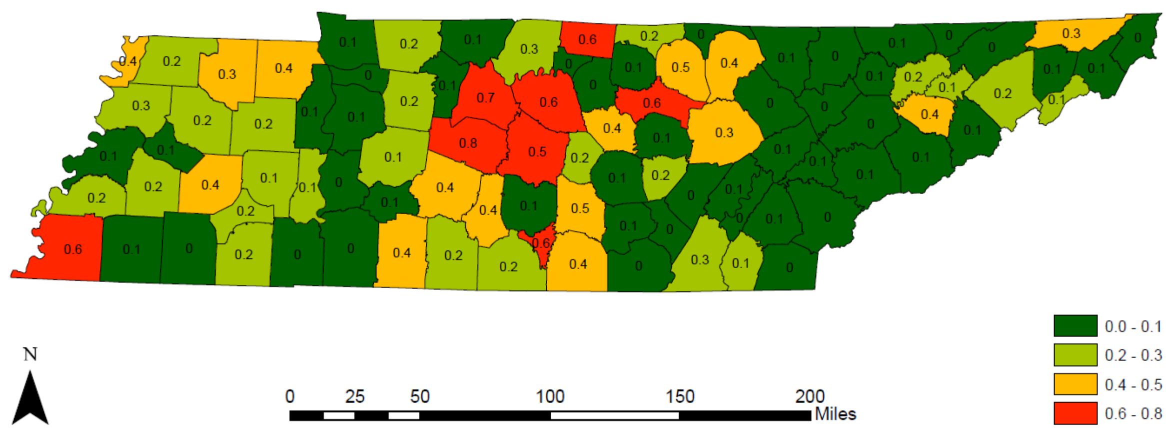

Figure H5. Average Annual Historic Lightning Events by County

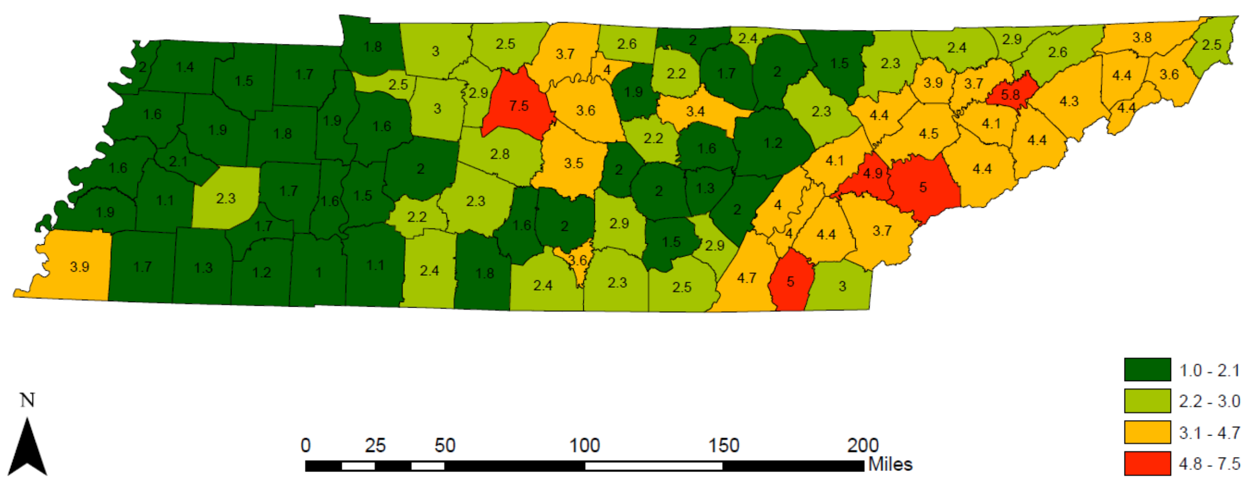

Figure H6. Average Annual Historic Thunderstorm Wind Events by County

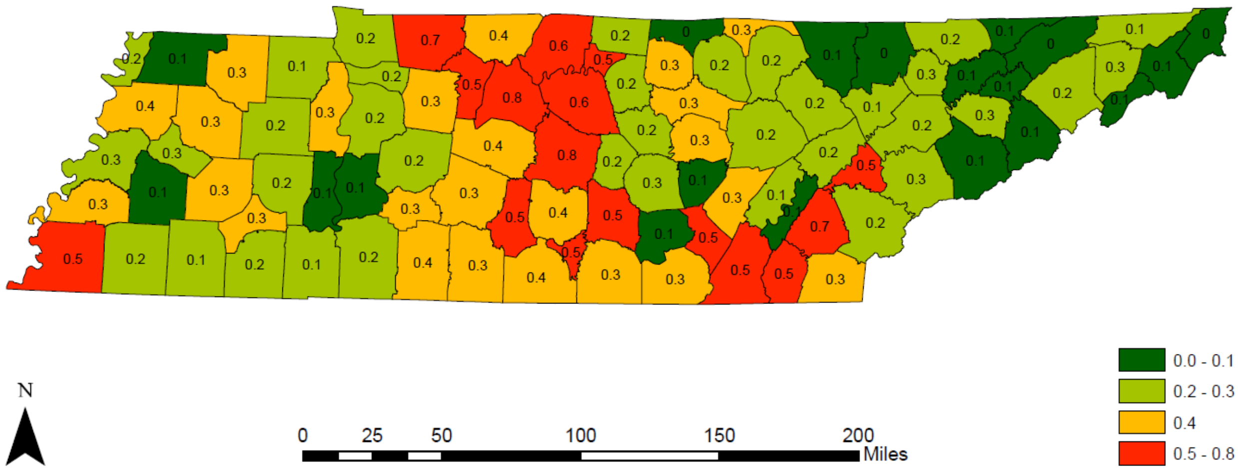

Figure H7. Average Annual Historic Twister Events by County

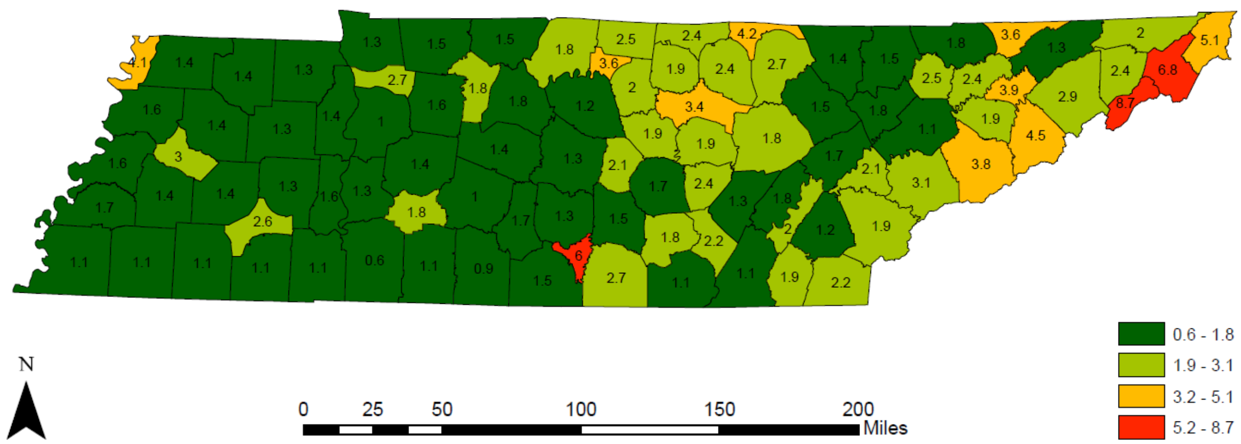

Figure H8. Average Annual Historic Winter Storm Events by County

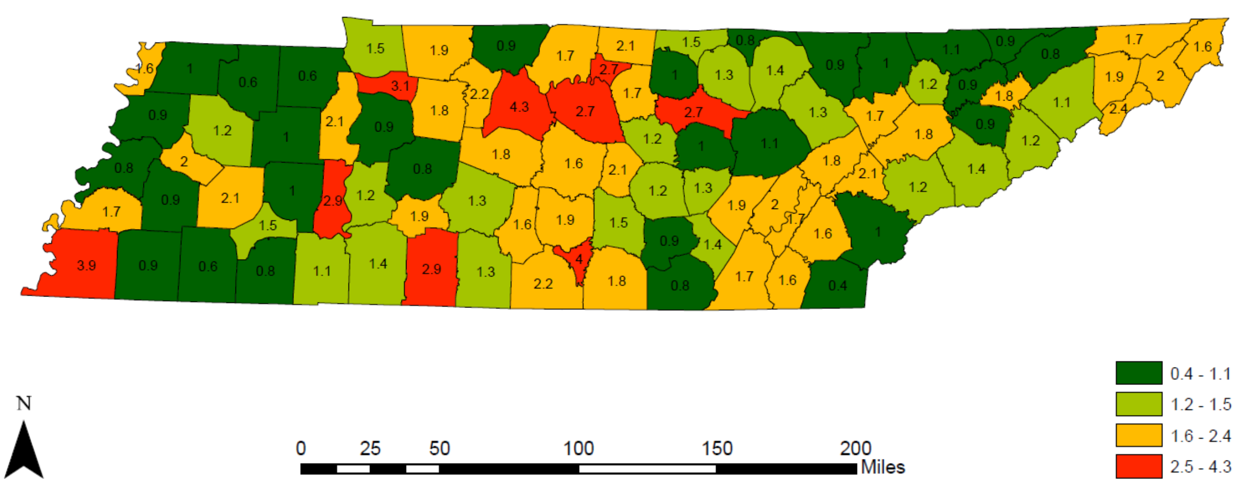

Figure H9. Average Annual Historic Hydrologic Events by County

Appendix I – Projected Future Precipitation and Temperature Analysis Using CMIP3 Data Tool[27] (3 Sigma Consultants, 2015)

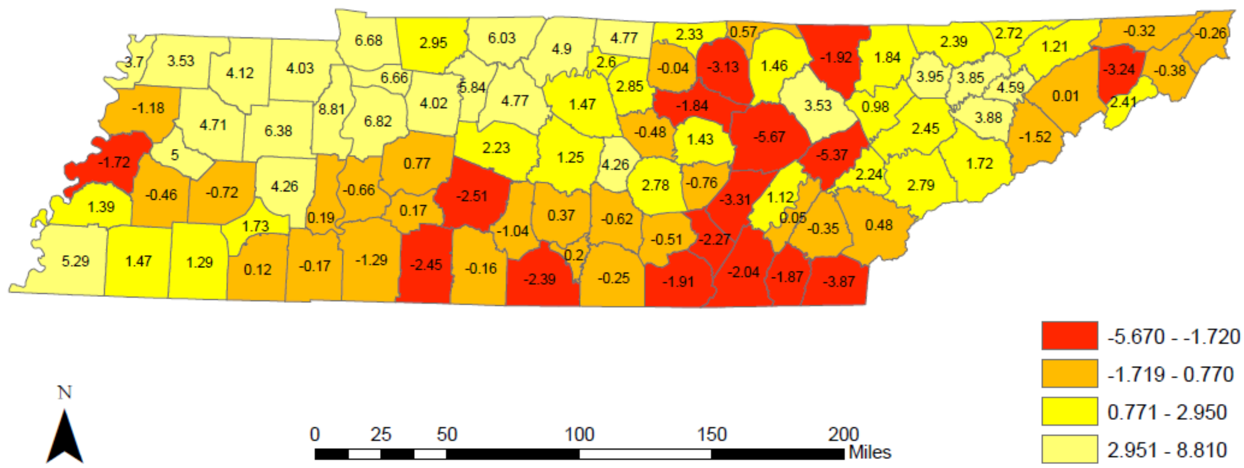

Figure I1. Percent Change in Low Precipitation Values by County – 2035

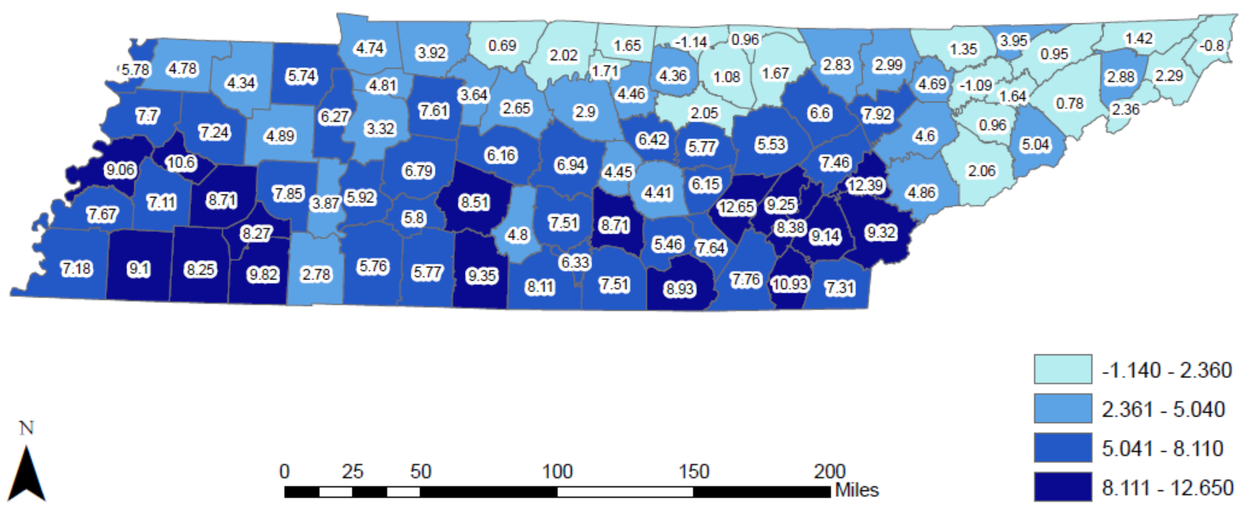

Figure I2. Percent Change in High Precipitation Values by County – 2035

[27] The maps included within Appendix I were received from 3 Sigma Consultants as used in the TDOT study. It should be noted that the number of significant figures included within the maps is inappropriate.

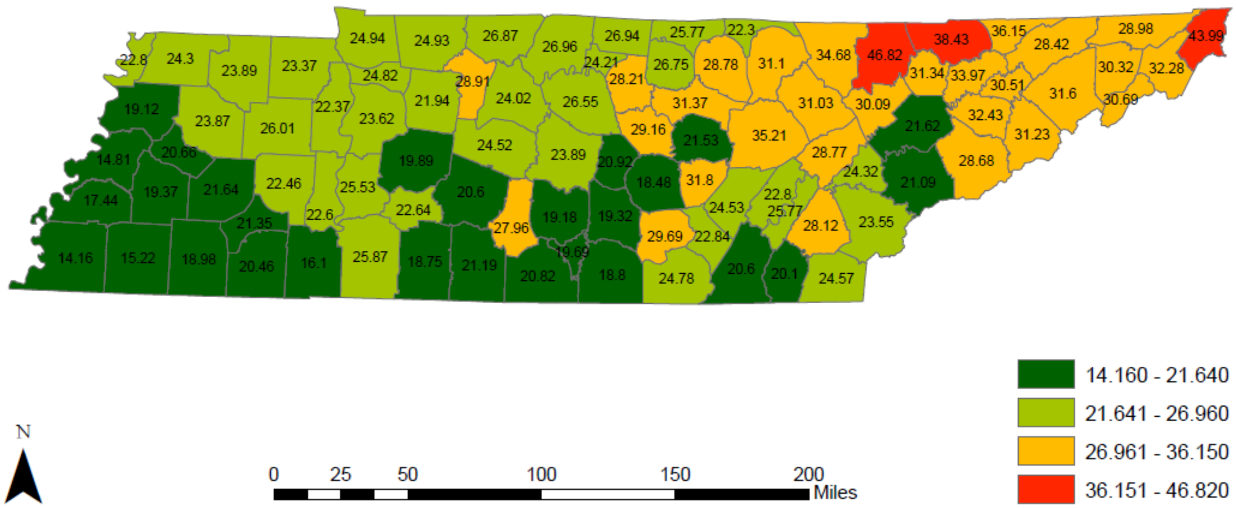

Figure I3. Percent Change in Low Temperature Values by County – 2035

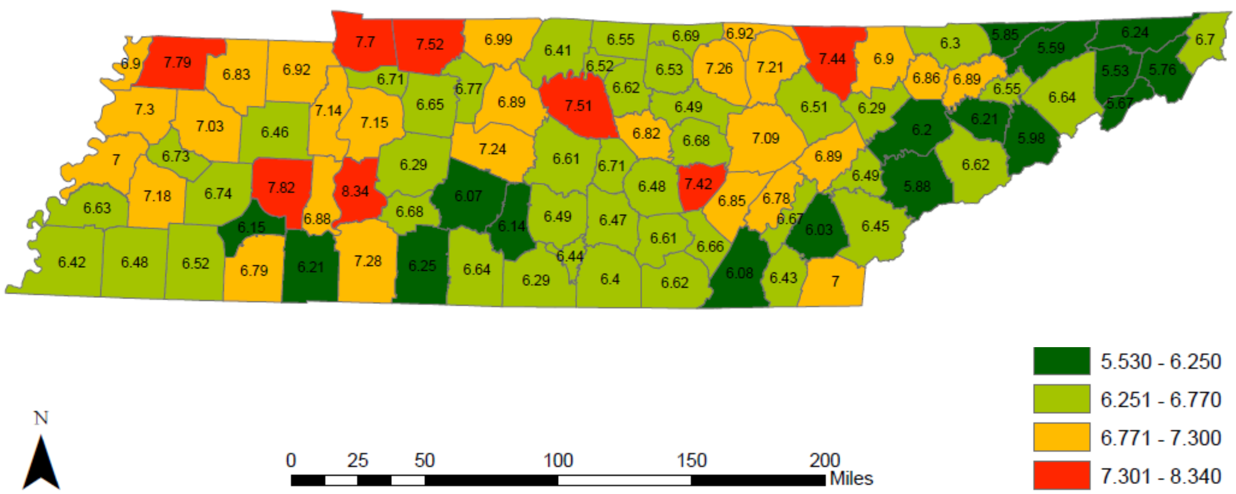

Figure I4. Percent Change in High Temperature Values by County – 2035

Appendix J – Thunderstorm Wind and Tornado Event Trend Analyses[28]

(3 Sigma Consultants, 2015)

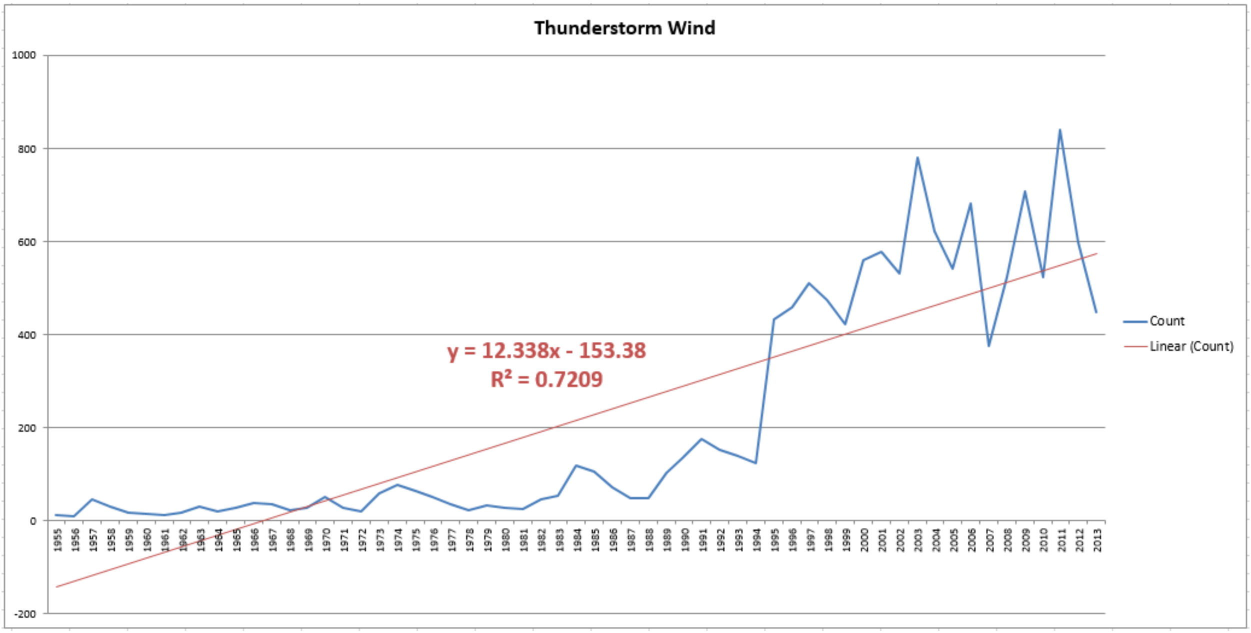

Figure J1. Annual number of reported thunderstorm winds in Tennessee, 1955-2013

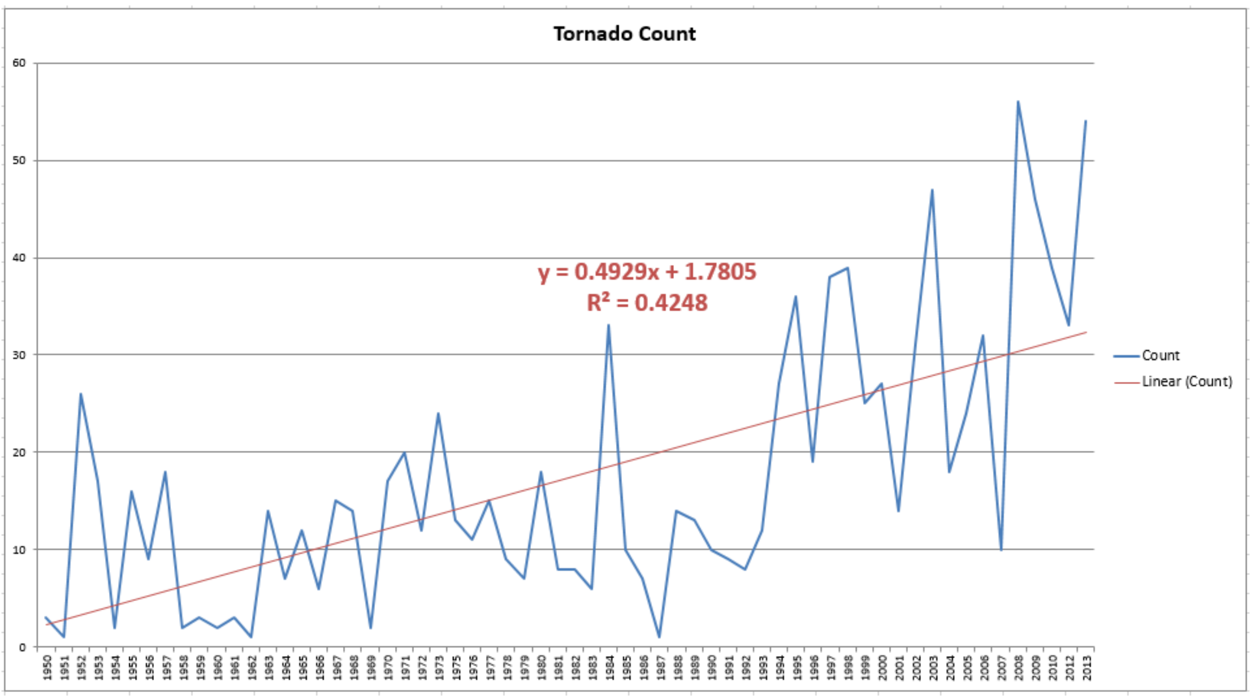

Figure J2. Annual number of reported tornadoes in Tennessee, 1950-2013

[28] Increases in thunderstorm wind and tornado trends reported are likely measurement artifacts and not increases in the actual number of severe storms. See NOAA research “Historical Records and Trends” and “Monitoring and Understanding Trends in Extreme Storms.”

Appendix K – Vulnerability Score Maps

Dining & Lodging Infrastructure

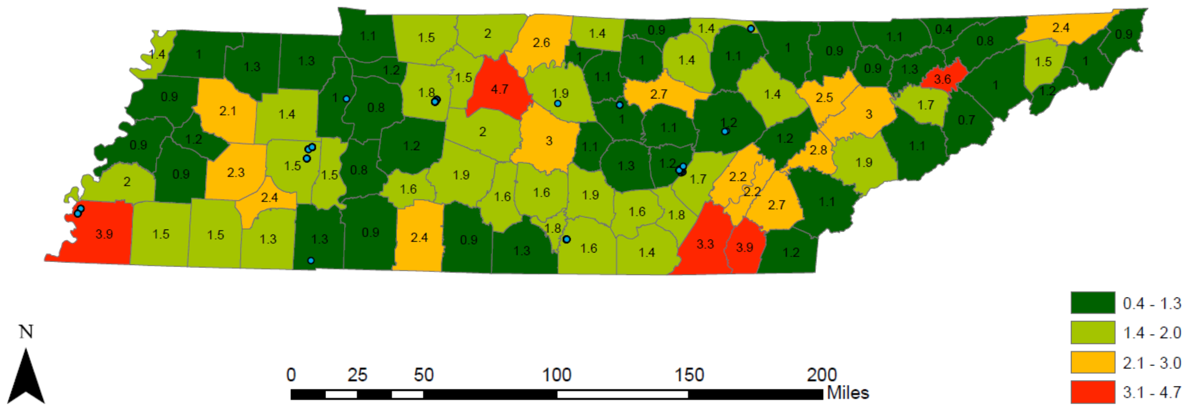

Figure K1. Historic Vulnerability of Critical Dining & Lodging Infrastructure to Hail by County

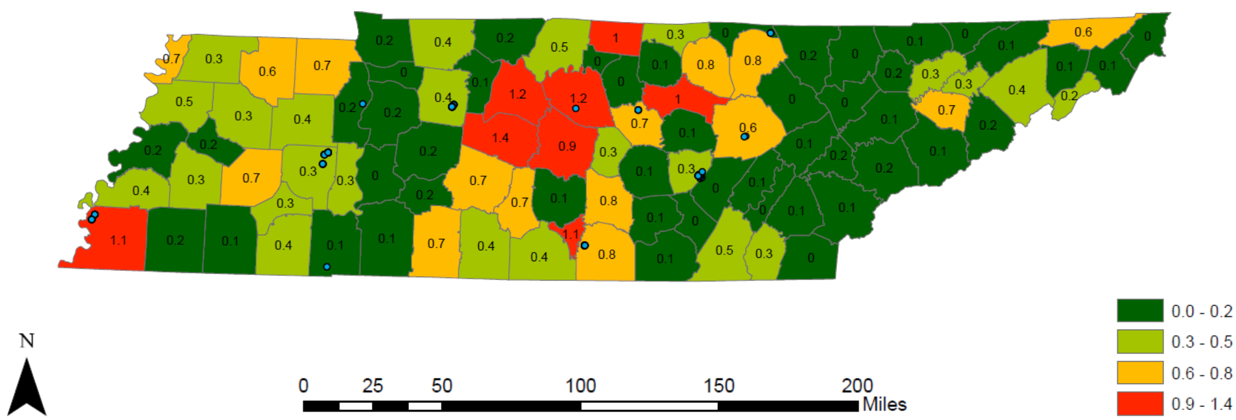

Figure K2. Historic Vulnerability of Critical Dining & Lodging Infrastructure to Lightning by County

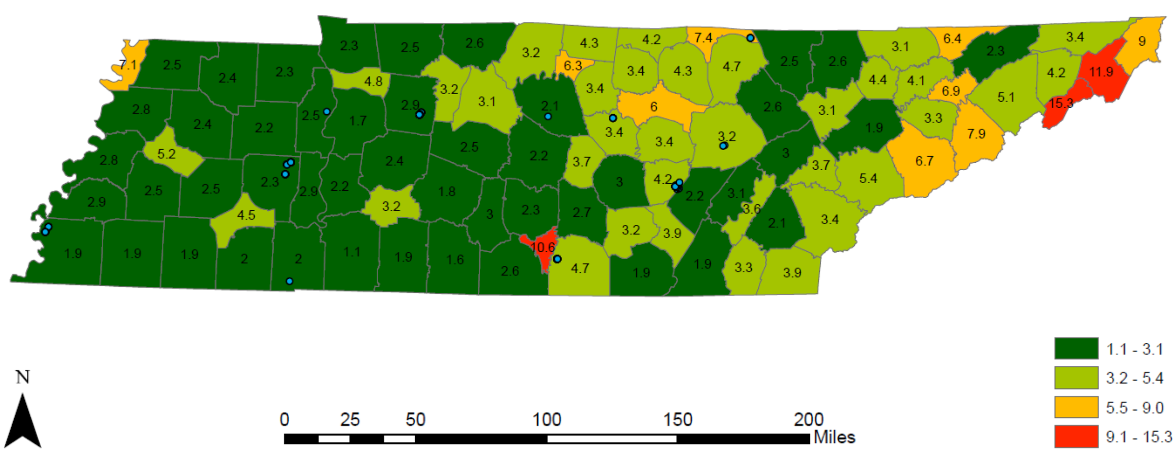

Figure K3. Historic Vulnerability of Critical Dining & Lodging Infrastructure to Winter Storms by County

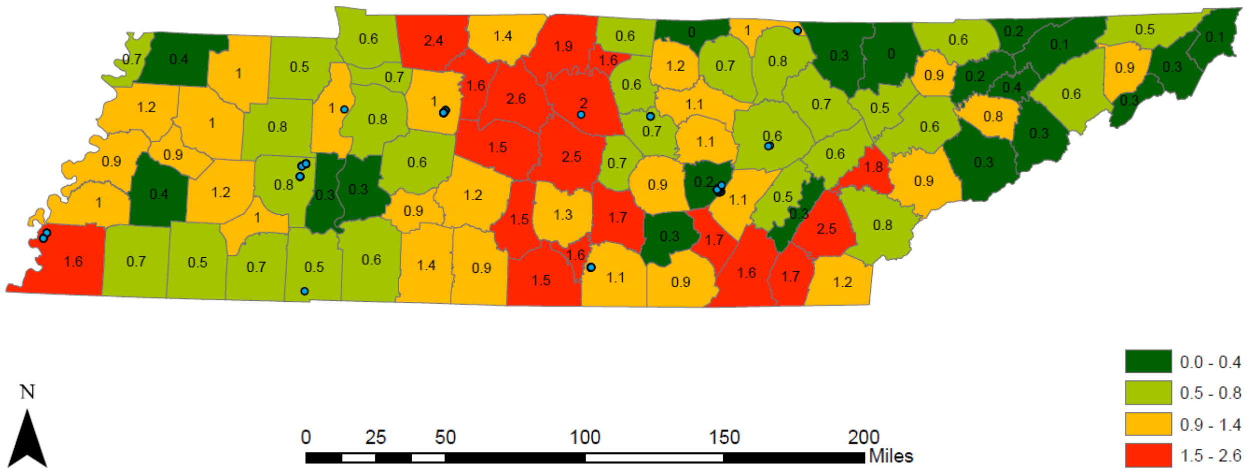

Figure K4. Historic Vulnerability of Critical Dining & Lodging Infrastructure to Tornadoes by County

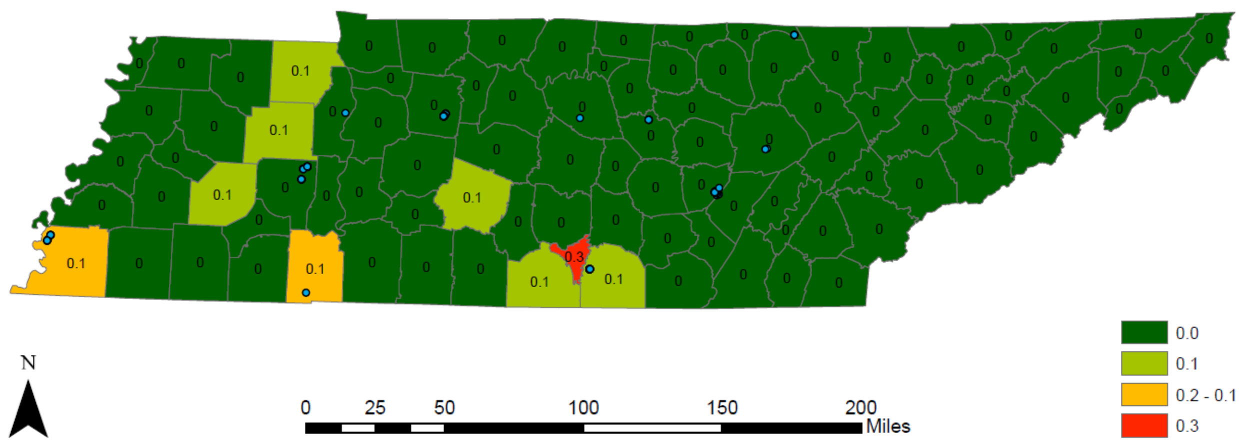

Figure K5. Future Vulnerability of Critical Dining & Lodging Infrastructure to Cold Events by County – 2035

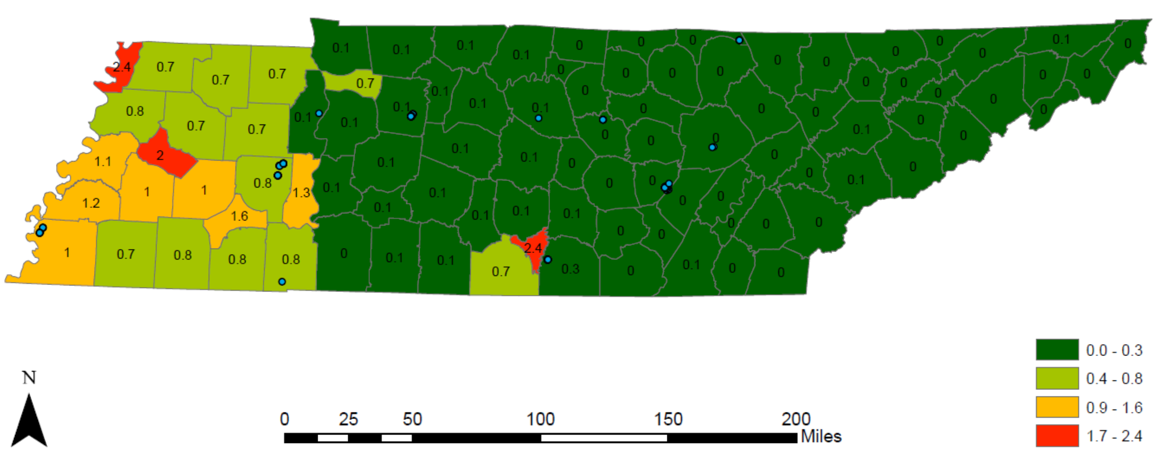

Figure K6. Future Vulnerability of Critical Dining & Lodging Infrastructure to Heat Events by County – 2035

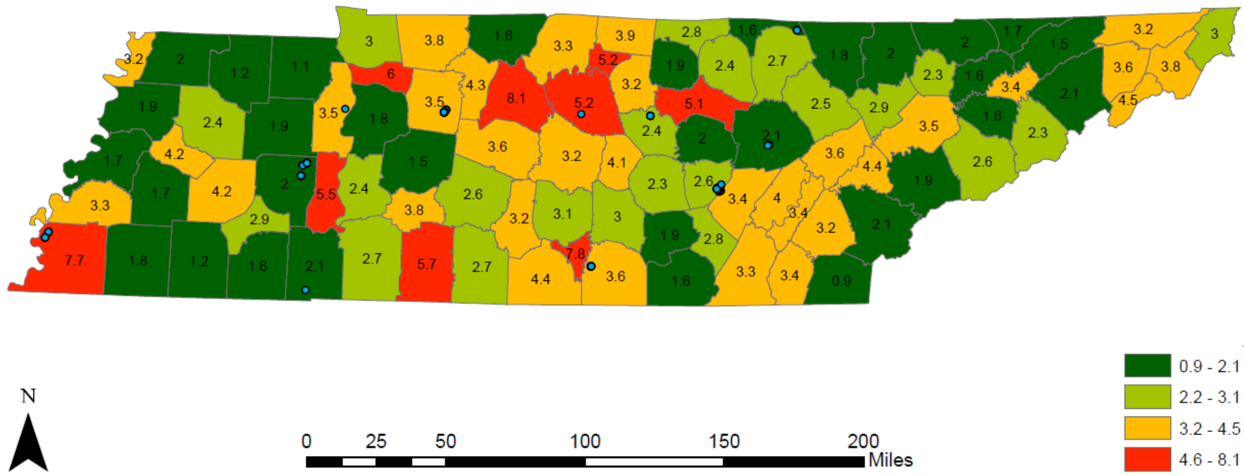

Figure K7. **Future Vulnerability of Critical Dining & Lodging Infrastructure to Hydrologic Events by County – 2035**

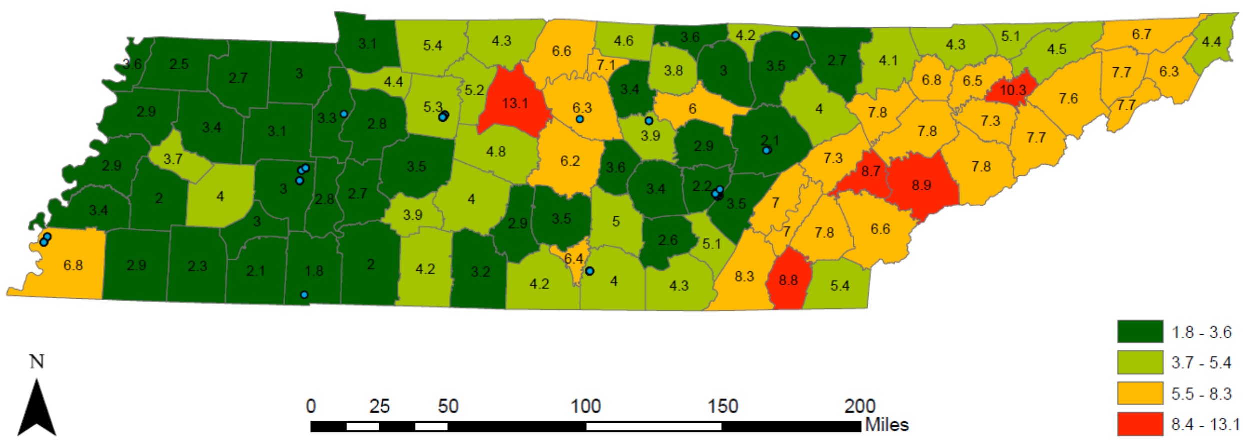

Figure K8. **Future Vulnerability of Critical Dining & Lodging Infrastructure to Thunderstorm Wind Events by County**

Camping & Outdoor Recreation Infrastructure

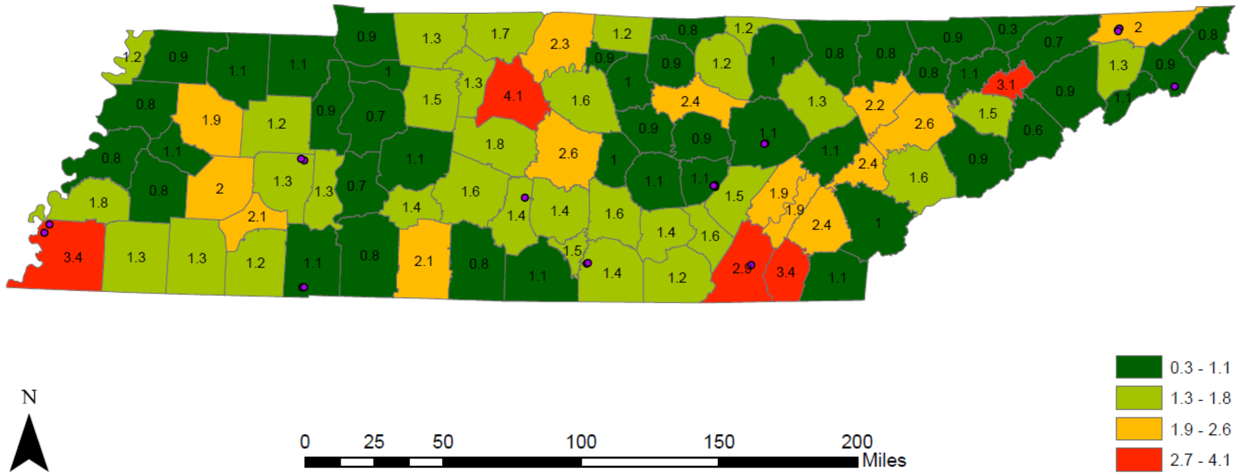

Figure K9. Historic Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Hail by County

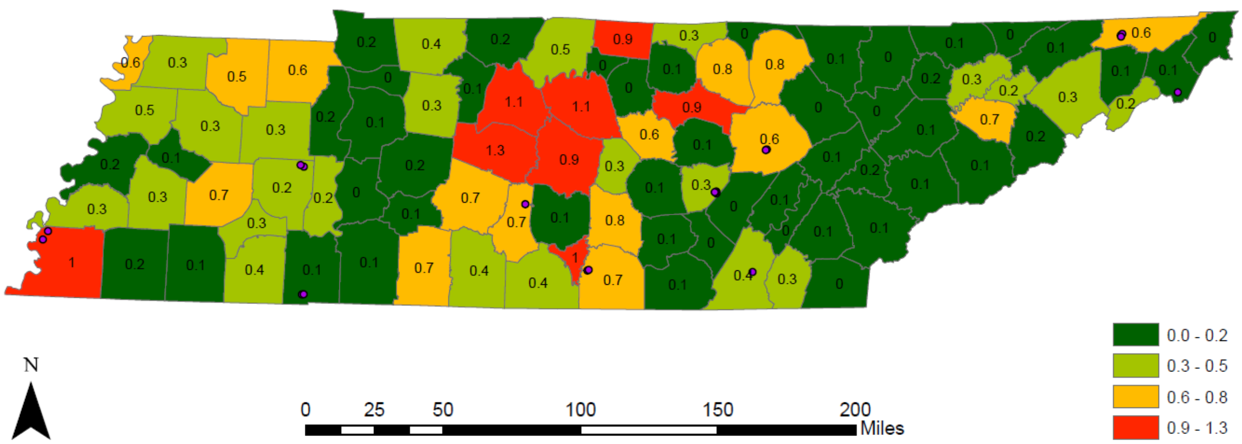

Figure K10. Historic Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Lightning by County

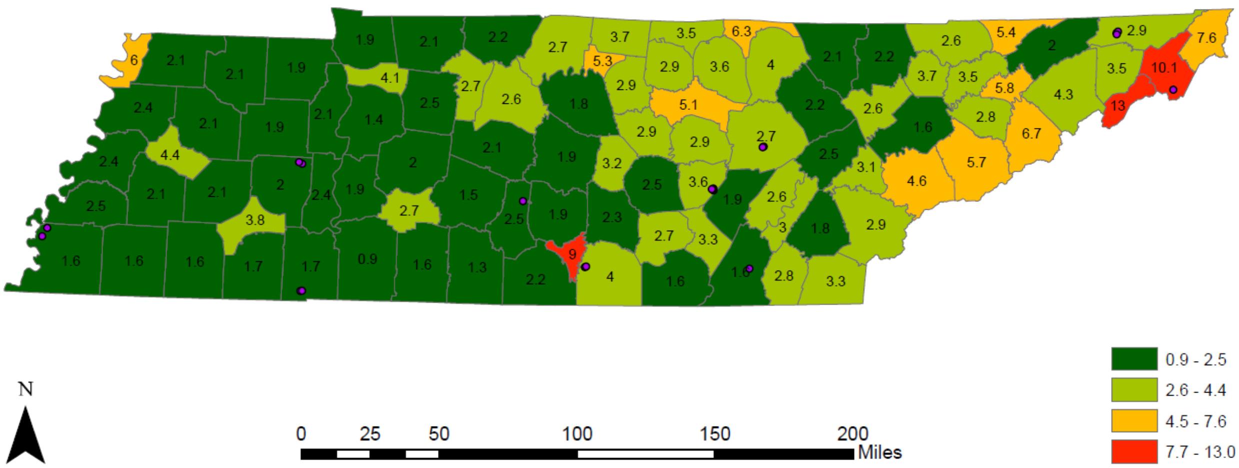

Figure K11. **Historic Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Winter Storms by County**

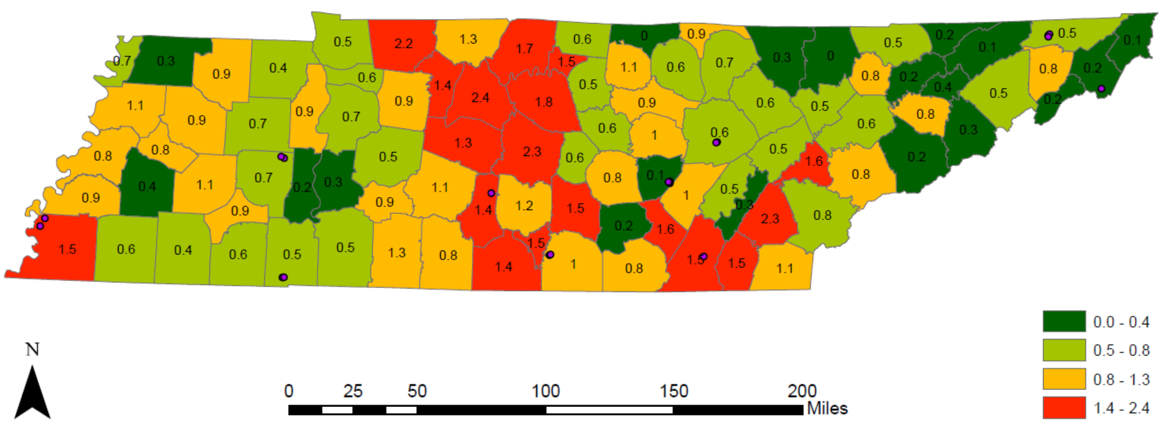

Figure K12. **Historic Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Tornadoes by County**

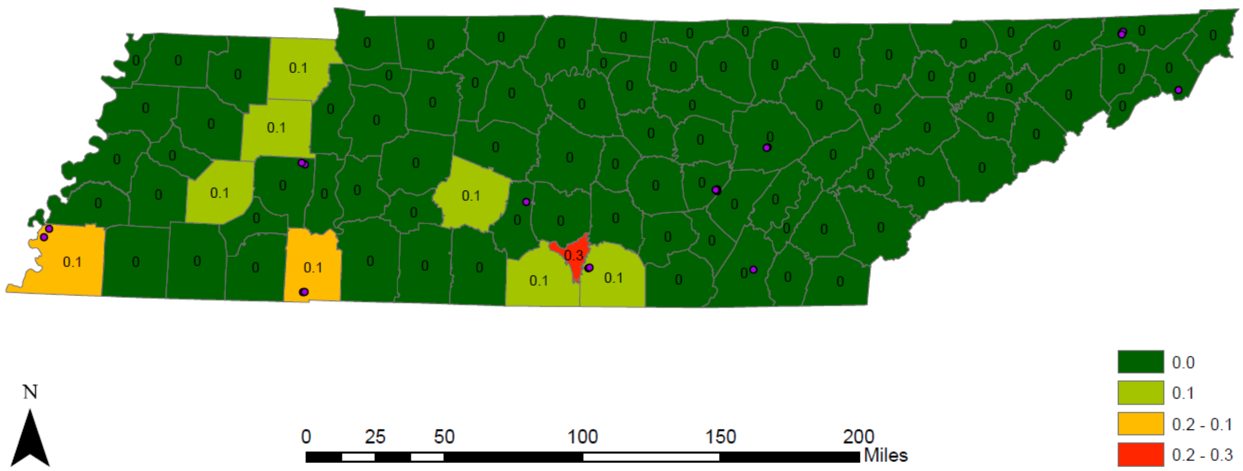

Figure K13. Future Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Cold Events by County – 2035

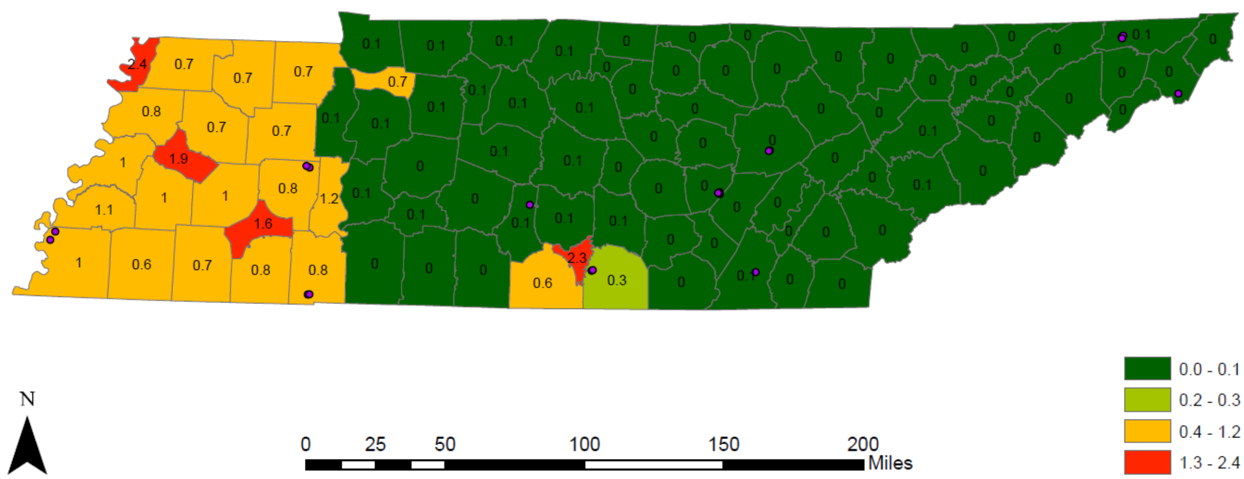

Figure K14. Future Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Heat Events by County – 2035

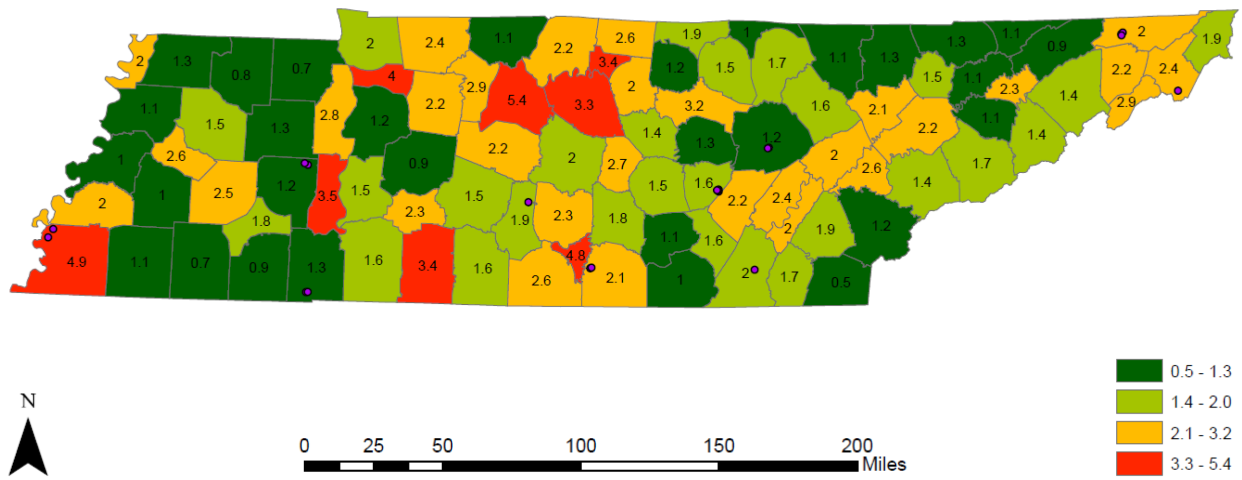

Figure K15. Future Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Drought Events by County – 2035

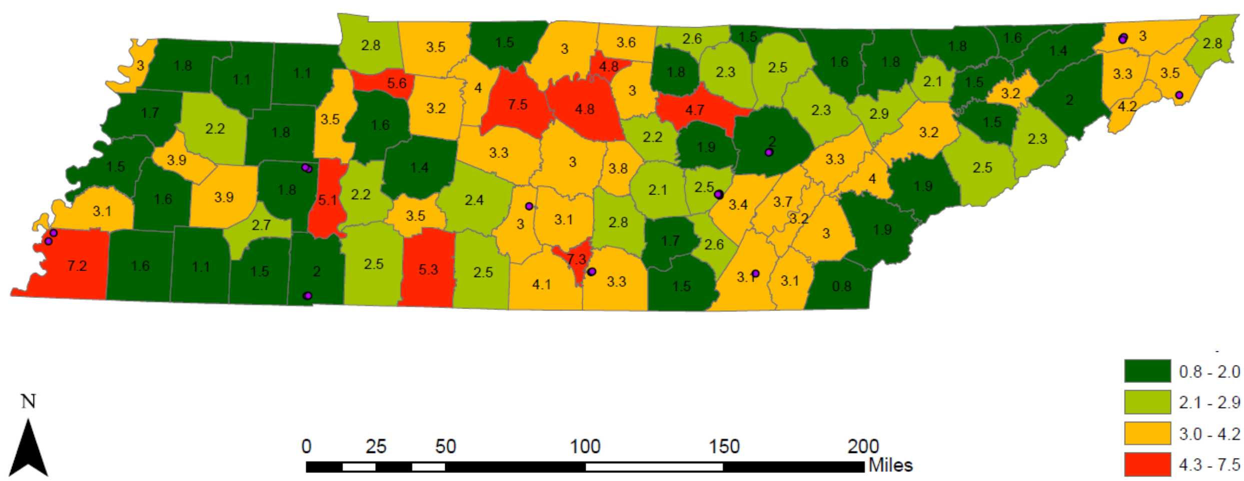

Figure K16. Future Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Hydrologic Events by County – 2035

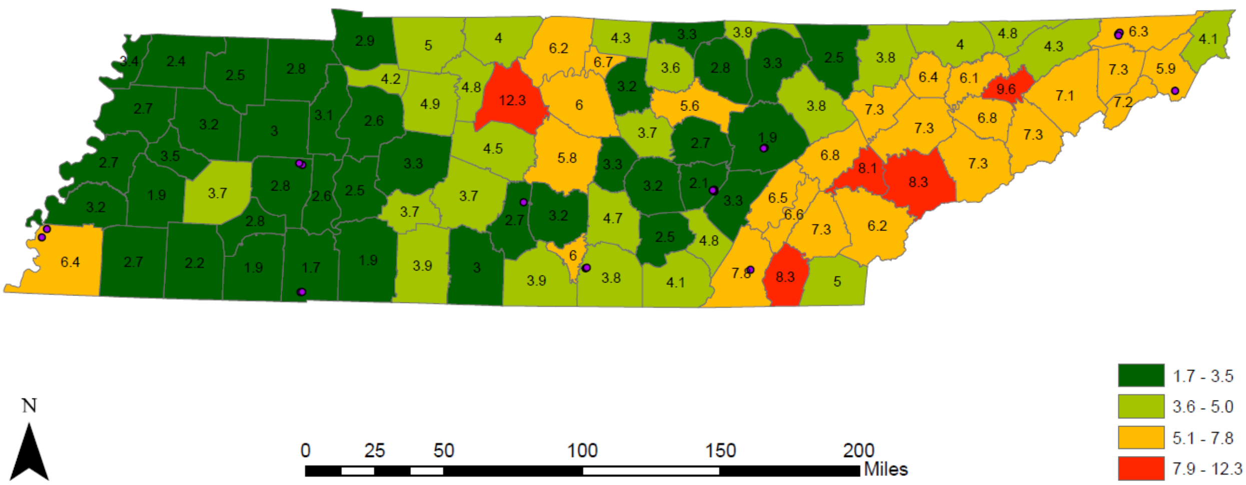

Figure K17. Future Vulnerability of Critical Camping & Outdoor Recreation Infrastructure to Thunderstorm Wind Events by County

Operations Infrastructure

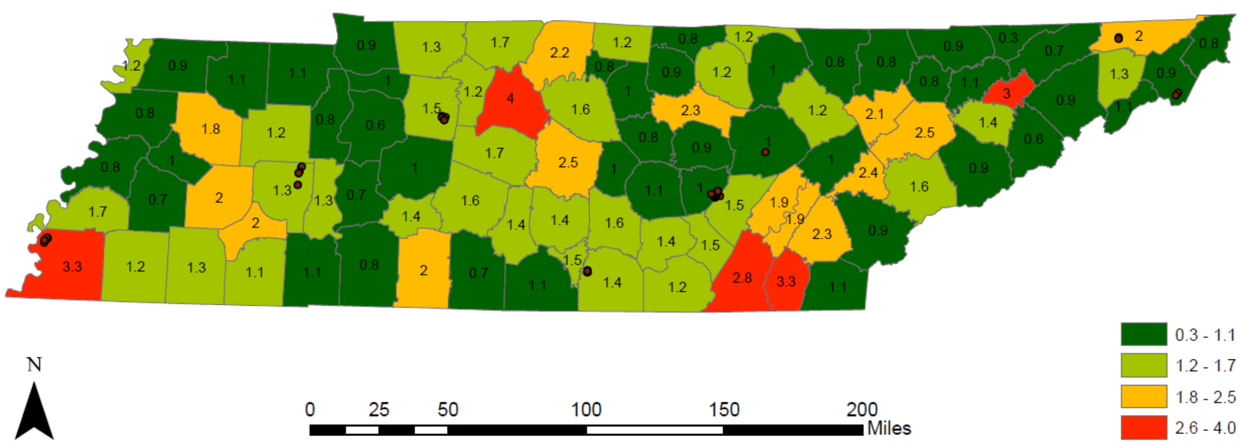

Figure K18. Historic Vulnerability of Critical Operations Infrastructure to Hail by County

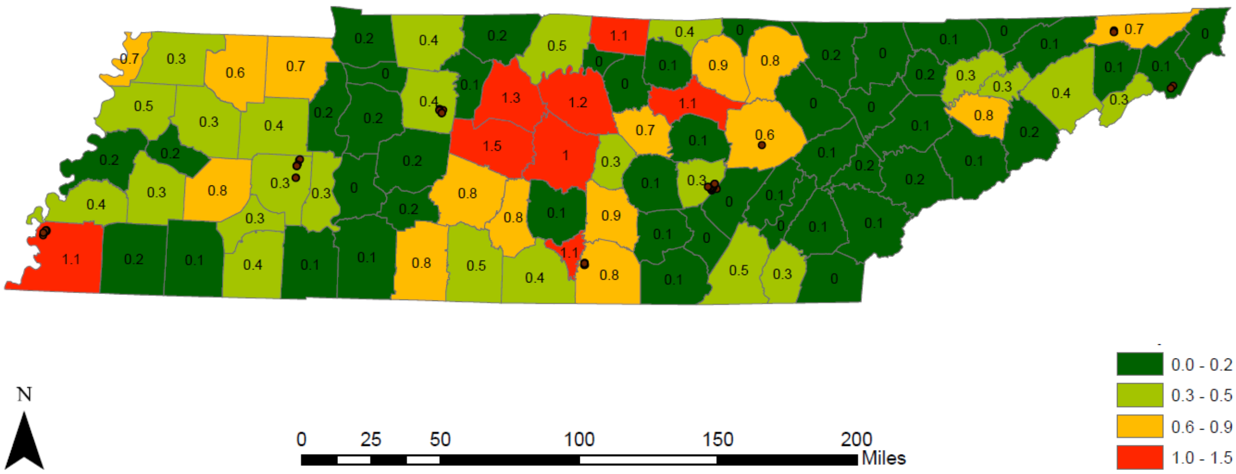

Figure K19. Historic Vulnerability of Critical Operations Infrastructure to Lightning by County

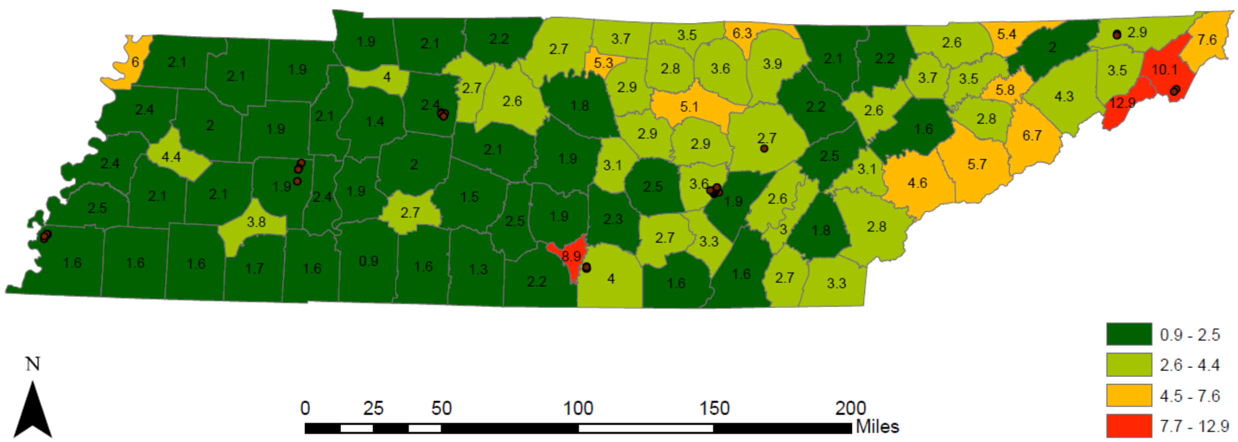

Figure K20. Historic Vulnerability of Critical Operations Infrastructure to Winter Storms by County

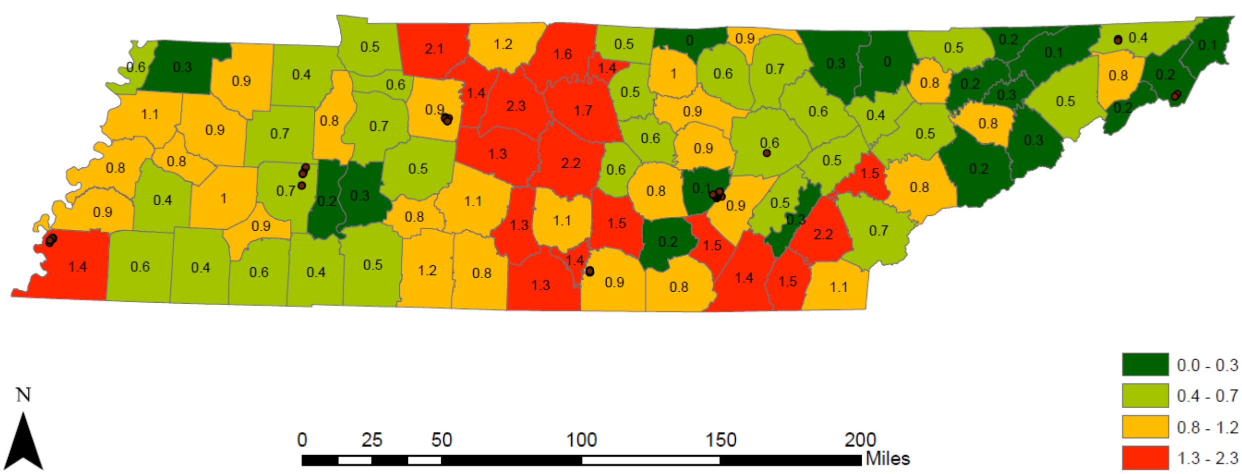

Figure K21. Historic Vulnerability of Critical Operations Infrastructure to Tornadoes by County

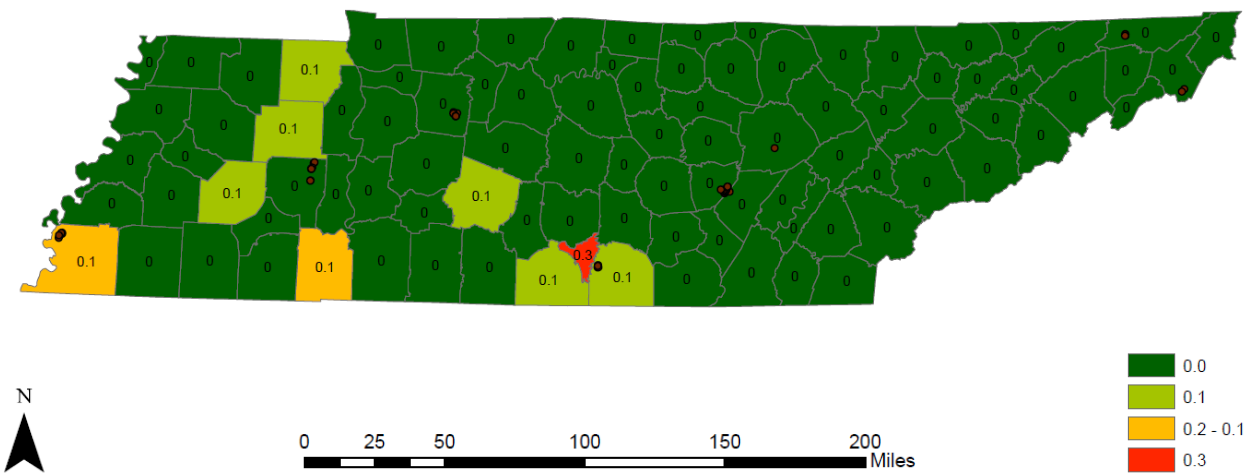

Figure K22. **Future Vulnerability of Critical Operations Infrastructure to Cold Events by County – 2035**

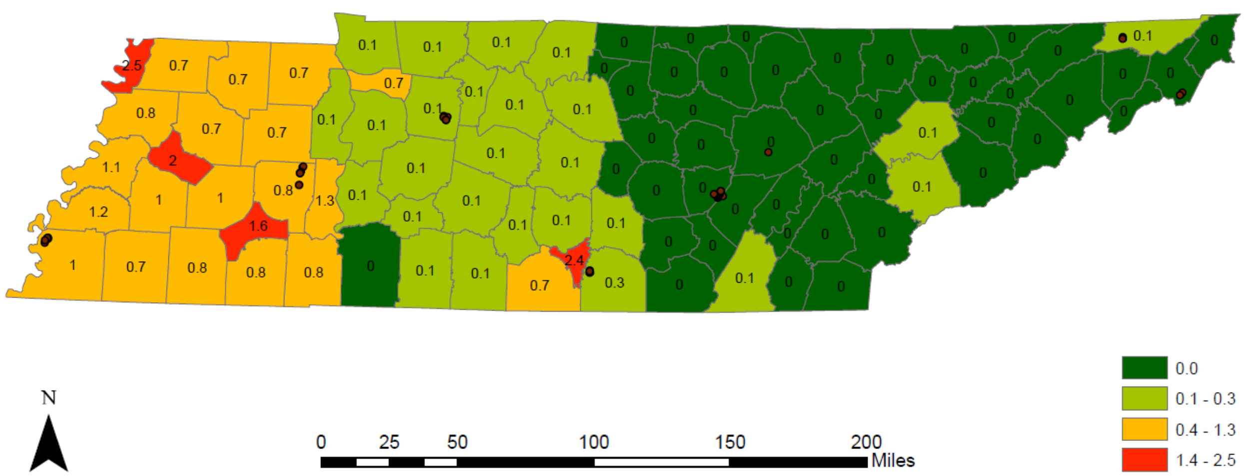

Figure K23. **Future Vulnerability of Critical Operations Infrastructure to Heat Events by County – 2035**

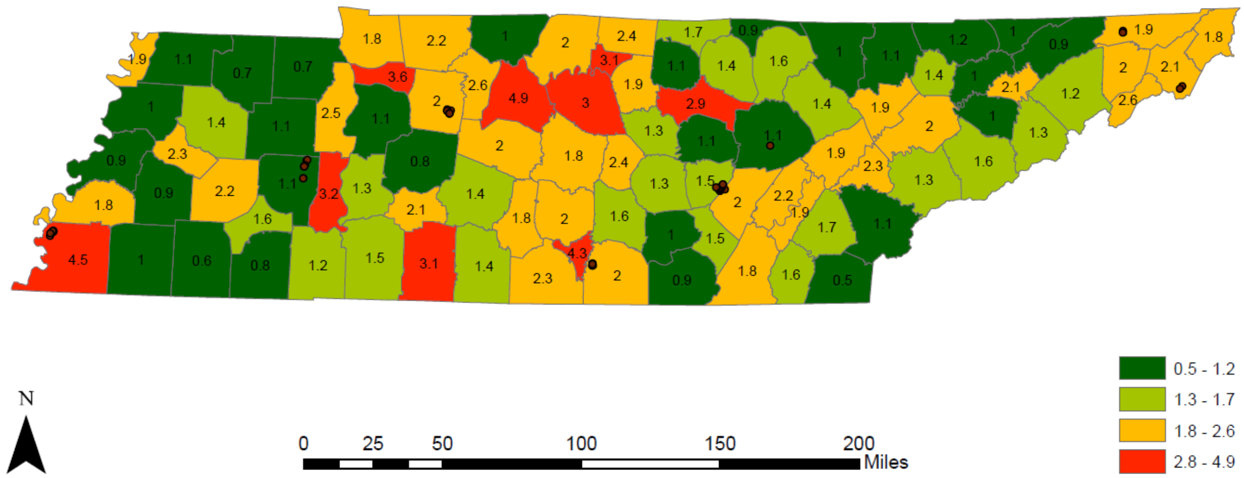

Figure K24. **Future Vulnerability of Critical Operations Infrastructure to Drought Events by County – 2035**

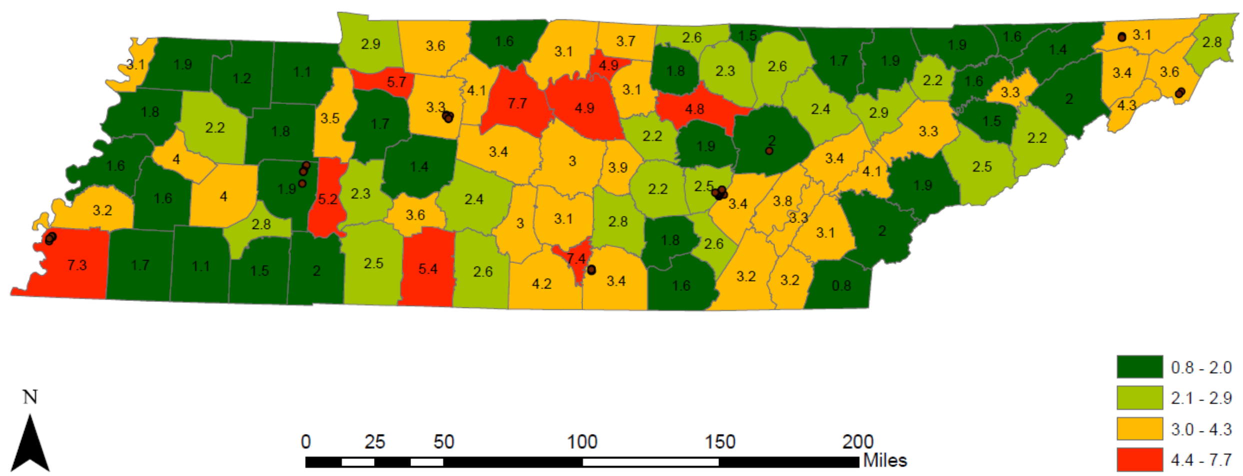

Figure K25. **Future Vulnerability of Critical Operations Infrastructure to Hydrologic Events by County – 2035**

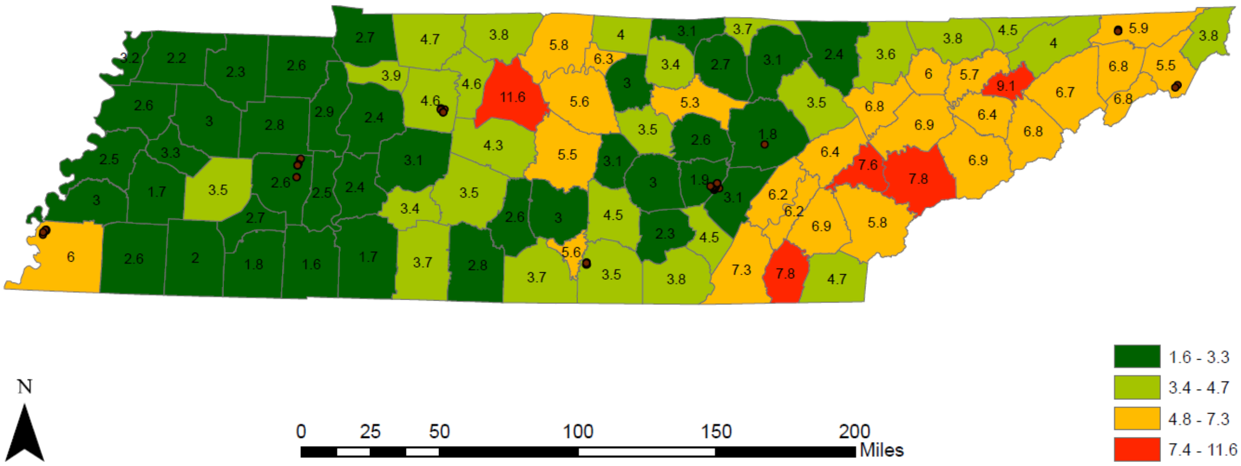

Figure K26. Future Vulnerability of Critical Operations Infrastructure to Thunderstorm Wind Events by County

Retail Infrastructure

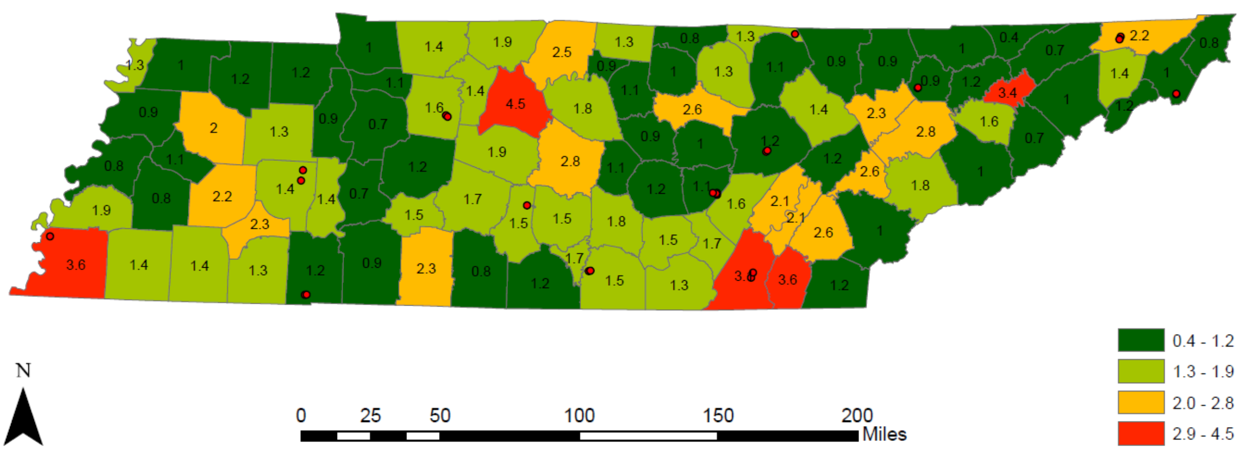

Figure K27. Historic Vulnerability of Critical Retail Infrastructure to Hail by County

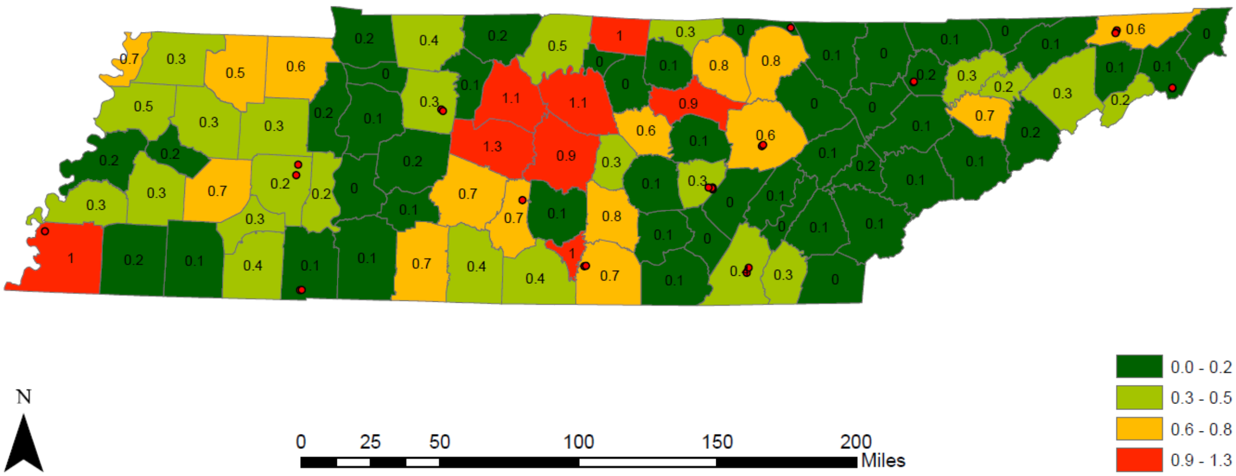

Figure K28. Historic Vulnerability of Critical Retail Infrastructure to Lightning by County

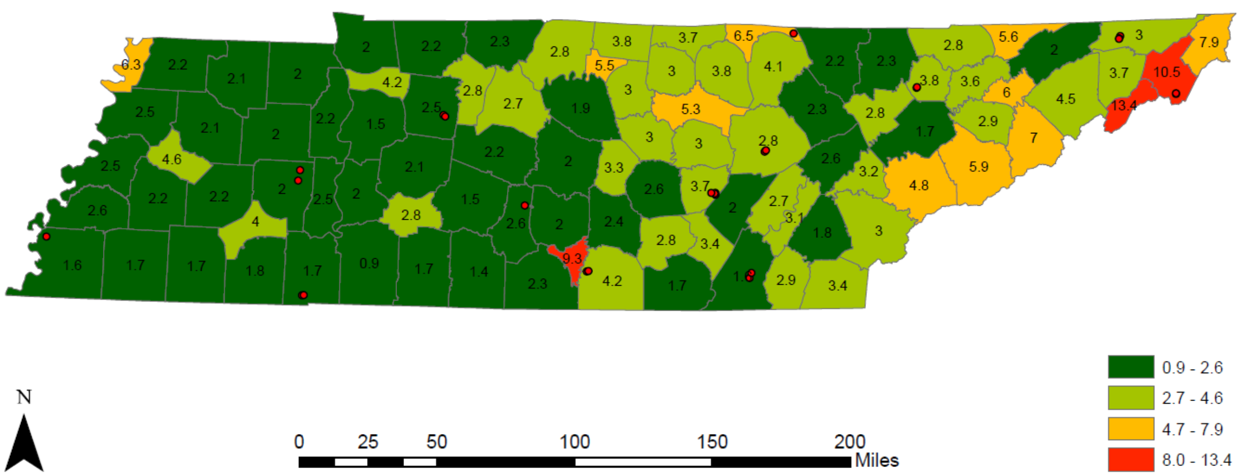

Figure K29. Historic Vulnerability of Critical Retail Infrastructure to Winter Storms by County

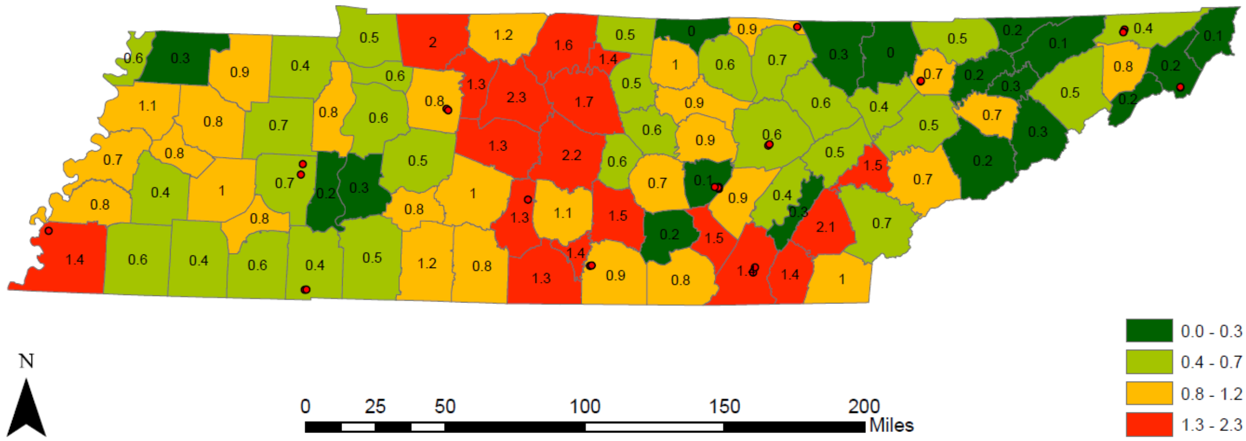

Figure K30. Historic Vulnerability of Critical Retail Infrastructure to Tornadoes by County

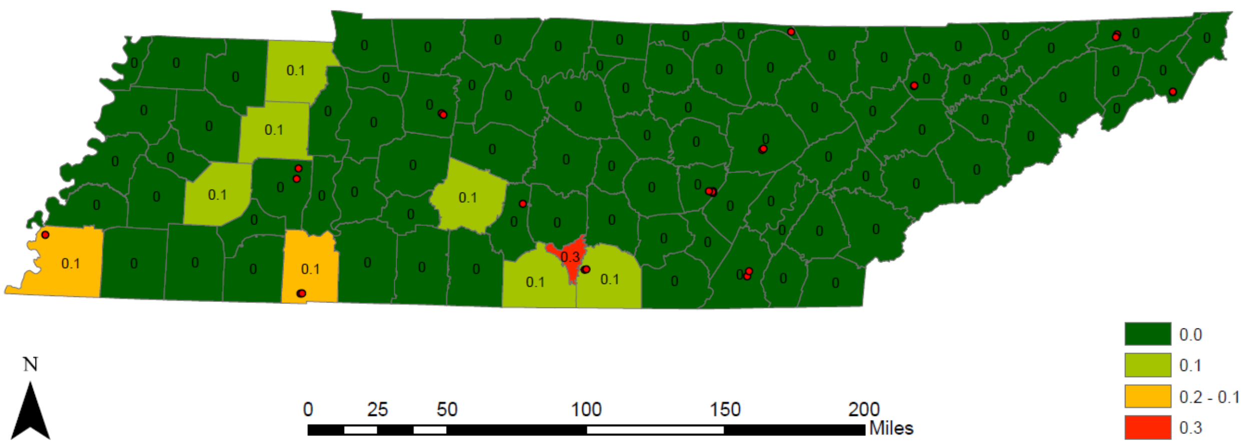

Figure K31. Future Vulnerability of Critical Retail Infrastructure to Cold Events by County – 2035

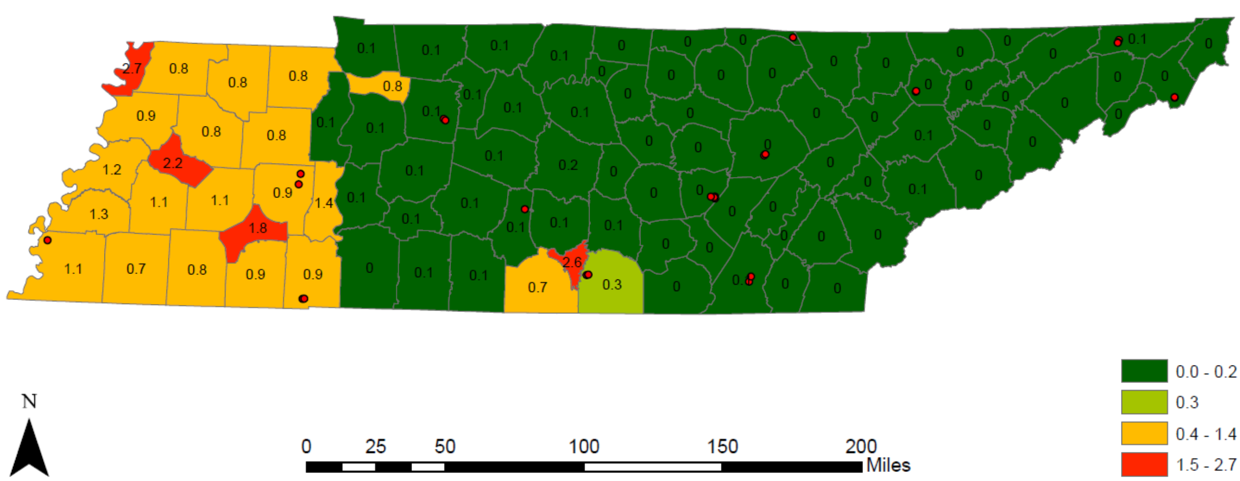

Figure K32. Future Vulnerability of Critical Retail Infrastructure to Heat Events by County – 2035

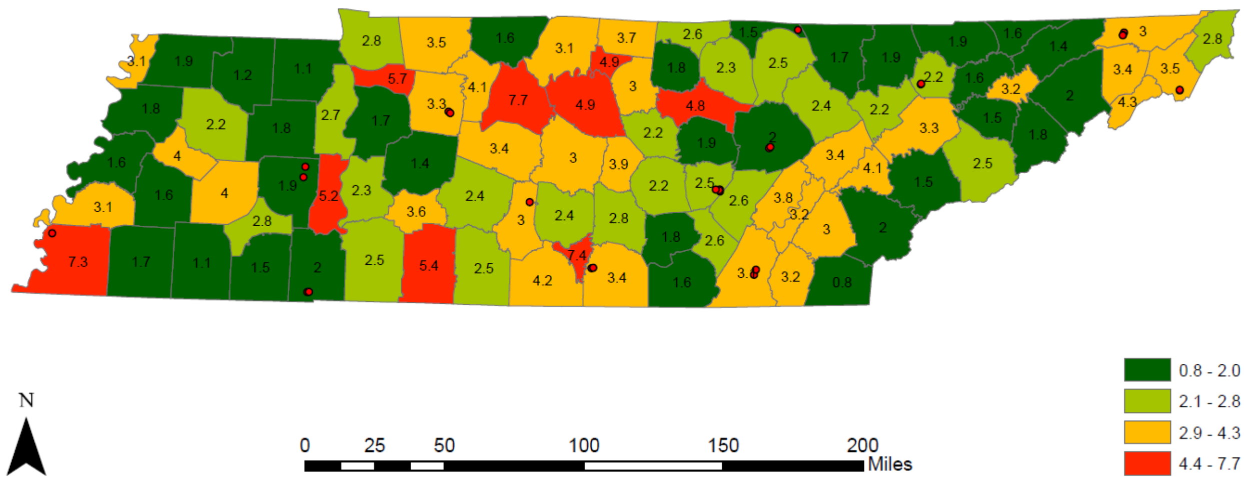

Figure K33. Future Vulnerability of Critical Retail Infrastructure to Hydrologic Events by County – 2035

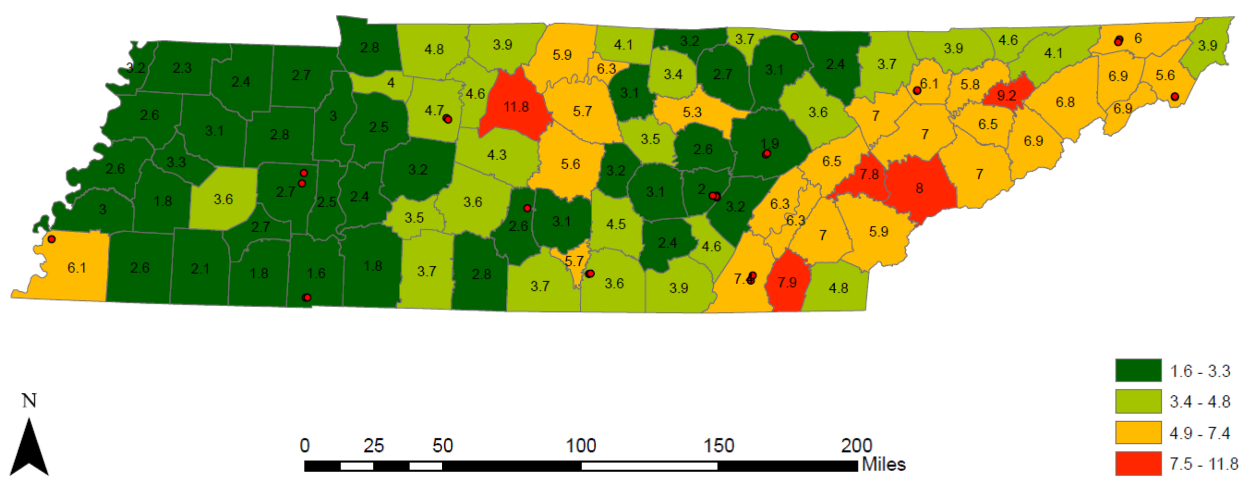

Figure K34. Future Vulnerability of Critical Retail Infrastructure to Thunderstorm Wind Events by County