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Comment on the plan in its entirety or review the hazards sections that you are most familiar with. In an effort to efficiently collect and organize comments, please select Comment Form below and complete with your basic contact information, comment(s) and corresponding page number(s). All comments will be reviewed prior to returning the draft document to the consultants for final updates.

Comment Form

State of Rhode Island Hazard Identification and Risk Assessment

August 2016

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Approval and Implementation

Hazard Identification and Risk Assessment (HIRA) and Consequence Analysis (CA)

The *Hazard Identification and Risk Assessment (HIRA) a*nd Appendices, including the Consequence Analysis, have been approved for implementation by:

_____ _____

Peter T. Gaynor Date
Director, Rhode Island Emergency Management Agency (RIEMA)

_____ _____

Gina M. Raimondo Date
Governor, State of Rhode Island

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Record of Changes

Table 1: Record of Changes

Change Number	Section	Date of Change	Individual Making Change	Description of Change

Record of Distribution

Table 2: Record of Distribution

Date of Delivery	Number of Copies Delivered	Method of Delivery	Name, Title, and Agency/Organization of Receiver

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1.0 Introduction

1.1 Purpose

The purpose of this document is to provide a statewide overview of how various natural, manmade, and technological hazards impact the State of Rhode Island. This Hazard Identification and Risk Assessment (HIRA) undertakes an all-hazards identification, classification, and vulnerability indexing process to ensure hazard analysis is comprehensive and all-encompassing.

For the purposes of this HIRA, a natural hazard is defined as an event or physical condition that has the potential to cause fatalities, injuries, property and infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss. In addition, a manmade hazard includes any disastrous event caused directly and principally by one or more identifiable deliberate or negligent human actions, while a technological hazard is a hazard originating from technological or industrial conditions, including accidents, dangerous procedures, or failures.[1]

These hazards can be exacerbated by societal behavior and practice, such as building in a floodplain, along a sea cliff, or an earthquake fault. All of these hazards may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage if the extent, magnitude, and impact is significant. While it is impossible to prevent and mitigate all hazards, the impacts of these hazards can, at a minimum, be mitigated or, in some instances, prevented entirely.

Rhode Island is not immune to any of these hazard types. Hurricanes and related coastal flooding, winter storms, and riverine flooding affect Rhode Island on a recurring basis. Rhode Island's vulnerability to hurricanes and tropical storms is rated as high. There are 21 coastal area communities in the state that are vulnerable to wave actions and wind hazards, such as hurricane storm surge. Much of the coastline on the Atlantic Ocean consists of barrier beaches that are open to the full force of destructive hurricane waves. Other damages associated with hurricanes and tropical storms include inland flooding, sea level rise, and tornadoes. The most serious inland flood threats occur when the eye of the hurricane passes just to the west of Rhode Island at a time of high tide. This type of flooding poses an additional health risk as it involves the overflow of storm-sewer systems and is usually caused by inadequate drainage following heavy rain, rapid snow melt, or an extreme storm surge up Narragansett Bay. In addition, Rhode Island is home to numerous pieces of critical infrastructure that are vulnerable to both manmade hazards, such as a cyber compromise or terrorism, and technological hazards, such as an infrastructure failure or transportation accidents.

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[1] Federal Emergency Management Agency. "Threat and Hazard Identification and Risk Assessment Guide." http://www.fema.gov/media-library-data/8ca0a9e54dc8b037a55b402b2a269e94/CPG201_htirag_2nd_edition.pdf

Identifying the risk and vulnerability for a community is critical when determining how to allocate finite resources to carry out feasible and appropriate mitigation actions. The hazard analysis involves identifying all of the hazards that potentially threaten Rhode Island, and then analyzing them individually to determine the degree of threat posed by each hazard. Addressing risk and vulnerability through hazard mitigation measures will reduce societal, economic, and environmental exposure to natural hazard impacts.

For multi-hazard identification, all hazards that may potentially impact the state should be identified, including natural, manmade, and technological hazards, as well as cascading emergencies—situations when one hazard triggers others sequentially. For example, severe flooding that damages buildings that store hazardous, water-reactive chemicals could result in critical contamination problems that would dramatically escalate the type and magnitude of events. Dam failures may occur as a result of an earthquake, creating a dangerous flash flooding scenario for communities located in dam inundation areas.

1.2 2016 HIRA Update

This 2016 HIRA consolidates, updates, and streamlines content from the Rhode Island Hazard Mitigation Plan (HMP) 2014 Update. Significant changes to the HIRA include:

- Addition of manmade and technological hazards;
- Completion of a consequence analysis for the top ten hazards;
- Restructuring, consolidating, and renaming of hazards and hazard groups;
- Update of all maps and data to encompass changes since Rhode Island HMP 2014 Update; and
- Amendment to critical facility data and structures information to include Rhode Island Geographic Information System (RIGIS) data sets.

The information in this section has been reviewed and revised by the State Interagency Hazard Mitigation Committee (SIHMC), as well as subject-matter experts. The SIHMC has validated that the information contained within this section adequately represents the risk and vulnerability in Rhode Island.

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2.0 Hazard Identification

In order to fulfill the planning guidelines outlined in the Disaster Mitigation Act (DMA) 2000 and the Emergency Management Accreditation Program (EMAP), this HIRA addresses natural hazards, human-caused hazards, and technological hazards. The previously approved Rhode Island HMP 2014 Update focused on natural hazards and this 2016 HIRA update expands to all hazards. For the purposes of the Rhode Island 2016 HIRA, hazards have been grouped by hazard type (natural, human-caused, and technological) as well as similarity of hazard events, occurrences, and typical impacts. Table 3 includes the hazard categories and corresponding hazards, which are listed in order of frequency, starting with the most frequent. The following tables outline the identified hazards and groupings as well as the process involved in hazard identification with Table 4 showing natural hazards, Table 5 showing human-caused and technological hazards.

Table 3: Hazard Identification and Hazard Groupings

Natural Hazards	Human-Caused Hazards	Technological Hazards
Severe Winter Weather Ice Storm Snow	Cybersecurity Incident	Infrastructure Failure Communications Emergency Services Energy Information Technology Transportation Systems Water and Wastewater Systems
Flood Riverine Coastal Flash Urban	Chemical Incident	
High Wind	Terrorism Foreign and Domestic	
Extreme Heat	Biological Incident	
Hurricane and Tropical Storms Nor'easter Storm Surge	Radiological Incident	
Extreme Cold	Civil Unrest	
Thunderstorm Hail Lightning		
Dam Failure		
Fire Urban Wild		
Sea Level Rise		
Epidemic		
Drought		
Earthquake		
Tornado		

Table 4: Natural Hazard Identification Process

Hazard of Concern	How and Why Hazard was Identified
Severe Winter Weather Ice Storm Snowstorm	• Review of historical disaster declarations and National Weather Service (NWS) National Climatic Data Center's (NCDC) Storm Events Database • NWS weather station data average annual snowfall • Eight (8) declared disaster events in Rhode Island were winter weather related events
Flood Riverine Coastal Flash Urban	• Review of historical disaster declarations and NWS NCDC Storm Events Database • Review of Flood Insurance Rate Maps (FIRMs), National Flood Insurance Program (NFIP) policies and claims, and repetitive loss (RL) and severe repetitive loss (SRL) properties • Flooding impacts Rhode Island nearly every year and results in the majority of the damages associated with hazard events • The National Hurricane Center (NHC); The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model • Nine (9) declared disaster events in Rhode Island were flood events
High Wind	• Review of historical disaster declarations and NWS NCDC Storm Events Database • American Society of Civil Engineers (ASCE) Minimum Design Loads for Buildings and Other Structures • Four (4) declared disaster events in Rhode Island were high wind events
Extreme Heat	• Review of historical disaster declarations and NWS NCDC Storm Events Database
Hurricane and Tropical Storms Nor'easter Storm Surge	• Review of historical disaster declarations and NWS NCDC Storm Events Database • NWS hurricane data • ASCE Minimum Design Loads for Buildings and Other structures • Seven (7) declared disaster events in Rhode Island were hurricane, tropical storm, or coastal events
Extreme Cold	• Review of historical disaster declarations and NWS NCDC Storm Events Database

Hazard of Concern	How and Why Hazard was Identified
Thunderstorm Hail Lightning	• Review of historical disaster declarations and NWS NCDC Storm Events Database • Four (4) declared disaster events in Rhode Island were high wind events
Dam Failure	• Review of historical disaster declarations • United States Army Corps of Engineers (USACE) National Inventory of Dams data • There are 667 dams in Rhode Island, 96 high hazard, and 81 significant hazard rating (2015 Annual Report to the Governor)
Fire Urban Wild	• Review of historical disaster declarations, NWS NCDC Storm Events Database, Rhode Island Division of Forest Environment • SIHMC input • SILVIS Lab Wildland Urban Interface (WUI) data
Sea Level Rise	• Input from SIHMC, Rhode Island Sea Level Rise (SLR) Committee, Rhode Island Sea Grant College Program data • Coastal communities have the potential to be affected by SLR • The Atlantic Ocean makes up the southern border of Rhode Island
Epidemic	• Numerous bodies of water located in the state that assist with the breeding of mosquitos and other waterborne pathogens
Drought	• Review of historical disaster declarations, NWS NCDC Storm Events Database, U.S. Drought Monitor and Drought Impact Reporter • The entire State of Rhode Island is subject to the effects of drought
Earthquake	• Review of historical data, including United States Geological Survey (USGS) and Weston Observatory • Earthquakes have impacted Rhode Island in the past. Between 1568 and 2014, there have been over 34 earthquake events with epicenters in or near Rhode Island • Peak Ground Acceleration (PGA) data
Tornado	• Review of historical disaster declarations and NWS NCDC Storm Events Database

Table 5: Human-Caused and Technological Hazard Identification Process

Hazard of Concern	How Hazard was Identified
Cybersecurity Incident	• Most of Rhode Island's critical infrastructure is linked to some technology-based platform, which is a key vector of attack in a cybersecurity incident
Chemical Incident	• There are 724 Tier III facilities in Rhode Island • Since 1989, seven (7) major chemical incidents have occurred in Rhode Island
Terrorism Foreign and Domestic	• Terrorist attacks can occur anywhere; Rhode Island is an attractive target due to its proximity to major urban areas
Biological Incident	• Intentional biological incidents can cause serious public health risks and have the potential to overwhelm health care facilities/professionals as well as first responder resources
Radiological Incident	• Rhode Island is within the 50-mile Ingestion Exposure Pathway for two (2) nuclear power plants
Civil Unrest	• Seven (7) large-scale (15,000 to 100,000 people), state-supported events occur within Rhode Island each year
Infrastructure Failure	• Rhode Island is home to numerous pieces of critical infrastructure across all six (6) identified sectors

As part of the 2016 HIRA update, epidemic was added as a hazard, in order to align with its inclusion in the Threat and Hazard Identification and Risk Assessment (THIRA). In addition, human-caused hazards and technological hazards were added to the overall vulnerability assessment to address EMAP accreditation. Climate change is included in the discussion of the identified hazards in this HIRA as an "amplifier" and is not profiled as an independent hazard.

It should be noted that the above hazards are not a complete listing of all hazards that may occur in Rhode Island. The SIHMC agreed that this listing accurately represents the hazards that impact Rhode Island most frequently and have the potential to cause fatalities, injuries, property and infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss. The following hazards are not addressed in the HIRA:

- Avalanche
- Expansive soils
- Land subsidence
- Landslides
- Volcanoes
- Tsunamis

The hazards listed above were considered and discussed during several SIHMC meetings, but it was decided that these hazards would not be included in the HIRA due to:

- The low frequency of occurrence;
- The minimal probability of occurrence; and/or
- The lack of resources to devote to further research the likelihood of potential occurrence or impact.

2.1 Disaster History

Historically, hurricanes and winter weather-related events have caused the most damage to the state and its citizens. Recent disasters have shifted the attention of Rhode Island's citizens and government officials to the resultant human, economic, and environmental impacts. The State of Rhode Island has had nine (9) state of disaster emergency declarations within the last two decades and 22 federally declared disasters since 1954. The most recent federal declaration occurred in April 2015, due to a Severe Winter Storm and Snowstorm. Table 6 shows how many federally-declared disasters and emergencies have occurred from 1954 to August 2016.

These disasters had significant impacts on Rhode Island, and its residents were forced to bear the majority of the costs of clean up and restoration of services. Disasters impact the state through death and injury; loss of residences, property, and possessions; lost wages, tax revenue, and business revenue; and the immeasurable psychological and sociological costs to disaster victims and their families. In considering the economic costs of disasters, it is important to recognize that small- to medium-sized businesses, which provide the majority of jobs in an average community, are at a high risk for failure following a disaster.

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Federally-Declared Disaster

Local and state government share the responsibility for protecting Rhode Island citizens and for helping them recover when a disaster strikes. In some cases, a disaster is beyond the response capabilities of state and local government. In 1988, the Stafford Act was enacted to support state and local governments and their citizens when disasters overwhelm them and exhaust their resources. This law, as amended, established a process for requesting and obtaining a Presidential Disaster Declaration, which defines the type and scope of assistance available from the Federal Government and sets the conditions for obtaining that assistance.[2]

An important resource for identifying hazards that can affect the state is the record of federal disaster declarations. According to the Federal Emergency Management Agency (FEMA), there have been 12 major disaster declarations for Rhode Island since 1954. Table 6 has been updated to include events since the Rhode Island HMP 2014 Update and expanded to include the incident period of the declared event.

[2] *A Guide to the Disaster Declaration Process and Federal Disaster Assistance*. FEMA March 4, 2008.

The most recent declared disaster recovery (DR) project in the state are summarized below:

- **DR-4212**[3]**:** A major disaster declaration (DR-4212) was declared on April 3, 2015, for Bristol, Kent, Newport, Providence, and Washington counties affected by a severe winter storm and snowstorm during the period of January 26-28, 2015. The total Public Assistance (PA) Program cost estimate for the entire State of Rhode Island was $8,423,228. The governor requested PA in response to this severe winter weather event—publicly known as Winter Storm Juno—and funds were made available to state and eligible local governments, and certain private non-profit organizations on a cost-sharing basis. The assistance covered emergency work and the repair or replacement of facilities damaged by the severe winter storm and snowstorm in Bristol, Kent, Newport, Providence, and Washington counties. In addition, the disaster declaration authorized snow assistance for a period of 48 hours in those counties.

- **DR-1894**:[4] A major disaster declaration (DR-1894), commonly known as the 2010 floods, was declared on March 29, 2010, for Bristol, Kent, Newport, Providence, and Washington counties affected by a severe storms and flooding during the period of March 12, 2010, to April 12, 2010. Record rains caused flooding that destroyed homes, businesses, and infrastructure. The impacts were most severe along the Pawtuxet, Wood, and Pawcatuck rivers, and their tributaries, where bridges and dams washed out, including the Blue Pond, Geneva Pond, and Usquepaugh dams.[5] The total public assistance (PA) cost estimate for the entire State of Rhode Island was $25,063,551.58. This funding was made available to state and eligible local governments for emergency work and the repair or replacement of facilities damaged by the flooding.

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Table 6: Federally Declared Disasters and Emergencies in Rhode Island 1954 – 2015.

Note: Total assistance values not inflated.

Disaster Number	Declaration Date	Description	Individual Assistance Total	Public Assistance Total	Hazard Mitigation Grant Program Total
4212	4/3/2015	Severe Winter Storm and Snowstorm	N/A	$8,423,229	$1,327,144
4107	3/22/2013	Severe Winter Storm and Snowstorm	N/A	$7,057,671	$1,070,561
4089	11/3/2012	Hurricane Sandy	$421,341	$6,519,140	$1,525,853
3355 (DR4089)	10/29/2012				

[3] http://www.fema.gov/disaster/4212
[4] http://www.fema.gov/disaster/1894
[5] http://www.ecori.org/smart-growth/2010/6/7/what-made-the-flood-of-2010-so-devastating.html

Disaster Number	Declaration Date	Description	Individual Assistance Total	Public Assistance Total	Hazard Mitigation Grant Program Total
4027	09/03/2011	Tropical Storm Irene / Hurricane Irene	N/A	$9,260,898	$1,608,921
3334 (DR4027)	8/27/2011				
3311 (DR1894)	03/30/2010	Severe Storms and Flooding	N/A	N/A	
1894	03/29/2010	Severe Storms and Flooding	$37,033,311	$17,043,832	$11,033,039
1704	05/25/2007	Severe Storms and Island/Coastal Flooding	N/A	$605,080	$86,280
3255	09/19/2005	Hurricane Katrina Evacuation	N/A	$1,110,010	
3203	02/17/2005	Snow	N/A	$6,273,609	
3182	03/27/2003	Snowstorm	N/A	$2,002,984	
3123	11/19/1996	Major water main break	N/A	N/A	
1091	01/24/1996	Blizzard	N/A	N/A	
3102	03/16/1993	Blizzards, High Winds, and Record Snowfall	N/A	N/A	
3094	09/16/1992	Water Contamination	N/A	N/A	
913	08/26/1991	Hurricane Bob	N/A	N/A	
748	10/15/1985	Hurricane Gloria	N/A	N/A	
548	02/16/1978	Snow, Ice	N/A	N/A	
3058	02/07/1978	Blizzards and Snowstorms	N/A	N/A	
39	08/20/1955	Hurricane, Flood	N/A	N/A	
23	09/02/1954	Hurricanes	N/A	N/A	

National Climatic Data Center (NCDC)

This update used NCDC Storm Data, published by the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The storm events database contains information on storms and weather phenomena that have caused loss of life, injuries, significant property damage, and/or disruption to commerce. Efforts are made to collect the best available information, but because of time and resource constraints, information may not be verified, and the accuracy or validity of the information will not be guaranteed by the NWS.

Most of the events from NCDC are not associated with a federal emergency or federal disaster. If the event occurred at the same time as an event that was later determined to be a federal emergency or federal disaster, it is included with the NCDC data even if it occurred in a county not included in the federal declaration. High wind events (including hail and lightning) make up more than 40.8 percent of the events for the jurisdictions, followed by winter storms (28.3 percent), and flooding (13.0 percent), and thunderstorm wind (13.0 percent).

Table 8 and Table 9 show the total damages and annualized damages for each jurisdiction and hazard type. Three-quarters of past damages and estimated further losses relates to flooding. These estimates are believed to be an underrepresentation of the actual losses experienced from events that go unreported or that are difficult to quantify, and are not likely to appear in the NCDC database.[6] This is especially true with hurricanes. When available, these values have been supplemented in each of the hazard-specific sections with information available from SIHMC members and state agencies.

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[6] https://www.ncdc.noaa.gov/stormevents/faq.jsp

Table 7: NCDC Total Number of Events (1993-2016)

County Name	Flood	Hurricane	Wind	Hail	Lightning	Tornado	Winter Storm	Drought	Extreme Cold	Extreme Heat	Thunderstorm
Bristol	24	1	60	5	3	2	51	1	0	0	17
Kent	41	2	127	27	7	4	134	2	5	21	48
Newport	20	1	85	11	7	2	49	2	2	2	15
Providence	90	3	128	53	22	9	165	2	4	8	100
Washington	34	1	98	20	5	1	57	2	0	3	30

Table 8: NCDC Total Property Damages

County Name	Flood	Hurricane	Wind	Hail	Lightning	Tornado	Winter Storm	Thunderstorm	Total
Years of Record	1993-2016	1993 - 2016	1956- 2016	1956 - 2016	1956 - 2016	1950 - 2016	1993 - 2016	1956-2016	
Bristol	$6,811,578	$10,615	$104,015	$0	$96,647	$49,907	$193,061	$269,674	$7,265,823
Kent	$30,561,878	$69,000	$747,455	$0	$618,001	$456,737	$587,140	$333,215	$33,040,211
Newport	$7,102,801	$21,231	$531,685	$0	$92,484	$0	$382,699	$34,784	$8,130,900
Providence	$36,425,720	$99,341	$1,084,122	$22,181	$722,140	$7,017,419	$14,721,015	$1,691,052	$60,091,928
Washington	$36,361,506	$15,923	$543,020	$0	$47,079	$52,001	$266,614	$1,269,113	$37,286,143
Statewide	$117,263,482	$216,110	$3,010,297	$22,181	$1,576,351	$7,576,064	$16,150,529	$3,597,837	$145,815,014

Table 9: NCDC Annualized Total Property Damages

County Name	Flood	Hurricane	Wind	Hail	Lightning	Tornado	Winter Storm	Thunderstorm	Total
Years of Record	1993-2016	1993 - 2016	1956- 2016	1956 - 2016	1956 - 2016	1950 - 2016	1993 - 2016	1956-2016	
Bristol	$283,816	$442	$1,705	$0	$1,584	$745	$8,044	$4,421	$300,359
Kent	$1,273,412	$2,875	$12,253	$0	$10,131	$6,817	$24,464	$5,463	$1,335,415
Newport	$295,950	$885	$8,716	$0	$1,516	$0	$15,946	$570	$323,583

County Name	Flood	Hurricane	Wind	Hail	Lightning	Tornado	Winter Storm	Thunderstorm	Total
Years of Record	1993-2016	1993 - 2016	1956-2016	1956 - 2016	1956 - 2016	1950 - 2016	1993 - 2016	1956-2016	
Providence	$1,517,738	$4,139	$17,772	$364	$11,838	$104,738	$613,376	$27,722	$2,297,687
Washington	$1,515,063	$663	$8,902	$0	$772	$776	$11,109	$20,805	$1,558,090
Statewide	$4,885,978	$9,005	$49,349	$364	$25,842	$113,076	$672,939	$58,981	$5,756,553

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3.0 Risk Assessment

The HIRA provides a factual basis for developing mitigation strategies and prioritizing those jurisdictions that are most threatened by and vulnerable to hazards. This section details the risk assessment process and the methods used to rank hazards risks. Results from this process and accompanying methods will be presented in hazard-specific sections that follow.

3.1 Ranking Methodology

In this section, the methodology of scoring vulnerability for the profiled hazards will be explained as it relates to each hazard. The discussion of the methodology is critical to understanding how and why hazards are prioritized differently in Rhode Island. Many of the hazards assessed in this HIRA did not have quantifiable probability or impact data, thus a semi-quantitative ranking system was used to compare all of the hazards of interest instead.

A standardized methodology, which allows for greater flexibility and room for subject matter expertise, was developed to compare different hazards' risk on a county basis. This method prioritizes hazard risk based on a blend of quantitative factors extracted from NCDC and other available data sources. These factors include:

- Likelihood of occurrence (expected frequency) (Table 10);
- Likely range of impact (predictable size and location of impact) (Table 11); and
- Probable level of impact (estimated strength, magnitude, onset, duration, and damage potential) (Table 12).

Three (3) ranking components were used to identify county-based hazard rankings. Likely range of impact and probable hazard magnitude parameters were rated on a scale of one (1) through three (3), with those rated at one (1) considered as low risk and those rated at three (3) considered as high risk. Likelihood of hazard occurrence was rated on a scale of one (1) through (4), in which the probability of future occurrence ranged from less than a one percent chance in the next 100 years (score of 1) to near 100 percent probability of happening within 12 – 60 months (score of 4).

As shown in Table 12, three (3) criteria (injuries and deaths, infrastructure shutdown, and structure damage) were taken into account to assign the probable hazard magnitude. It should be noted that each criteria was evaluated independently and the overall score for this factor was determined based on the maximum score of the three (3) criteria. For example, if a hazard was determined to have no injuries and deaths, but would result in significant structure damages, the probable hazard magnitude assigned would be a three (3).

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The scores for each of the factors (likelihood of hazard occurrence, likely range of impact, and probable hazard magnitude) were summed at a county level for each hazard separately, allowing for easy comparison between counties for each hazard type. A summation of all the scores for all hazards in each county provides an overall, all-hazards composite hazard index.

Table 10: Likelihood of Hazard Occurrence

Likelihood	Score	Frequency of Occurrence
Highly Likely	4	Near 100 percent probability within next 12-60 months
Likely	3	Between 10 percent and 100 percent probability in next 12-60 months and one incident during the next ten years
Potential	2	Between one percent and 10 percent probability in next 12-60 months, or one incident during the next 100 years
Unlikely	1	Less than one percent probability in the next 12-60 months, or less than one chance in the next 100 years

Table 11: Likely Range of Impact

Size of Area	Score	Jurisdictional Coverage
Large	3	40 percent to 100 percent of the total jurisdictional boundaries
Medium	2	10 percent to 40 percent of the total jurisdictional boundaries
Small	1	10 percent or less of the total jurisdictional boundaries

Table 12: Probable Hazard Magnitude

Intensity and Impacted Area	Score	Magnitude
Significant More than 50 percent	3	• Multiple deaths and severe injuries • Medium shutdown of some critical infrastructure and facilities • 20 percent to 50 percent of residential and 10 percent to 25 percent of commercial structures are severely damaged
Limited 10 to 50 percent	2	• Some injuries • Short shutdown of some critical infrastructure and facilities • Less than 10 percent of residential and commercial structures damaged

Intensity and Impacted Area	Score	Magnitude
Negligible Less than 10 percent	1	• Minor injuries • No shutdown of critical infrastructure and facilities • Scattered incidental residential and commercial structure damages

3.2 Composite Hazard Index

The composite hazard index characterizes vulnerability in general terms of low, medium, or high hazard propensity. To determine overall risk, the scores for each of the parameters were added together for each hazard to estimate the total county risk due to that hazard. The overall or total hazard score for the state was determined by calculating the average hazard risk for each of the counties. Table 13 shows how the rankings were assigned.

Table 13: Composite Hazard Index

Area Size	Small (1)	Medium (2)	Large (3)	Small (1)	Medium (2)	Large (3)	Small (1)	Medium (2)	Large (3)
Magnitude / Occurrence	Significant (3)			Limited (2)			Negligible (1)		
Highly Likely (4)	Mod	High	High	Mod	Mod	High	Mod	Mod	Mod
Likely (3)	Mod	Mod	High	Mod	Mod	Mod	Low	Mod	Mod
Potential (2)	Mod	Mod	Mod	Low	Mod	Mod	Low	Low	Mod
Unlikely (1)	Low	Mod	Mod	Low	Low	Mod	Low	Low	Low

Limitations of Ranking

The NWS does not guarantee the accuracy or validity of the information used for weather-related hazards. Although the historical records in the database often vary widely in their level of detail, the NWS does have a set of guidelines for use in the preparation of event descriptions; these were followed in researching this hazard analysis[7].

As previously described, NCDC is not a complete data source. It was chosen for use in ranking because of its standardized collection of many of the hazards that impact Rhode Island. Unfortunately, the data set is somewhat lacking in terms of hurricanes and geological hazards. As a result, the ranking can only characterize the current form of the data.

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[7] http://www.spc.noaa.gov/wcm/data/2008bams.pdf

4.0 Vulnerability Analysis

Vulnerability includes all populations and assets (environmental, economic, and critical facilities) that may be at risk from natural, human-caused, and technological hazards. Vulnerability analysis measures the level of assets, populations, or resources within a given region, city, or town. The vulnerability is a function of the built environment, local economy, demographics, and environmental uses of a given region.

4.1 Facility Analysis

The damage to and destruction of the built environment, particularly in Rhode Island's six (6) critical lifeline sectors (Communications, Emergency Services, Energy, Information Technology, Transportation Systems, and Water/Wastewater Systems) represents enormous economic, social, and general functional costs to a community, while also impeding emergency response and recovery activities.

More and more people live in the areas most vulnerable to hurricanes, within 50 miles of the Gulf of Mexico or the Atlantic Ocean. It is here where, for many coastal states, tremendous amounts of valuable infrastructure exist, especially transportation lifelines. A nonfunctional road can have major implications for a community: general loss of productivity; disruption of physical access preventing residents from getting to work or other daily activities; prevention of emergency vehicles from reaching destinations; associated health and safety implications; and potential access difficulties causing the disruption of important lifeline supplies, such as food and other deliveries to the community.

Damaged or destroyed utility lines and facilities—including electricity, computer and satellite links, gas, sewer, and water services—can cripple a region after a disaster. Power lines are often badly damaged or destroyed, resulting in the loss of power for days, weeks, or even months. This is particularly critical considering modern societies' dependence on electricity. In addition to basic modern household appliances being affected, public water supplies, and water treatment and sewage facilities can also be impacted. Electric pumps cannot pump drinking water into an area without power, and even if they could, the water delivery system could be breached in several areas. The loss of level elevated water tanks also results in a lack of safe drinking water. Even disaster victims who do get water may have to boil it to eliminate waterborne pathogens introduced to the supply in breached areas.

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The 2016 HIRA update completed analysis of state facilities, infrastructure, and critical facilities vulnerability using 10 RIGIS datasets in their current form. Table 14 breaks down the dataset and the asset type for the facilities included in this update. Although not a complete representation of all the possible types of facilities, this dataset is a good representation of critical and state facility locations in Rhode Island. The available data only contains the general location of each of the facilities, as no attribute information was available (such as building value and sprinkler systems). In addition, facilities are represented only as geographic points, so the full spatial extent of larger facilities is not considered.

Table 14: Datasets included in vulnerability assessment. Source: RIGIS

Structures and Facilities	Publication Date	Total Structures/Facilities
Law Enforcement	December 2014	70
Fire Stations	November 2014	155
Hospitals	March 2013	20
Schools	April 2008	677
Dams	September 2014	667
Town and City Halls	March 2013	39
Airports (E911 B2)	April 2016	10
State Facilities	June 2001	189
Fishing and Boating Access	August 2012	207
Marinas	January 1996	78
E911 RI (Single Family)	April 2016	260,825
E911 R2 (Multi-Family)		83,411
E911 C1 (Commercial)		19,422
E911 C9 (Commercial Other)		2,151
E911 I1 (Industrial)		520

Several overlapping datasets are available through RIGIS. In an effort to reduce duplication and capture the majority of the facilities, the above datasets were utilized. It should be noted that Law Enforcement was used in place of Correctional Institutions, Fire Stations in place of Emergency Medical Services (EMS), Schools to capture call schools including higher education and as a result the school layer was more comprehensive compared to the Colleges and Universities data. The State Facilities dataset overlaps several of the critical facilities, as they are state-owned facilities, and as a result were determined to be used to capture the facilities. E911 data was used to capture residential, commercial, industrial, and airport structures. This dataset provides additional categories for public; upon review, it was determined that the individual RIGIS datasets were more comprehensive for the vulnerability assessment.

Many of the buildings in Rhode Island are critical to disaster preparedness and response, although not all critical facilities are state-owned. For example, many privately-owned buildings and structures (such as hospitals, power plants, and certain industrial facilities) are critical to societal function, especially during emergencies and disasters. Thus, critical facilities data collection extended to a broader array of critical facilities than would be available by only using state-owned facilities.

Each individual hazard section includes analysis results in the risk assessment section for the defined facilities. When hazard data was available, facilities and structures were intersected with hazard-specific data to determine the building's risk zone; this includes flood, hurricane and tropical storm, fire, and sea level rise. Facilities and structures were assigned a 30-foot buffer around the point feature to estimate a structure footprint. Potential dollar loss and/or exposed building value of state and critical facilities were not completed due to lack of building-specific details in the spatial datasets.

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5.0 Hazard Profile: Natural Hazards

The following subsections present a description of each type of hazard Rhode Island may experience. The information presented in this section has been expanded upon to include human-caused and technological hazards. Facilities data, new in the 2016 HIRA update, has been included in the vulnerability analysis as applicable.

Climate change is both a present threat and an ongoing hazard that is expected to have a significant impact on municipalities, including those in Rhode Island. It acts as an amplifier for existing natural hazards.[8] Extreme weather events have become more frequent during the past half-century, and this trend is projected to continue.[9] For instance, more frequent intense precipitation events may translate into more frequent flash flooding episodes. The National Climate Assessment and Development Committee has documented that the average temperature across the United States has increased 1.5°F since 1895, with the majority of the increase since 1980. Weather events have and will continue to become more intense and frequent, and will result in health and livelihood related impacts; such as water supply, agriculture, transportation, and energy. The impact of dynamic storm events includes, but is not limited to, more frequent and intense heat waves, increases in ocean and freshwater temperatures, frost-free-days, heavy downpours, floods, sea level rising, droughts, and wildfires.[10]

5.1 Severe Winter Weather

Description

Severe winter weather includes heavy snow and ice storms that can affect the entire state. A heavy snow is generally defined as having more than eight (8) inches of accumulation in less than 24 hours. Heavy snow can bring a community to a standstill by inhibiting transportation, knocking down trees and utility lines, and causing structural collapse in buildings not designed to withstand the weight of the snow. Repair and snow removal costs can be significant and surpass annual municipal salt and snow removal budgets, often before the end of the season. A winter storm warning

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[8] ***The Copenhagen Diagnosis***, *2009: Updating the World on the Latest Climate Science*. I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.http://www.copenhagendiagnosis.com/

[9] IPCC, 2012 - Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.) Available from Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 8RU ENGLAND, 582 pp.

[10] National Climate Assessment and Development Advisory Committee (NCADAC) January 2013 Draft Climate Assessment Report. http://ncadac.globalchange.gov/

is issued when snowfall is expected to accumulate more than four (4) inches in 12 hours and/or a quarter inch or more of freezing rain accumulation.

The term ice storm is used to describe occasions when damaging accumulations of ice are expected during freezing rain situations. Ice storms result from the accumulation of freezing rain, which is rain that becomes super-cooled and freezes upon impact with cold surfaces. Freezing rain most commonly occurs in a narrow band within a winter storm that is also producing heavy amounts of snow and sleet in other locations. If extreme cold conditions are combined with low or no snow cover, the cold can better penetrate downward through the ground and potentially create problems for underground infrastructure, as well. When utilities are affected and heating systems are compromised or do not work, water and sewer pipes can freeze and even rupture.

Location

Average annual snowfall based on extrapolation of weather station snow climatology data is shown in the figure below. Although somewhat more variable in terms of distribution, northwest portions of Providence and Kent counties see these heavy snowfall events with greater frequency (roughly five or six events per year) compared to Bristol, Newport, and Washington counties that tend to have less than two significant events per year. Providence County will likely see annual snowfall totals over 57 inches, with the greatest impacts and vulnerability in western Glocester and northern Foster communities. Burrillville and Scituate also have an elevated risk and associated damages. The majority of the $387,488 in annualized damages for Providence County will be located within these four (4) municipalities. Heavy snow can affect the entire State of Rhode Island, but the highest amounts occur in the northern and northwestern areas of the state as shown in the figure below. This figure is based on best available data from NCDC using three decades of snowfall normals.[11]

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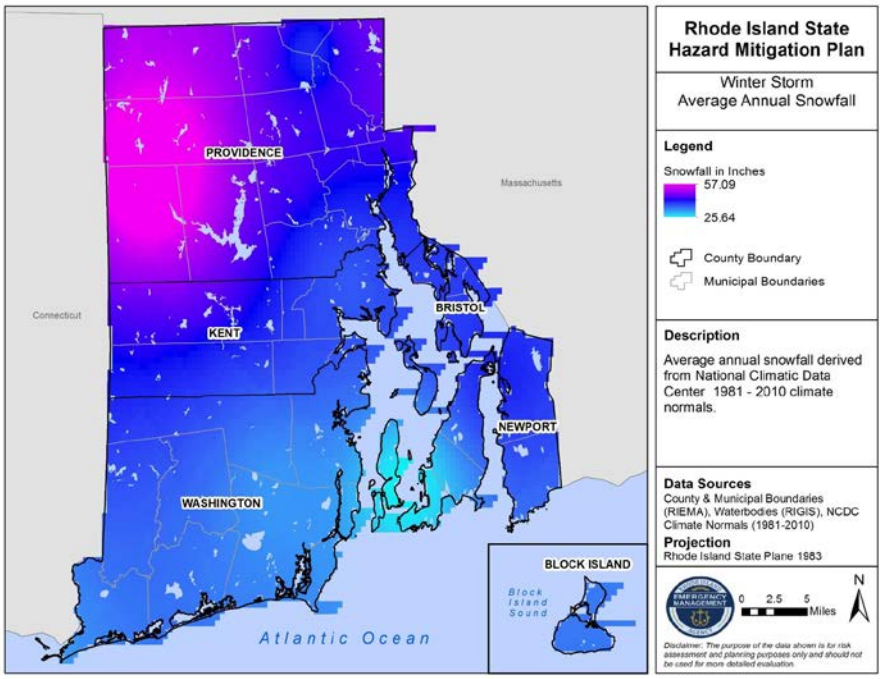
[11] https://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/climate-normals/1981-2010-normals-data

Figure 1: Rhode Island Winter Storm Average Annual Snowfall



Extent

Based on the data collected from 1981-2010, the average annual snowfall for Rhode Island is 33.8 inches, which exceeds the national average of 22.4 inches. The record snowfall occurred from February 5-7, 1978, during the Blizzard of 1978. The storm produced hurricane-force winds and resulted in over 27 inches of snow accumulation in Providence. This event serves as the storm of record for Rhode Island amongst the number of severe winter storms that the state has experienced over the last several years.

Even though there is no universally accepted scale to measure a snowstorm, the Northeast Snowfall Impact Scale (NESIS), developed by Paul Kocin and Louis Uccellini of the National Weather Service (NWS), characterizes and ranks high-impact Northeast snowstorms. These storms have large areas of 10-inch snowfall accumulations and greater. The five (5) categories of NESIS are: Extreme, Crippling, Major, Significant, and Notable shown in Table X. The index differs from other meteorological indices in that it uses population information in addition to meteorological measurements. Thus NESIS gives an indication of a storm's societal impacts. The Blizzard of 1978 scored a 6.25 on the scale and was classified as Crippling based on its widespread impact and extreme conditions.

Table 15: NESIS Values

Category	NESIS Value	Description
1	1—2.499	Notable
2	2.5—3.99	Significant
3	4—5.99	Major
4	6—9.99	Crippling
5	10.0+	Extreme

Ice storms can be the most devastating winter weather phenomena and are often the cause of automobile accidents, power and communication system outages, personal injury, and death. Moreover, they can hinder the delivery of emergency services needed in response to these catastrophes and endanger the responders. Ice storms accompanied by wind gusts cause the most damage.

The Sperry–Piltz Ice Accumulation (SPIA) Index is a scale for rating ice storm intensity, based on the expected storm size, ice accumulation, and damages on structures, especially exposed overhead utility systems. Sid Sperry of the Oklahoma Association of Electric Cooperatives and Steven Piltz from the National Weather Service office in Tulsa, Oklahoma, developed the index together. The SPIA Index uses forecast information to rate an upcoming ice storm's impact from 0 (little impact) to 5 (catastrophic damage to exposed utility systems), as shown below in Figure 2.

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Figure 2: SPIA Index

The Sperry-Piltz Ice Accumulation Index, or "SPIA Index" – Copyright, February, 2009

ICE DAMAGE INDEX	* AVERAGE NWS ICE AMOUNT (in inches) *Revised-October, 2011	WIND (mph)	DAMAGE AND IMPACT DESCRIPTIONS
0	< 0.25	< 15	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	0.10 – 0.25	15 - 25	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
	0.25 – 0.50	> 15	
2	0.10 – 0.25	25 - 35	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
	0.25 – 0.50	15 - 25	
	0.50 – 0.75	< 15	
3	0.10 – 0.25	> = 35	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
	0.25 – 0.50	25 - 35	
	0.50 – 0.75	15 - 25	
	0.75 – 1.00	< 15	
4	0.25 – 0.50	> = 35	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
	0.50 – 0.75	25 - 35	
	0.75 – 1.00	15 - 25	
	1.00 – 1.50	< 15	
5	0.50 – 0.75	> = 35	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.
	0.75 – 1.00	> = 25	
	1.00 – 1.50	> = 15	
	> 1.50	Any	

(Categories of damage are based upon combinations of precipitation totals, temperatures and wind speeds/directions.)

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Previous Occurrences

In Rhode Island, there is no single database or repository of consistent, detailed descriptions of the types of ongoing "normal" winter hazards that occur. Detailed information only exists for the unusual events that cause an exceptional amount of hardship (i.e., snow and ice removal), threats to public safety, and major damage to public and private property, such as the Blizzard of 1978, the 1991 Halloween Storm, the 2003 President's Day Storm, and the 2005 Blizzard.

Major disaster declaration (DR-4212), or Winter Storm Juno, was declared on April 3, 2015 for Bristol, Kent, Newport, Providence and Washington counties. This Severe Winter Storm and Snowstorm occurred during the period of January 26-28, 2015 and made federal assistance funds requested by the Governor available to state and eligible local governments and certain private nonprofit organizations on a cost-sharing basis for emergency work and the repair or replacement of facilities damaged in Bristol, Kent, Newport, Providence, and Washington counties. In addition, the disaster declaration authorized snow assistance for a period of 48 hours for Bristol, Kent, Newport, Providence, and Washington counties.

A major disaster declaration (DR-4107) was declared on March 22, 2013 due to a severe winter storm and snowstorm in Bristol, Kent, Newport, Providence, and Washington counties. Reports indicated that this storm stretched from New Jersey to Maine and into Canada. More than two (2) feet of snow fell in Rhode Island overnight. National Grid estimated more than 180,000 customers lost power.

Probability of Future Events

The severity of winter weather events in Rhode Island is difficult to accurately determine. Days of frigid, arctic air and below freezing temperatures may be followed by days of mild temperatures in the 40s or 50s. Snowfall and rainfall vary; however, Rhode Island residents can expect to experience several nor'easters, which usually bring coastal erosion and a possibility for blizzard conditions or heavy rainstorms dependent on the temperature.

Based on history and climatic conditions, there is a high likely probability that winter hazards will continue to occur and impact Rhode Island, with the probability of a winter storm event occurring within the next 12-60 months near 100 percent. Using NCDC data, a reasonable determination of the probability of future winter storm events can be made. Winter storms have had significant impacts on Rhode Island in the past and are likely to impact the state in the future. An examination of NCDC data suggests that on an annual basis, approximately two (2) to six (6) winter weather events of some significance occur in any particular county (Table 16) which can be related to a highly likely probability of occurrence, which indicates that there is a near 100% probability that a winter storm event will occur in the next 12-60 month period. Table 17 provides the annualized events qualitative ranking used for determining probability of future events.

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Table 16: NCDC Winter Weather Storm Events. Source: NWS NCDC

County Name	Number of Events	Annualized Events	Total Damages	Annualized Damages
Years of Record	1956-2016			
Bristol	51	2.13	$193,061	$8,044
Kent	134	5.58	$587,140	$24,464
Newport	49	2.04	$382,699	$15,946
Providence	165	6.88	$14,721,015	$613,376
Washington	57	2.38	$266,614	$11,109

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA determined severe winter storms to be a high priority hazard in Rhode Island. As described in the profile above, severe winter weather events within the state are highly likely within the next year to three (3) years. Severe winter weather events have a large range of impact, accounting for 40 to 100 percent of the jurisdictional boundaries. The probable hazard magnitude for severe winter weather ranges from limited magnitude, including some injuries, no shutdown of critical infrastructure and facilities, and less than 10 percent of residential and commercial structures damaged from the events. Table 17 outlines the hazard rankings for each of the hazard priority criteria related to severe winter storms.

Table 17: Severe Winter Weather Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Highly Likely** *Near 100 percent probability within next 12-60 months*	**Large** *40 to 100 percent of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Limited** *Less than 10 percent of residential and commercial structures damaged*	**High**

Vulnerability and Impact to People and Property

Impacts of winter storms are primarily quantified by the financial costs associated with preparing for, responding to, and recovering from severe winter weather. In general, the northwestern areas of Rhode Island experience winter weather of significance with greater frequency than the rest of the state. Electrical utilities and communications, as well as transportation systems, are vulnerable to damages from winter storms. Damage to power lines or communications towers has the potential to cause power and communication outages for residents, businesses, and critical facilities. Extended power outages would require residents to look for supplemental heat sources; improper use of these sources could result in house fires. The cost of snow removal, repairing damages, and the loss of business caused by power outages can have severe economic impacts on cities and towns. Injuries and deaths related to heavy snow usually occur as a result of vehicle accidents. Casualties also occur due to overexertion while shoveling snow and hypothermia caused by overexposure to the cold weather.

The current facilities datasets do not contain attribute information to accurately quantify facility vulnerability due to severe winter weather. Facility data necessary for vulnerability assessment includes, but is not limited to: roof type; building construction type; building and contents values; and use. (For example, the type of roof would help to determine whether or not it is a flat roof and therefore more susceptible to heavy snow loads). To address the vulnerability of infrastructure to the impacts of ice storms, it is important to complete an inventory of utility lines as they are very susceptible to breakage when ice forms on the lines, and this of course results in power failure. It is also important to describe this potential impact in terms of the direct impact, such as a power failure, on Rhode Island's economy.

State and critical facilities often do not have redundant power sources and are not even wired to accept a generator for auxiliary heat. Winter-related events can adversely affect people, some more than others. Infants and persons 65 years or older are especially vulnerable. General observations by NOAA indicate that in winter deaths related to the exposure to cold, 50 percent were over 60 years old, more than 75 percent were male, and about 20 percent of deaths occurred in the home. Of winter deaths related to ice and snow: about 70 percent occurred in automobiles, 25 percent were people caught out in the storm, and the majority of deaths were males over 40 years old (for example, from heart attacks while shoveling snow).

Human vulnerability is based on the availability, reception, and understanding of advanced warnings of impending significant winter weather events, such as Winter Storm Watches and Warnings issued by the NWS, and heeding the advice of local officials. In some cases, despite having access to technology (computer, radio, television, etc.) that allows for the reception of a watch or warning, language differences are sometimes a barrier to individuals understanding and responding to them. Injuries and death during winter storms are usually caused from transportation accidents and hypothermia. Snow and ice can cause disruptions in transportation lines and utilities resulting in emergency response delays. Secondary effects of winter storms include carbon monoxide poisoning and house fires from increased and improper use of alternative heating sources. Socially vulnerable populations and rural communities are especially at risk in winter storms.

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5.2 Flood

Description

A flood, generally developing over a period of days from slow or fast rising waters, is defined by the NFIP as:

- A general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties from:

overflow of inland or tidal waters; unusual and rapid accumulation or runoff of surface waters from any source; or a mudflow; or

- The collapse or subsidence of land along the shore of a lake or similar body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels that result in a flood as defined above.

Floodplains, by their very nature, are the low, flat, periodically flooded lands adjacent to rivers, lakes, and oceans, and are subject to geomorphic (land-shaping) and hydrologic (water flow) processes. It is only during and after major flood events that the connections between a river and its floodplain become more apparent. These areas form a complex physical and biological system that not only supports a variety of natural resources, but also provides natural flood and erosion control. In addition, the floodplain represents a natural filtering system, with water percolating back into the ground and replenishing groundwater. When a river is divorced from its floodplain with levees and other flood control structures, the natural benefits are either lost, altered, or significantly reduced.

Floods are measured by the crest height of the water; how many feet over the flood stage it has reached; the recurrent interval; and the number of feet the wall of water has created. Nuisance flooding has significantly increased along the Northeast Coast of the U.S. More intense rainfall, as a result of climate change, is likely to increase peak flooding, particularly in urban environments in the future. The magnitude of this increase is dependent on the level and rate of greenhouse gas emissions through the end of the century.

Riverine Flooding

Riverine flooding is a function of precipitation levels (both rain and snow) and water runoff volumes within the stream or river. Riverine flooding is defined as the periodic occurrence of overbank flows of rivers or streams resulting in partial or complete inundation of the adjacent floodplain. The recurrence interval of a flood is defined as the average time interval, in years, expected to take place between the occurrences of a flood of a particular magnitude and an equal or larger flood. Flood magnitude rises with increasing recurrence interval. When land next to or within the floodplain is developed, these cyclical floods can become costly and hazardous events.

Flash Flooding

A flash flood is the fastest-moving type of flood. It happens when heavy rain collects in a stream or gully, turning the normally calm area into an instant rushing current. Any flood involves water rising and overflowing its normal path. A flash flood is a specific

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type of flood that appears and moves quickly across the land, with little warning, making it very dangerous.

Flash floods are the result of heavy rainfall concentrated over one area. Most flash flooding is caused by slow-moving thunderstorms, thunderstorms that repeatedly move over the same area, or heavy rains from hurricanes and tropical storms. Dam failures can create the most damaging flash flood events. When a dam or levee breaks, a large quantity of water is suddenly let loose downstream, destroying anything in its path. The best response to any signs of flash flooding is to move immediately and quickly to higher ground.

Urban Flooding

Urban flooding occurs where there has been development within stream floodplains. This is partly a result of the use of waterways for transportation purposes in earlier times. Sites adjacent to rivers and coastal inlets provided convenient places to ship and receive commodities. Floodways and wetlands, which are the natural storage basins for flood waters, were filled to accommodate development. The price of this accessibility to the rivers was increased flooding of the ensuing urban areas. Urbanization increases the magnitude and frequency of floods by increasing impermeable surfaces, increasing the speed of drainage collection, reducing the carrying capacity of the land, and occasionally overwhelming sewer systems. The most common result from these areas flooding is poor or insufficient storm water drainage, high groundwater levels, and high percentage of impervious surfaces that prevent groundwater recharge. More often than not, when heavy rains occur, Rhode Island's aging sewer systems or combined sewer overflows (CSOs) are overrun and this results in raw sewage flowing into Narragansett Bay, often creating bay closures to shell fishing and swimming.

Coastal Flooding

Coastal flooding is typically a result of storm surge and wind-driven waves, which erode the coastline. These conditions are produced by hurricanes or tropical storms during the summer and fall, and Nor'easters and other large coastal storms or extra-tropical storms during the fall, winter, and spring. Storm surges may overrun barrier islands and push sea water up coastal rivers and inlets, blocking the downstream flow of inland runoff. Thousands of acres of crops and forest lands may be inundated by both saltwater and freshwater. Escape routes, particularly from barrier islands, may be cut off quickly, stranding residents in flooded areas and hampering rescue efforts.

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Location

In general, the flood hazard varies by location and type of flooding. Coastal areas are most at risk from flooding caused by hurricanes, tropical storms, and nor'easters. Low-lying coastal areas in close proximity to the shore, sounds, or estuaries are exposed to the threat of flooding from storm surge and wind-driven waves, as well as from intense rainfall. Areas bordering rivers may also be affected by large discharges caused by heavy rainfall over upstream areas. Inland areas are most at risk from flash flooding caused by intense rainfall over short periods of time. Stream flow tends to increase rapidly. Large amounts of impervious surfaces in urban areas increase runoff amounts and decrease the lag time between the onset of rainfall and stream flooding. Manmade channels may also constrict stream flow and increase flow velocities.

Specifically, all Rhode Island communities are subject to flooding. The state has39 incorporated municipalities, five (5) counties and one (1) tribal nation (Narragansett Indian Tribe) that have elected to participate in the NFIP in order to make federally-subsidized flood insurance available to their residents. Figure 3 shows the flood hazard areas within the state, while Table 18 summarizes the total area within each of the flood hazard area types. Washington County has over 40 percent of the state's floodplains, followed by Providence County with 31 percent. Bristol, Kent, Newport, Providence, and Washington are at risk for flooding. Based on Table 18, Providence and Washington have far larger Special Flood Hazard Areas than the other counties.

Providence has a 25.22 square mile area of Zone A and a 13.76 square mile area of Zone AE which is one of the largest areas in Rhode Island, indicating a greater risk of widespread flooding should such an event occur. Washington County has the largest of the group, 30.43 square miles in Zone A and 15.70 square miles in Zone AE. These two counties represent 85 percent of Zone A flood area and 64 percent of Zone AE, which is a substantial flood zone area at risk.

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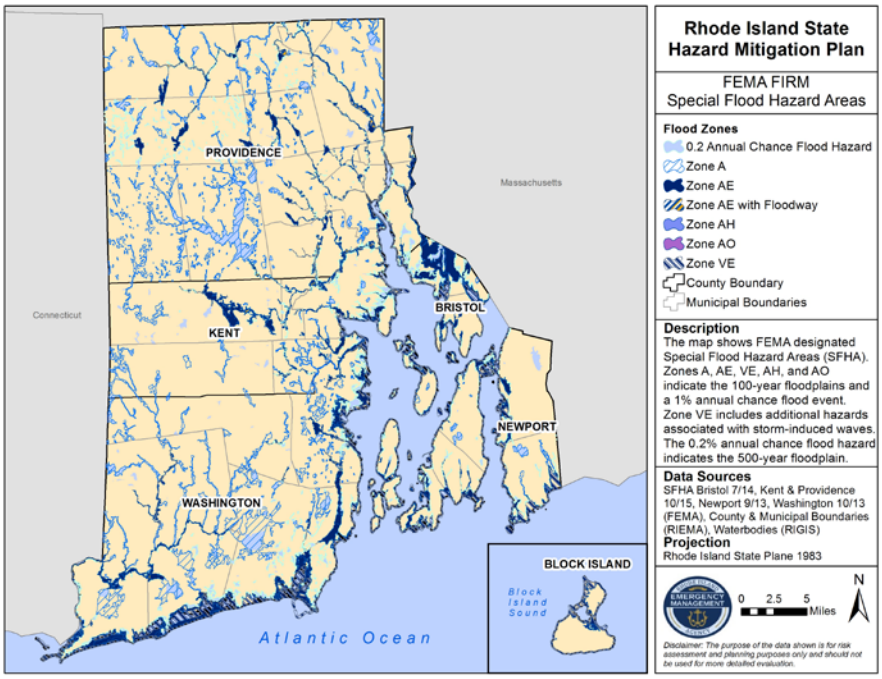
Table 18: FEMA Special Flood Hazard Areas within jurisdictions by flood zone

County Name	Zone A (sq. mi)	Zone AE (sq. mi)	Zone AO (sq. mi)	Zone AH (sq. mi)	Zone VE (sq. mi)	500-year (sq. mi)	Zone X Levee (sq. mi)
Bristol	0.080	7.614	0.002	0.000	3.872	3.205	0.000
Kent	6.520	8.255	0.007	0.000	4.066	3.161	0.024
Newport	1.817	5.827	0.000	0.000	23.525	4.289	0.000
Providence	24.853	13.300	0.000	0.008	2.525	5.985	0.652
Washington	30.463	20.673	0.000	0.000	21.205	10.002	0.000
Total	**63.735**	**55.669**	**0.009**	**0.008**	**55.194**	**26.643**	**0.676**

Figure 3: FEMA Special Flood Hazard Area zones within Rhode Island



Riverine flooding in Rhode Island may be associated with hurricanes, the aftermath of winter storms, spring snow melts combined with heavy rains, or may take place independently of major storm activity. The Blackstone River Basin and the Pawtuxet River watershed of Narragansett Bay Drainage Basin have had long histories of flooding, with records dating as far back as 1818.

Specific areas prone to riverine and urban flooding include:

- Pawtuxet River: The Pawtuxet River runs through the communities of Coventry, Warwick, West Warwick, and Cranston. Frequent flooding occurs, due to the river's shallow depths from sediment buildup, increased development, lack of pervious surface, and other localized drainage issues. The Pawtuxet River experienced the most significant flooding in recorded history during the March 2010 floods. Flood levels hit historic levels, with a record of 20.79 feet on March 29, 2010.
- Pawcatuck River: The Pawcatuck River and tributaries run west to east through the southern reaches of the state, including portions of Westerly, Richmond, and North Kingstown. There is limited development in these areas; however, during significant flood events, flooding damages do occur.
- Woonasquatucket River: The Woonasquatucket River runs from Smithfield to Providence. The areas surrounding this river are densely populated and developed with a combination of mixed use lots, including residential and commercial properties.
- Natick Area: Natick is an area located within the Town of West Warwick. This area is relatively flat and has a combination of mixed use structures, including commercial, industrial, and residential. Natick was hit incredibly hard during the March 2010 floods. NFIP staff assisted with building inspections, technical support, and site visits after the flood receded.
- East Providence: There are a number of low lying areas in East Providence that routinely get flooded, including Riverside and Marsh Street off Waterman Avenue. Marsh Street and the surrounding area are adjacent to freshwater wetlands, which fill up and create a "bathtub" effect during significant rain events.

The one percent annual chance flood event is a determination that a flood has a one percent chance of being equaled or exceeded in any year. This measurement is a risk for flood insurance and other rates for mitigation efforts against such floods and is an estimation based on the 100-year floodplains. Zones A, AE, and VE in Table 18 indicate areas subject to a one (1) percent annual chance flood event with additional hazards associated with storm-induced waves. Beavertail Road at Mackerel Cove, Matunuck Beach Road, and Arnolds Neck Road are examples of coastal flood prone access routes. Areas vulnerable to coastal flooding include Nausauket, Oakland Beach, Buttonwoods,

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and Conimicut in Warwick, the Port of Providence area, the Newport Harbor area, Narragansett Bay, the Bristol Harbor, and New Shoreham.

Extent

Even though there is no universally accepted scale for flooding, given previous occurrences in Rhode Island, the magnitude of a future hazard event could be as severe as the water height measured and inundation experienced during the 2010 floods. The Pawtuxet River rose to 20.79 feet, breaking a number of records during the historic multi-week rain event. Inland areas are most at risk from flash flooding caused by intense rainfall over short periods of time. Cranston, Warwick, West Warwick, Westerly, and Coventry experienced the most severe flash flooding in 2010. Portions of the state also experienced flooding equivalent to the 0.2 and one (1) percent annual chance event.

Populations and property are extremely vulnerable to flooding. Homes and business may suffer damage and be susceptible to collapse due to heavy flooding. Floodwaters can carry chemicals, sewage, and toxins from roads, factories, and farms; therefore, any property affected by the flood may be contaminated with hazardous materials. Debris from vegetation and man-made structures may also be hazardous following a flood. In addition, floods may threaten water supplies and quality, and initiate power outages.

In the future, more intense rainfall, as a result of climate change, is likely to increase peak flooding, particularly in urban environments. The magnitude of this increase is dependent on the level and rate of greenhouse gas emissions through the end of the century.

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Previous Occurrences

Flooding is the most prevalent and frequent natural hazard that impacts the state. Though there is no distinct flood season in Rhode Island and major river flooding can occur in any month of the year, studies have identified three (3) prevalent times throughout the year that are more prone to flood activity:

- Late winter/spring melt
- Late summer/early fall
- Early winter

According to FEMA's disaster declaration database, Rhode Island has experienced 22 disaster or emergency declarations, with 12 of them related to severe flooding and

hurricanes.[12] Flood events have caused significant damage and impact to Rhode Island; several historic events are described below:

- In August 1955, record flooding along the main rivers in the Blackstone River Basin in Rhode Island and Massachusetts, and the Thames River Basin (predominantly in Connecticut) occurred, resulting from torrential rainfall accompanying Hurricane Diane. Damages from the 1955 flood were estimated at approximately $28 million for Rhode Island, with the Woonsocket area hardest hit in the state. Except for a small local protection project in Blackstone, Massachusetts, there were no federal flood control projects in operation at the time of the flood. Subsequently, two projects in Rhode Island, for Upper and Lower Woonsocket, and two projects in Massachusetts were constructed for Blackstone River Basin flood protection. The USACE estimates that these projects prevented about $8 million in damages during the March 1968 flood.
- Prior to the 2010 floods, the March 1968 flood constituted as the record flood in the state. The March 1968 flood resulted from heavy rainfall that followed a period of sustained snowmelt, which had caused stream flows to be significantly above normal.
- In January 1979, flooding in the Belmont Park area, a residential section built in and adjacent to a flood hazard area in Warwick, occurred when a combination of above-normal temperatures and rainfall caused the Pawtuxet River to overflow its banks, inundating about 30 acres of land in the area of Belmont Park. Flooding had worsened with increased upstream development. To prevent repeated flooding, some 60 homes were purchased and demolished. Currently, frequent flooding of the Pawtuxet River in the Natick Flats section between Warwick and West Warwick have been investigated for potential flood control measures by the USACE.
- In March 2010, Rhode Island encountered the worst flooding in its recorded history on a number of the state's largest rivers including, but not limited to, the Pawtuxet, Pawcatuck, and Woonasquatucket. The incredible amount of precipitation in February and March 2010, along with saturated soils, high water tables, lack of leaf cover, and limited pervious surfaces all contributed to the disastrous March floods. The hardest hit areas in the state included Warwick, West Warwick, Coventry, and Cranston, which are located around the Pawtuxet River, and Westerly, which is located along the Main Stem Pawcatuck River. The USGS river gage at the Pawtuxet River in Cranston hit Record Flood Stage at 14.98 feet on March 15, 2010, and was then quickly superseded by another Record Flood Stage of 20.79 feet on March 31, 2010. Prior to these two back-to-back Record Flood Stages, the highest recorded level of the Pawtuxet River at Cranston was 14.5 feet on June 7, 1982.

[12]https://www.fema.gov/disasters?field_state_tid_selective=34&field_disaster_type_term_tid=All&field_disaster_declaration_type_value=All&items_per_page=60#

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- On August 27, 2011, Tropical Storm Irene, DR-4027 (Emergency Declaration 3334), hit Rhode Island. A major disaster was declared on September 3, 2011. A preliminary damage assessment report from FEMA brought the total PA cost to $9,260,898. Reports estimated that up to half of Rhode Island residents were left without power after Irene knocked down trees and power lines. The majority of damage was caused by wind, with reported wind gusts up to 71 mph, as well as storm surge causing coastal damage in Narragansett Bay. Hurricane Sandy, DR-4089, swept through the region in October 2012, leaving significant damage all along the coast. Beaches along Westerly, including Misquamicut, were devastated and almost unrecognizable.[13] More than 122,000 people lost power.[14] A FEMA report released in June 2013 estimated that four federal disaster relief programs provided support totaling $39.4 million—most of which ($31.1 million) came from the NFIP—helping Rhode Island recover from this disaster, with the following funding break outs:
    - PA: more than $5.3 million in grants for state and local agencies and some private nonprofits;
    - Individual Assistance (IA): more than $423,000 in grants paid directly to eligible individuals and families to meet basic needs for housing and cover other essential disaster-related expenses;
    - U.S. Small Business Administration (SBA): more than $2.6 million in low-interest disaster recovery loans to Rhode Island homeowners, renters, and business owners of all sizes.

Probability of Future Events

Bristol, Kent, Newport, Providence and Washington have a highly likely probability of 100 percent within the next 12-20 months. With a likely range of 10 to 40 percent of the total jurisdictional boundaries of the state. This probability is based on the variety of disasters that increase the intake of water (such as snow, rain, and hurricanes) and accounts for the parts of the Rhode Island that are on flood plains (Bristol, Kent, and Washington). The severity of the floods depends on the severity of the main source of increased water flow and the mitigation measures taken to prevent large scale flooding.

During the past 30 years, the Federal Government has shifted focus from flood "control" to flood "management." The primary impetus for this shift is continuing flood losses experienced during the latter half of the twentieth century and the first decade of the present century. The goal of flood management is to prevent loss of life and

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[13] http://www.masslive.com/news/index.ssf/2012/10/hurricane_sandy_leaves_beaches.html
[14] http://www.cbsnews.com/8301-201_162-57544801/a-state-by-state-look-at-superstorms-effects/

damage to public and private property by reducing the effects of flood damage and forming effective plans for recovery and rehabilitation.

The one (1) percent annual chance event (or base flood) is a regulatory standard used to administer and enforce floodplain management programs. FEMA has delineated both the Special Flood Hazard Area (SFHA) and the lower risk premium zones applicable to the community to promote sound floodplain management. SFHAs depict areas subject to the one (1) percent annual chance flood and area designated as A or V zones on the maps. Lower risk areas, the 0.2 percent annual chance flood, are displayed to demonstrate extent of potential flooding. The main recurrence intervals used on the Flood Insurance Rate Maps (FIRMS) are shown in Table 19.

Table 19: Annual probability based on flood recurrence intervals

Flood Recurrence Interval	Annual Chance of Occurrence
10-year	10.0%
50-year	2.0%
100-year	1.0%
500-year	0.2%

Flooding is often a result of the occurrence of other natural hazards, such as hurricanes and tropical storms, winter and coastal storms, ice jams, dam failures, and severe precipitation events. Rhode Island has historically experienced all these natural hazards at one time or another and can expect to experience them in the future. According to NCDC records, there have been 209 flood events in Rhode Island since January 1993 (Table 20). These events resulted in a total of $110.5 million in estimated property damages (in adjusted dollars) according to NCDC records. Rhode Island can expect between two (2) to six (6) flood events per year, which can be related to a highly likely probability of occurrence. Providence County has experienced the most flood events in the state and is predicted to continue to experience upward of six (6) events per year. Table 20 provides the annualized events qualitative ranking used for determining probability of future events. The hazard ranking shown in Table 21 includes the probability of future events by county.

Table 20: NCDC Flood Events

Jurisdiction	Number of Events	Annualized Events	Property Damages	Annualized Damages
Bristol	24	1.00	$6,811,578	$283,816
Kent	41	1.71	$30,561,878	$1,273,412
Newport	20	0.83	$7,102,801	$295,950
Providence	90	3.75	$36,425,720	$1,517,738
Washington	34	1.42	$36,361,506	$1,515,063
Total	**209**	**8.71**	**$117,263,482**	**$4,885,978**

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined flooding to be a high priority hazard in Rhode Island. As described in the profile above, flood events within the state are highly likely within the next year to three (3) years. Flood events have a medium range of impact, accounting for 10 to 40 percent of jurisdictional boundaries. Hazard magnitude for flood ranges is considered to have limited magnitude, including minor to some injuries, short duration of shutdown for some critical infrastructure and facilities, and less than 10 percent of residential and commercial structures damaged from the events. **Error! Reference source not found.**Table 21 outlines the hazard rankings for each of the hazard priority criteria related to flooding.

Table 21: Flood Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Highly Likely** *Near 100% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Limited** *Short shutdown of some critical infrastructure and facilities*	**Limited** *Less than 10% of residential and commercial structures damaged*	**High**
Kent County			**Limited** *Some injuries*			
Newport County						
Providence County						
Washington County						

Vulnerability and Impact to People and Property

All areas of Rhode Island continue to be vulnerable to flooding and the impacts associated with this natural hazard. Rhode Island is a water-rich state, in that it has many rivers, streams, and brooks flowing within and between its boundaries and other states. Past land use patterns and the continued use of structures within areas vulnerable to flooding will continue to promote future risk and vulnerability of flood impacts to structures and people. Local land use regulations and ordinances have done much to curb unregulated development within flood hazard areas. However, Rhode Island is one of the older states in the nation, with limited land resources. This places a high value on all property within the state. The limitation of land availability and high property values will continue to encourage the reuse of land and structures in areas vulnerable to flooding.

Many factors contribute to the relative vulnerabilities of areas within the floodplain. Population and property in floodplains or areas prone to flooding is a critical factor in determining vulnerability to flooding. Additional factors that contribute to flood vulnerability range from specific characteristics of the floodplain to characteristics of the structures located within the floodplain. Flooding has the potential to cause significant damage and destruction; flood water can transport large objects, structure foundations, or hazmat chemicals downstream.

Extensive flooding may result in road closures and event evacuation of residences and businesses. Depending on the severity of the flood, this could result in structures being uninhabitable, leading to the need to rebuild or relocate. In some cases, businesses may have to close their doors for good. If utilities and infrastructure are damaged, residents and critical facilities would have to look for supplemental power (generators) or water supplies. Roadways would become flooded, possibly resulting in essential facilities becoming isolated or emergency services rerouted in response to calls. A catastrophic flood could lead to injury or death.

Based on NCDC historical data (1993 through 2016), Rhode Island is highly likely to experience between one (1) and four (4) flood events per year accounting for annualized damages between $283,816 in Bristol County and $1.5 million in Providence and Washington counties. Specific areas prone to riverine and urban flooding are summarized in the hazard description section of the flood profile.

In order to determine the number of facilities and structures within FEMA's SFHA, the facility and structure points with a 30-foot buffer were intersected with the National Flood Hazard Layer (NFHL). This analysis, depicted in Table 22 and Table 23, shows 30,676 structures and facilities located within the SFHA by municipality and flood zone; if a structure is located within multiple flood zones, the conservative zone was assigned. Over 44 percent of the structures are located within the 0.2 percent annual chance flood (500-year flood) zone, of which 78 percent are single-family residential structures.

Table 22: Number of facilities and structures located within FEMA effective SFHA by Municipality

County	Municipality	500-yr	Zone A	Zone AE	Zone AE within Floodway	Zone AH	Zone AO	Zone VE	Grand Total
Bristol	**County Total**	**3,003**		**2,582**				**186**	**5,771**
	Barrington	2,064		1,314				52	3,430
	Bristol	231		484				110	825
	Warren	708		784				24	1,516

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County	Municipality	500-yr	Zone A	Zone AE	Zone AE within Floodway	Zone AH	Zone AO	Zone VE	Grand Total
Kent	**County Total**	**3,014**	**212**	**2,164**	**137**		**22**	**309**	**5,858**
	Coventry	96	52	519	26				693
	East Greenwich	78	64	211	6				359
	Warwick	2,613	51	1,250	20			309	4,243
	West Greenwich		16						16
	West Warwick	227	29	184	85		22		547
Newport	**County Total**	**1,851**	**33**	**1,938**	**6**			**873**	**4,701**
	Jamestown	142	1	54				81	278
	Little Compton	78	21	95				28	222
	Middletown	92		52	6			16	166
	Newport	875		965				183	2,023
	Portsmouth	510	11	639				449	1,609
	Tiverton	154		133				116	403
Providence	**County Total**	**1,520**	**462**	**1,340**	**252**	**4**		**104**	**3,682**
	Burrillville	56	71	109	37				273
	Central Falls	32		50	7				89
	Cranston	288	5	327	36			28	684
	Cumberland	9	75	23	5				112
	East Providence	704		120	12			61	897
	Foster		49						49
	Glocester	34	42	144	4				224
	Johnston	16	15	105	30				166
	Lincoln	4		23	9				36
	North Providence	40	20	58	6				124
	North Smithfield	39	41	26	1				107
	Pawtucket	23	5	32	10			2	72
	Providence	142	59	170	52	4		13	440
	Scituate	17	50	37	10				114
	Smithfield	8	22	64	21				115
	Woonsocket	108	8	52	12				180
Washington	**County Total**	**4,254**	**466**	**4,809**	**52**			**1,083**	**10,664**
	Charlestown	547	32	824	3			157	1,563
	Exeter	1	43		4				48
	Hopkinton	3	58	17	19				97
	Narragansett	1,259		1,275				201	2,735

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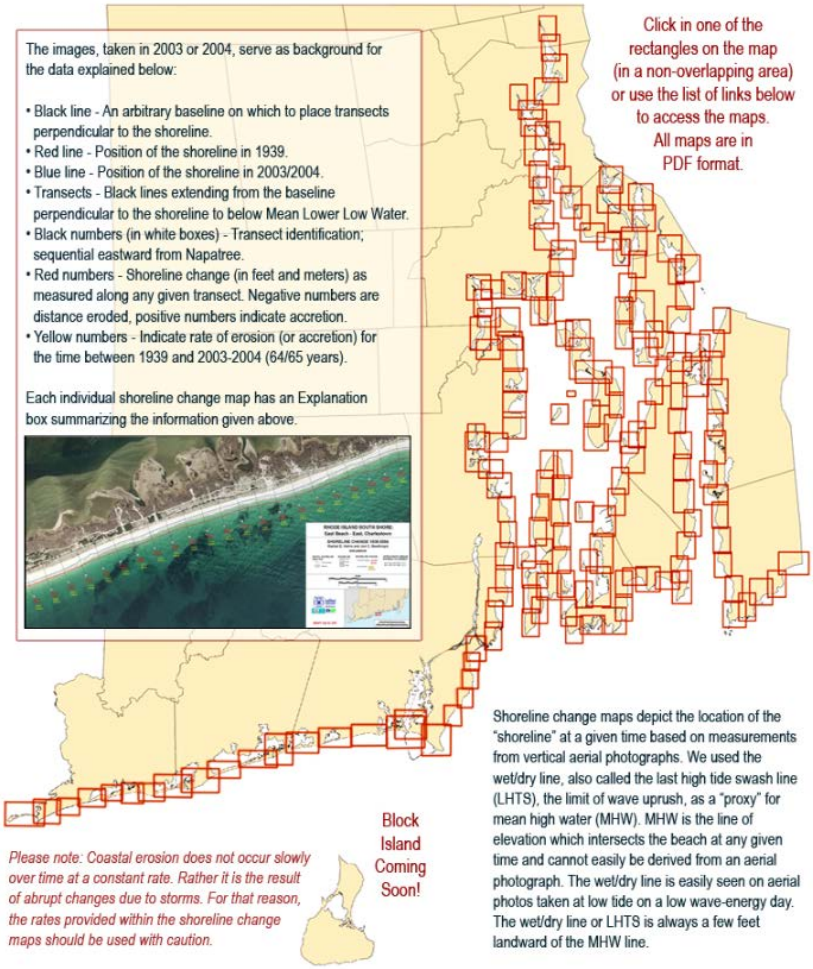
County	Municipality	500-yr	Zone A	Zone AE	Zone AE within Floodway	Zone AH	Zone AO	Zone VE	Grand Total
	New Shoreham	3		63				23	89
	North Kingstown	1,081	154	867	11			196	2,309
	Richmond	2	36	17	3				58
	South Kingstown	593	120	620	3			296	1,632
	Westerly	765	23	1,126	9			210	2,133
	Grand Total	**13,642**	**1,173**	**12,833**	**447**	**4**	**22**	**2,555**	**30,676**

Table 23: Number of facilities and structures located within FEMA effective SFHA by Type

Structures and Facilities Type	500-yr	Zone A	Zone AE	Zone AE within Floodway	Zone AH	Zone AO	Zone VE	Grand Total
Airports			2					2
Dams	33	176	57	132			6	404
Fire Stations	5		6			1		12
Hospitals	1							1
Law Enforcement	1		2					3
Marinas	9		29				34	72
Fish Boat Access	4	43	42	12			49	150
Schools	20	1	11					32
State Facilities	6	3	13	1				23
Town and Cities	1		1					2
Single Family Residential (R1)	10,637	794	9,918	99		7	2,066	23,521
Multi-Family Residential (R2)	1,970	91	1,461	65	4	7	117	3,715
Commercial (C1)	855	59	1,157	127		6	239	2,443
Commercial Other (C9)	65	4	94	8		1	40	212
Industrial (I1)	35	2	40	3			4	84
Grand Total	**13,642**	**1,173**	**12,833**	**447**	**4**	**22**	**2,555**	**30,676**

In addition to the FEMA SFHA mapping, the Rhode Island Coastal Resources Management Council (CRMC) provides shoreline change maps that show the shoreline rates of change that are applied to the council's regulatory programs to address issues including setbacks of activities from coastal features. The available maps are shown below in Figure 4.

Figure 4: Shoreline Change Maps. Source: Rhode Island CRMC



National Flood Insurance Program (NFIP)

The NFIP was established in 1968, with the passage of the National Flood Insurance Act, to reduce the loss of life and property associated with flooding while offering property owners an opportunity to financially protect themselves. Participation in the NFIP is based on an agreement between the municipality and the Federal Government. If a municipality agrees to adopt and enforce a floodplain ordinance designed to reduce future flood risks, all citizens in the participating municipality can purchase flood insurance. Floodplain management begins at the community level with operation of a community program of corrective and preventative measures for reducing flood damage. These measures take a variety of forms; for inclusion in the NFIP, communities adopt their flood hazard maps and the community Flood Insurance Study (FIS), as well as a FEMA-compliant floodplain management ordinance that regulates activity in the floodplain.

Currently, all 39 municipalities and one tribal nation in Rhode Island participate in the NFIP. As part of the NFIP, the Federal Government provides FIRMs to municipalities that agree to regulate development in high risk flood areas. The maps identify flood prone areas that form the basis for the federally-backed flood insurance rates. The flood risk information presented on the FIRMs is based on historic, hydrologic, and hydraulic data, as well as open-space conditions, flood-control works, and development. Data on active NFIP policies was obtained from FEMA's BureauNet database and is summarized below. Table 24 shows the NFIP flood policy and claim information by each participating municipality. There are 14,530 active policies for Rhode Island NFIP communities. Rhode Islanders pay $19.1 million annually in premiums for $3.7 billion in coverage. Since January 1, 1978, there have been 6,450 total losses of more than $120.1 million. Five (5) municipalities have more than 1,000 insurance policies in force. The average claim payment on active policies is $18,628. The Town of Narragansett in Washington County accounts for nearly 10.2 percent of the policies in force and 10.8 percent of the total coverage, followed by the City of Warwick in Kent County that accounts for 9.4 percent of the policies in force and 8.7 percent of the total coverage. It should be noted that the information presented here does not take into account any of the uninsured losses caused by flooding.

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Table 24: NFIP policies and claims paid in Rhode Island as of April 30, 2016. Source: FEMA BureauNet

County	Municipality	Number of Polices In-Force	Coverage Total $	Annual Premium	Number of Claims	Claim Total Value	Average Claim Value $
Bristol	Barrington	1,192	$353,065,000	$1,349,831	428	$1,564,878	$3,656
	Bristol	542	$128,511,700	$770,423	195	$1,425,902	$7,312
	Warren	449	$90,041,500	$547,064	137	$1,225,074	$8,942
Kent	Coventry	301	$80,648,300	$200,583	73	$1,281,242	$17,551
	East Greenwich	186	$49,330,300	$218,818	87	$497,713	$5,721
	Warwick	1,365	$324,864,100	$2,046,345	857	$10,889,413	$12,706
	West Greenwich	11	$3,122,000	$4,082	2	$10,427	$5,214
	West Warwick	161	$31,875,900	$186,381	161	$6,040,921	$37,521
Newport	Jamestown	220	$64,707,200	$198,908	59	$242,334	$4,107
	Little Compton	153	$41,842,800	$195,578	32	$318,972	$9,968
	Middletown	139	$42,405,800	$187,227	50	$267,231	$5,345
	Newport	1,246	$304,995,600	$2,111,861	288	$7,065,786	$24,534
	Portsmouth	707	$165,383,700	$1,261,845	203	$745,860	$3,674
	Tiverton	175	$43,978,300	$247,083	89	$471,939	$5,303
Providence	Burrillville	47	$12,888,500	$37,363	18	$117,975	$6,554
	Central Falls	56	$6,878,600	$46,602	28	$438,404	$15,657
	Cranston	445	$118,109,700	$567,421	493	$14,582,242	$29,579
	Cumberland	52	$15,844,400	$61,256	46	$2,633,481	$57,250
	East Providence	274	$75,349,600	$301,449	116	$985,326	$8,494
	Foster	10	$2,516,000	$10,413	3	$35,025	$11,675
	Glocester	37	$8,129,300	$27,209	8	$17,682	$2,210

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County	Municipality	Number of Polices In-Force	Coverage Total $	Annual Premium	Number of Claims	Claim Total Value	Average Claim Value $
	Johnston	66	$18,519,000	$54,775	78	$3,784,588	$48,520
	Lincoln	235	$61,050,600	$81,320	60	$1,830,081	$30,501
	North Providence	147	$30,149,700	$130,981	128	$1,131,750	$8,842
	North Smithfield	40	$11,382,500	$43,506	13	$267,145	$20,550
	Pawtucket	88	$22,576,400	$48,289	37	$1,622,558	$43,853
	Providence	655	$174,826,900	$646,361	331	$10,407,163	$31,442
	Scituate	32	$8,004,500	$17,597	30	$554,950	$18,498
	Smithfield	156	$31,406,800	$89,172	30	$321,776	$10,726
	Woonsocket	158	$36,837,900	$91,427	7	$67,361	$9,623
Washington	Charlestown	728	$201,135,100	$1,043,071	248	$2,923,140	$11,787
	Exeter	28	$6,869,400	$13,161	8	$45,408	$5,676
	Hopkinton	24	$5,528,500	$17,466	15	$152,242	$10,149
	Narragansett	1,483	$404,084,300	$1,547,526	476	$8,143,423	$17,108
	New Shoreham	85	$25,696,800	$184,935	17	$346,760	$20,398
	North Kingstown	844	$233,623,200	$1,130,304	282	$1,592,481	$5,647
	Richmond	30	$9,191,000	$35,666	30	$1,686,422	$56,214
	South Kingstown	930	$232,914,000	$1,329,028	424	$7,068,808	$16,672
	Westerly	1,033	$270,576,400	$2,025,651	863	$27,345,381	$31,686
Total		**14,530**	**$3,748,861,300**	**$19,107,978**	**6,450**	**$120,149,266**	**$18,628**

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In an effort to mitigate structures in flood prone areas, FEMA established the Hazard Mitigation Assistance (HMA) Flood Mitigation Assistance Grant Program (FMA)[15] to provide funds for local governments to address the most egregious flood-prone properties with the most flood insurance claims. The program features a reduced non-federal match (from 25 percent to 10 percent) with an approved mitigation plan that specifies the state's strategy to reduce the number of RL and SRL properties. The amendment authorizes scheduled increases in flood insurance premium rates to actuarial rates for SRL property owners who refuse a formal and complete mitigation grant offer through the SRL grant program to mitigate an SRL structure.

Many flood-insured properties have had more than one claim. A property that is currently insured for which two or more NFIP losses (occurring more than 10 days apart) of at least $1,000 each have been paid within any 10-year period since 1978 is defined as a "repetitive loss property" by the NFIP program.

Residential SRL properties are single family structures consisting of one (1) to four (4) residences that have flood insurance which have incurred flood related damages on four (4) or more separate occasions with the amount of each claim exceeding $5,000 and the cumulative amount of the total claims paid exceeding $20,000; or cumulative amount of the claims exceeds the value of the property, when at least two separate claim payments have been made. In either case, at least two (2) losses must have occurred within a 10-year time span; claims must be more than 10 days apart.

As of June 2016, there were 441 repetitive loss and 12 severe repetitive loss properties in Rhode Island. There were 1,266 losses involving repetitive loss properties with payouts of $56,619,333.28. The severe repetitive loss properties experienced 52 losses totaling $1,431,774.10 in paid claims.

Table 25 includes the number of non-mitigated RL and SRL structures. The City of Cranston in Providence County accounts for 17.6 percent of the non-mitigated RL properties, followed by the Town of Westerly in Washington County, and the City of Warwick in Kent County. The City of Warwick has the greatest number of SRL properties.

Table 25: Non-mitigated repetitive and severe repetitive loss properties as of June 30, 2016

County	Municipality	Total RL Properties	Total SRL Properties
Bristol	Barrington	11	0
	Bristol	12	0
	Warren	9	0

[15] https://www.fema.gov/flood-mitigation-assistance-grant-program

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County	Municipality	Total RL Properties	Total SRL Properties
Kent	Coventry	6	0
	East Greenwich	9	0
	Warwick	45	4
	West Greenwich	0	0
	West Warwick	20	0
Newport	Jamestown	1	0
	Little Compton	0	0
	Middletown	2	0
	Newport	20	0
	Portsmouth	7	0
	Tiverton	3	0
Providence	Burrillville	2	0
	Central Falls	5	0
	Cranston	78	1
	Cumberland	4	0
	East Providence	16	1
	Foster	1	0
	Glocester	0	0
	Johnston	14	2
	Lincoln	5	0
	North Providence	20	0
	North Smithfield	2	0
	Pawtucket	4	1
	Providence	25	0
	Scituate	2	0
	Smithfield	1	0
	Woonsocket	1	0
Washington	Charlestown	9	1
	Exeter	0	0
	Hopkinton	0	0
	Narragansett	18	1
	New Shoreham	0	0
	North Kingstown	13	0
	Richmond	1	0
	South Kingstown	26	0
	Westerly	49	1
	Total	**441**	**12**

The Community Rating System (CRS) is a voluntary program that recognizes and encourages a community's efforts that exceed the NFIP minimum requirements for floodplain management. The CRS program emphasizes three (3) goals: the reduction of flood losses, facilitating accurate insurance rating, and promoting the awareness of flood insurance. By participating in the CRS program, communities can earn a five (5) to 45 percent discount for flood insurance premiums based on the activities that reduce the risk of flooding within the community. A point system is used to rate communities based on the level of safety provided with the enforced floodplain management activities. A Class 9 community receives the lowest flood insurance premium discount of five percent while a Class 1 receives a discount of as much as 45 percent. Currently, eight (8) communities participate in the CRS and receive flood insurance premium discounts. These communities are shown in Table 26.

Table 26: CRS eligible community status as of May 2016. Source: FEMA

County	Municipality	CRS Entry Date	Current Effective Date	Current Class	% Discount for SFHA	% Discount for Non-SFHA
Bristol	Town of Bristol	5/1/13	5/1/13	8	10	5
Newport	Town of Middletown	10/1/91	4/1/00	8	10	5
Providence	City of East Providence	5/1/14	5/1/14	9	5	5
Providence	City of Pawtucket	10/1/14	10/1/14	8	10	5
Washington	Town of Narragansett	10/1/92	10/1/07	8	10	5
Washington	Town of North Kingstown	10/1/93	10/1/93	9	5	5
Washington	Town of Westerly	5/1/13	5/1/13	8	10	5
Washington	Town of Charlestown	5/1/15	5/1/15	7	15	5

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5.3 High Winds

Description

Wind is the motion of air past a given point caused by a difference in pressure from one place to another. Severe wind poses a threat to Rhode Island in many forms, including that produced by severe thunderstorms and tropical weather systems. The effects can include blowing debris, interruptions in elevated power and communications utilities, and intensified effects of winter weather. Harm to people and animals, as well as damage to property and infrastructure, may be the result. Two (2) basic types of damaging wind events, other than tropical systems, affect Rhode Island: synoptic-scale winds and thunderstorm winds. Synoptic-scale winds are high winds that typically occur with cold frontal passages or Nor'easters. When thunderstorm winds exceed 58 miles per hour (mph), the thunderstorm is considered severe and a warning is issued. Downburst winds result from the sudden descent of cool or cold air toward the ground. As the air hits the ground, it spreads outward, creating high winds like those in a thunderstorm. Unlike tornadoes, downburst winds move in a straight line, without rotation.

Rhode Island wind events can produce damage often associated with thunderstorms or tornadoes. In some instances, these events have been associated with weakening tropical weather systems, including downgraded tropical and sub-tropical storm systems. This section examines the risks associated with damaging wind events with emphasis on hurricanes, tornadoes, and thunderstorms.

Location

While all areas of Rhode Island are at risk from high speed winds, Washington and Newport counties, near the Narragansett Bay, are within highest wind speed area due to the direct proximity to the coast. Figure 5 below outlines Rhode Island wind speed zones. The highest wind speed locations (greater than 120 mph) reside within Washington County. This is the greatest risk area for high wind speeds, which occur in a variety of storms.

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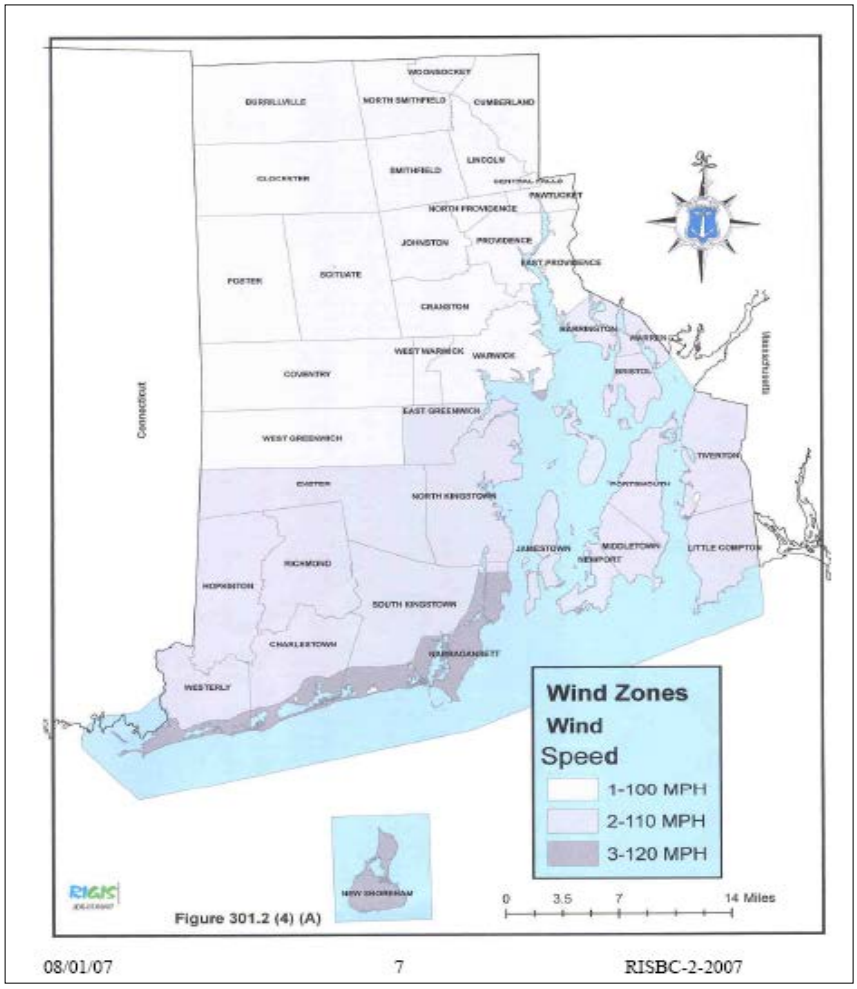
Figure 5: Rhode Island Wind Speed Zones



Extent

The Beaufort Wind Scale, outlined in Table 27, measures wind force based on the wind value in knots, the World Meteorological Organization (WMO) classification, and the appearance of wind effects. Based on the data presented, the Washington County area is at greater risk for higher force winds.

Table 27: Beaufort Wind Scale

Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects	
			On the Water	On Land
0	Less than 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Small waves (1-4 ft.) becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Moderate waves (4-8 ft.) taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger waves (8-13 ft.), whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Sea heaps up, waves 13-19 ft., white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Moderately high (18-25 ft.) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Twigs breaking off trees, generally impedes progress
9	41-47	Strong Gale	High waves (23-32 ft.), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs; slate blows off roofs
10	48-55	Storm	Very high waves (29-41 ft.) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"

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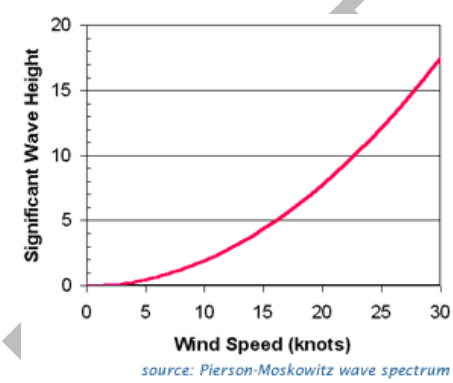
Force	Wind (Knots)	WMO Classification	Appearance of Wind Effects	
			On the Water	On Land
11	56-63	Violent Storm	Exceptionally high (37-52 ft.) waves, foam patches cover sea, visibility more reduced	
12	64+	Hurricane	Air filled with foam, waves over 45 ft., sea completely white with driving spray, visibility greatly reduced	

In addition, wind speed can impact wave height (as demonstrated in Figure 6). This would ultimately affect coastal areas where the risk for increased wave height could lead to other cascading effects such as flooding.

Figure 6: Pierson-Moskowitz Wave Spectrum



Human vulnerability is largely determined by the availability and reception of early warnings for the approach of meteorological events that cause high winds, and by the availability of nearby shelters. Individuals who immediately seek shelter in a sturdy building or metal-roofed vehicle are much safer than those who remain outdoors. Early warnings of high winds are also vital for aircraft flying through the affected area.

Previous Occurrences

Rhode Island has observed a number of very destructive wind events over the years. The NCDC has recorded 498 high wind events; these events have caused more than $15.5 million in total damages. Some of the most significant wind and lightning events in the state's history are listed in Table 28.

Table 28: NCDC Wind Events

Jurisdiction	Number of Events	Annualized Events	Property Damages	Annualized Damages
Bristol	60	0.98	$104,015	$1,705
Kent	127	2.08	$747,455	$12,253
Newport	85	1.39	$531,685	$8,716
Providence	128	2.10	$1,084,122	$17,772
Washington	98	1.61	$543,020	$8,902

Probability of Future Events

Historically, wind events have occurred throughout the state, with Providence and Kent counties experiencing the greatest number of events. Based on hazard analysis, Rhode Island is highly likely to experience severe high winds within 12–60 months near 100 percent.

Based on historical frequency of occurrence using NCDC data, a reasonable determination of probability of future high wind events can be made. An examination of NCDC data suggests that on an annual basis, approximately one to two wind events occur in any particular county in Rhode Island.

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Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined high wind to be a high priority hazard in Rhode Island. As described in the profile above, high wind events within the state are highly likely within the next year to three (3) years. High wind events have a medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Hazard magnitude for high wind varies and is considered to have limited magnitude, including some injuries, short duration shutdown of critical facilities and infrastructure, and scattered incidental, residential, and commercial structure damages from the events. Table 29 outlines the hazard rankings for each of the hazard priority criteria related to high wind.

Table 29: High Wind Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Highly Likely** *Near 100% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of some critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structure damages*	**High**
Kent County						
Newport County						
Providence County						
Washington County						

Vulnerability and Impact to People and Property

Wind impacts can be measured in financial terms, as well as fatalities and injuries. An examination of NCDC data shows that wind contributed to at least 20 injuries. Wind vulnerability is based in large part on building construction and standards. Other factors, such as location, condition, and maintenance of trees, also play a significant role in determining vulnerability.

Using historical records, it can be estimated that Rhode Island will experience between one (1) and two (2) high wind events in any given year. As presented in the NCDC data, property damage from high wind events can be very costly. Annualized damages range from $1,705 in Bristol County to $17,772 in Providence County. Within Providence County, Scituate and Pawtucket have experienced multiple wind events of increased size and magnitude, followed by Cranston and Providence. Richmond in Washington County has experienced significant damages due to wind-related events. As previously described, the NCDC loss estimates are only available at the county level and are believed to be an underrepresentation of the actual losses experienced due to hazards, as losses from events that go unreported or that are difficult to quantify are not likely to appear in the NCDC database; this is especially true with crop damages.

All facilities within Rhode Island are considered vulnerable to severe wind. The damages resulting from high winds are affected by the condition of the exposed structures, their design and construction, and the quality of the building materials. The location and construction of a facility plays a role in how it will be affected by severe wind events. If a tall structure is located on a hilltop, has other tall structures around it, or has large exposed windows, it may be damaged during a wind storm. Communications and power supplies may be compromised during wind events, and some critical facilities might not be equipped with a backup power source. As the facilities data sets are expanded to include construction and value information, analysis to thunderstorms should be reconsidered.

In many cases, residential and commercial structures built before the adoption of current state building codes and standards are vulnerable to high wind events. Utility lines, communication towers, and transportation networks can be impacted by high winds or flying debris.

There are 4,002 structures in the RIGIS E911 data categorized as mobile homes, which is the building stock data set considered most vulnerable. Of these structures, 1,310 are located within Kent County, 950 in Providence County, 929 in Washington County, and 813 in Newport County. The largest concentration of mobile homes is in Coventry, with a total of 1,075 mobile home structures. Table 30 summarizes the number of mobile homes by municipality and road names.

Table 30: Mobile Home Structures in Rhode Island (E911 Site Type R3)

County	Municipality	Number of Mobile Homes	Structures (#)
Bristol	Barrington	0	N/A
	Bristol	0	N/A
	Warren	0	N/A

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County	Municipality	Number of Mobile Homes	Structures (#)
Kent	Coventry	1,075	Airport Road (27) Cantaberry Lane (51) Kelly Lane (29) King Philip Road (22) Lane 6 (20) Lane 7 (21) Lane A (46) Lane B (30) Lane C (25) Lane D (20) Lane E (34) Lane F (45) Lear Drive (69) Leisure Way (41) Liena Rose Way (45) Linda Drive (39) Milton Lane (23) Park Lane (37) Sandra Circle (26) Torch Lane (47) Valiant Road (21) Wright Way (46)
	East Greenwich	42	Cooper Lane (36)
	Warwick	105	Toll Gate Road (102)
	West Greenwich	88	Blueberry Heights (26)
	West Warwick	0	N/A
Newport	Jamestown		N/A
	Little Compton	30	N/A
	Middletown	209	Bayview Park (89) Forest Park (70) Prospect Avenue (30)
	Newport	0	N/A
	Portsmouth	280	Cathy Circle (30) Debra Drive (28) Donna Drive (41) First Street (20) North Drive (31) Scotty Drive (22) Second Street (20) South Drive (24)
	Tiverton	294	Brayton Road (30) Bulgarmarsh Road (103) Crandall Road (2) Heritage Park (34)

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Providence	Burrillville	206	Hillside Drive (61) Maplewood Drive (47) Oak Terrace (42) Rexmere Road (23)
	Central Falls	0	N/A
	Cranston	23	Dyer Avenue (20)
	Cumberland	22	Diamond Hill Road (19)
	East Providence	71	East Drive (34) West Drive (35)
	Foster	10	N/A
	Glocester	193	Diamond Hill Road (31) Hemlock Road (24) Safari Road (39)
	Johnston	18	N/A
	Lincoln	63	Woodward Road (62)
	North Providence	0	N/A
	North Smithfield	0	N/A
	Pawtucket	331	Alpha Drive (40) Beverage Hill Avenue (29) Lowell Avenue (32) Manton Street (152) Stephanie Drive (21)
	Providence	1	N/A
	Scituate	7	N/A
	Smithfield	0	N/A
	Woonsocket	5	N/A
Washington	Charlestown	137	Foxtrot Drive (22) Jacob Perry Drive (27) Land Harbor Drive (21)
	Exeter	204	South Country Trail (75) Victory Highway (50)
	Hopkinton	60	N/A
	Narragansett	1	N/A
	New Shoreham (Block Island)	0	N/A
	North Kingstown	245	Krzak Road (108) Post Road (127)
	Richmond	118	Gardiner Road (108)
	South Kingstown	162	Holiday Court (27) Matunuck Beach Road (98)
	Westerly	2	N/A

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5.4 Extreme Heat

Description

Extreme heat conditions are defined by summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. In Rhode Island, when the outside temperature goes above 90 degrees for three (3) or more days, it is a heat wave. If the hot temperatures last for several weeks, it is called extreme heat. This definition for extreme heat may be refined to read: summertime temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. The Heat Index (HI) or the "Apparent Temperature" is an accurate measure of how hot it really feels when the Relative Humidity (RH) is added to the actual air temperature. The HI may be used to help determine when an extreme heat event is occurring. Heat alert procedures from the NWS are based mainly on HI values.

Location

Extreme heat impacts the entire State of Rhode Island. Citizens that live away from the coast in Kent, Providence, and Washington counties are at greater risk for extreme heat.

Specifically, within these counties, locations of high concentrations of the following at-risk populations are particularly sensitive to extreme heat:

- Infants and young children
- The elderly
- People with chronic conditions
- People who are obese
- Athletes
- Outdoor workers
- People of low socio-economic status

In the State of Rhode Island, trends indicate that deaths and emergency department visits are significantly higher on days with hot weather, even on days with a heat index below the current advisory threshold. For example, the risk of deaths for all causes is ~7% higher on days when the heat index is 95°F as compared to 75°F. Similarly, all-cause emergency department visits are ~6.6% higher over a week following a day where the heat index was 95°F as compared to 75°F.

Extent

Heat waves and extreme heat can cause dust storms or droughts. For individuals, heat waves and extreme heat can cause sunburn or heat-related illnesses. Older adults, young children, and anyone who has a chronic health condition are more susceptible to heat-related illnesses, including:

- Heat cramps: Muscle pains and spasms caused by heat and heavy exertion.

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- Heat exhaustion: Occurs during work or exercise in a hot, humid place and the body is dehydrated as a result of sweating.
- Hyperthermia: Fever and Heat stroke: Life-threatening medical emergency in which the body can no longer stay cool and the body temperature rises.

Most recently, the Rhode Island Department of Health established the Northeast Regional Heat Collaborative. The Collaborative examine the relationship between heat and morbidity and mortality in the Northeast and, based on research findings from New England and in collaboration with key partners across the region, the NWS Regional and Local offices in the Northeast are planning to modify the heat advisory threshold in our region. Specifically, under the updated criteria, heat advisories in New England will be issued when either the heat index is forecast to be 95-99°F for 2 or more days or the heat index is forecast to be 100-104°F for any length of time.[16]

Overall, the number of heat-related deaths in the state is declining. This indicates that the population has become better adapted to heat waves and extreme heat. This adaptation is most likely a result of improvements in medical technology; access to air-conditioned homes, cars, and offices; increased public awareness of potentially dangerous weather situations; and proactive responses of municipalities during extreme weather events.

Previous Occurrences

Heat has caused more deaths in the United States than any other type of extreme weather event, including tornadoes, hurricanes, floods, earthquakes, and lightning, resulting in more than 7,800 deaths from 1999 to 2009. With climate change, extreme heat and hot weather have already increased in frequency and magnitude. For example, in 1970, Providence had four (4) days with a maximum temperature over 90°F; however, due to climate change, this number has risen to 22 days. Figure 7 shows the rise in historic annual average temperature for the State of Rhode Island from 1895 to 2013.

Figure 7: Historical annual average temperature from 1895-2013 in Rhode Island. Source: NOAA National Climatic Data Center

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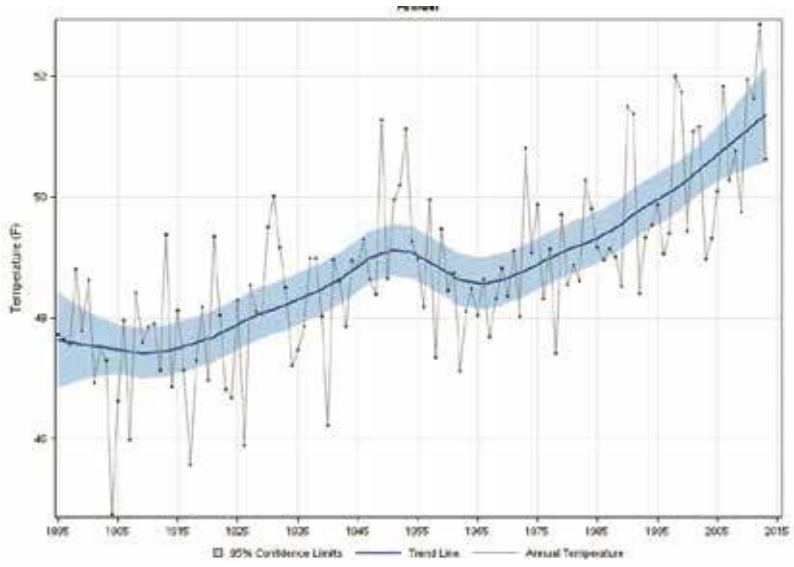
[16] Rhode Island Department of Health Heat Advisory Letter


Temperature (F)
95% Confidence Limits
Trend Line
Annual Temperature

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Probability of Future Events

On the whole, Rhode Island is highly likely to experience extreme heat events within 12-60 months. Kent, Providence, and Washington are highly likely, 100 percent probability to experience an extreme heat event within the next 12 to 60 months.

Regardless of any trends indicating heat-related deaths are declining, extreme heat events remain a danger. Specific high-risk groups of the population, including the elderly, sick, poor, homeless, handicapped, or those under the influence of drugs and alcohol, typically experience a disproportionate number of health impacts from extreme heat conditions. In addition, the number of days over 90°F is projected to continue to grow. Climate change studies estimate that by 2070, Rhode Island could have up to 50 days over 90°F per year.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined extreme heat to be a high priority hazard in Rhode Island. As described in the profile above, extreme heat events within the state are highly likely within the next year to three (3) years. Extreme heat events have a large range of impact, accounting for 40 to 100 percent of the jurisdictional boundaries. The hazard magnitude for extreme heat ranges and is considered to have negligible magnitude including minor injuries, no shutdown of critical infrastructure and facilities, and scattered incidental, residential, and commercial structure damages from the event. Table 31 outlines the hazard rankings for each of the hazard priority criteria related to extreme heat.

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Table 31: Extreme Heat Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Likely** *10% to 100% probability within next 12-60 months*	**Large** *40% to 100% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structure damages*	**High**
Kent County	**Highly Likely** *Near 100% probability within next 12-60 months*					
Newport County	**Likely** *10% to 100% probability within next 12-60 months*					
Providence County	**Highly Likely** *Near 100% probability within next 12-60 months*		**Limited** *Some injuries*			
Washington County			**Negligible** *Minor injuries*			

Vulnerability and Impact to People and Property

The main concern in periods of extreme heat is the potential public health impact, such as heat exhaustion or heat stroke. The entire state is susceptible and vulnerable to the occurrence of an extreme heat event. Similar to drought, the vulnerability of the state to extreme heat is increasing as water use and land use change. Even though there is some minor variation throughout the state in terms of areas potentially more prone to experience extreme heat conditions, it is assumed that the extreme heat hazard would impact buildings in a fairly uniform and negligible manner. Therefore, it is assumed that state-owned and critical facility buildings would sustain very minor, if any, direct physical damage from exposure to extreme heat.

Risks from exposure to extreme heat include sunburn, heat cramps, heat exhaustion, heat stroke, and death. It is assumed that the extreme heat hazard would impact the general population in a fairly uniform and negligible manner related to estimated damages. It should be noted that major urban areas in Rhode Island are more probable locations for extreme heat.

Although significant property damage is not typically attributed to extreme heat, these events can claim lives throughout Rhode Island. The majority of the injuries and deaths attributed to extreme heat are a result of heat exhaustion or improperly functioning air conditioning units. Extreme heat is also hazardous to livestock, agriculture, and structures, such as roads and bridges, and may diminish water and energy supplies, leading to an increased risk to human health.

5.5 Hurricane and Tropical Storm

Description

Tropical cyclones, a general term for tropical storms and hurricanes, are low pressure systems that usually form over the tropics. These storms are referred to as "cyclones" due to their rotation. Tropical cyclones are among the most powerful and destructive meteorological systems on earth. Their destructive phenomena include high winds, heavy rain, lightning, tornadoes, and storm surge. As tropical storms move inland, they can cause severe flooding, downed trees and power lines, and structural damage. Once a tropical cyclone no longer has tropical characteristics, it is then classified as an extratropical system.

There are three (3) categories of tropical cyclones:

1. Tropical Depression: maximum sustained surface wind speed is less than 39 mph.
2. Tropical Storm: maximum sustained surface wind speed from 39–73 mph.
3. Hurricane: maximum sustained surface wind speed exceeds 73mph.

Most Atlantic tropical cyclones begin as atmospheric easterly waves that propagate off the coast of Africa and cross the tropical North Atlantic Ocean and Caribbean Sea. When a storm starts to move toward the north, it begins to leave the area where the easterly trade winds prevail, and enters the temperate latitudes where the westerly winds dominate. This produces the eastward curving pattern of most tropical storms that pass through the Mid-Atlantic region. When the westerly steering winds are strong, it is easier to predict where a hurricane will go. When the steering winds become weak, the storm follows an erratic path that makes forecasting very difficult.

Storm Surge

Storm surge is the abnormal rise in water level caused by the wind and pressure forces of a hurricane or Nor'easter. Nationally, storm surge flooding has caused billions of dollars in damage and hundreds of deaths. Given today's ever-increasing population densities in coastal communities, the need for information about the potential for flooding from storm surge has become even more important. Storm surge heights in Rhode Island can reach more than 10 feet during hurricanes. The breaking wave height is related to water depth so that as water depth over a given surface increases with storm surge, larger waves can be generated.

There are a number of factors which contribute to the generation of storm surge, but the fundamental forcing mechanism is wind and the resultant frictional stress it imposes on the

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water surface. Winds blowing over a water surface generate horizontal surface currents flowing in the general direction of the wind. These surface currents in turn create subsurface currents which, depending on the intensity and forward speed of the hurricane or Nor'easter, may extend from one to several hundred feet below the surface. If these currents are in the onshore direction, water begins to pile up as it is impeded by the shoaling continental shelf causing the water surface to rise. This dome of water will increase shoreward until it reaches a maximum height at the shoreline or at some distance inland. The most conducive bathymetry for the formation of large storm surges is a wide, gently sloping continental shelf.

The magnitude of storm surge during a hurricane or tropical storm within a coastal basin is governed by both the meteorological parameters of the hurricane and the physical characteristics of the basin. The meteorological aspects include:

- Hurricane size: Measured by the radius of maximum winds. (Measured from the center of the hurricane to the location of the highest wind speeds within the storm. This radius may vary from as little as four (4) miles to as much as 50 miles.)
- Hurricane intensity: Measured by sea level pressure and maximum surface wind speeds at the storm center.
- Hurricane path, or forward track of the storm.
- Hurricane forward speed.

The counterclockwise rotation of the hurricane's wind field in combination with the forward motion of the hurricane typically causes the highest surge levels to occur to the right of the hurricane's forward track. This phenomenon has been observed in regions where the shoreline is typically straight and not fragmented by large inlets and bays, and when a hurricane travels generally perpendicular to the shore. In Rhode Island, the increased wind stress from the rotational wind field has a large effect on the level of surge. The contribution to surge generation from the forward motion of the storm can be greater than the contribution made by an increase in hurricane intensity.

The Rhode Island shoreline faces south, so storms passing to the west raise the highest storm surges for Rhode Island. In addition, Narragansett Bay funnels the surge northward where decreasing surface area amplifies the surge height. The 1938 Hurricane made landfall west of Rhode Island as a Category 3 hurricane with a forward speed in excess of 50 mph. Because the center of the storm made landfall in Connecticut, the Rhode Island shoreline experienced the highest storm surge levels.

The reduction of atmospheric pressure within the storm system results in another surge-producing phenomenon known as the inverted barometer effect. Within a region of low pressure, the water level will rise at the approximate rate of 13.2 inches per inch of mercury drop. This can account for a rise of one (1) to two (2) feet near the center of the hurricane. This effect is considered to be a more important factor in the open ocean where there is no depth-related restrictions to water flow.

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Nor'easter

An extra-tropical coastal storm, known as a Nor'easter, is typically a large, counter-clockwise wind circulation around a low pressure center. The storm radius is often as large as 1,000 miles, and the horizontal storm speed is about 25 mph, traveling up the eastern United States coast. Sustained wind speeds of 1040 mph are common during a Nor'easter, with short-term wind speeds gusting up to 70 mph. Unlike hurricanes and tropical storms, Nor'easters can sit off shore, wreaking damage for days. Nor'easters are a common winter occurrence in New England and repeatedly result in flooding, various degrees of wave and erosion-induced damage to structures, and erosion of natural resources, such as beaches, dunes, and coastal bluffs. The erosion of coastal features commonly results in greater potential for damage to shoreline development from future storms.

Howling winds associated with Nor'easters also have the potential to produce significant storm surge, similar to that of a Category One (1) hurricane. In addition, these types of storms can also produce wind gusts to near hurricane force, as well as flooding rain and crippling snowfall.

Nor'easters cause varying amounts of coastal erosion depending on the intensity and the duration of the storm; the tidal phase at the time of the storm (neap or spring tide); the path of the storm; and the time interval between storms. Back-to-back storms do not allow time for the beaches and dunes to recover sand that has been transported offshore.

Damages resulting from Nor'easters are often due to undermining the structures that were previously behind the dunes or on the top of coastal bluffs. Damages to a house that topples off an embankment are usually much costlier than damages resulting from localized areas of flooding.

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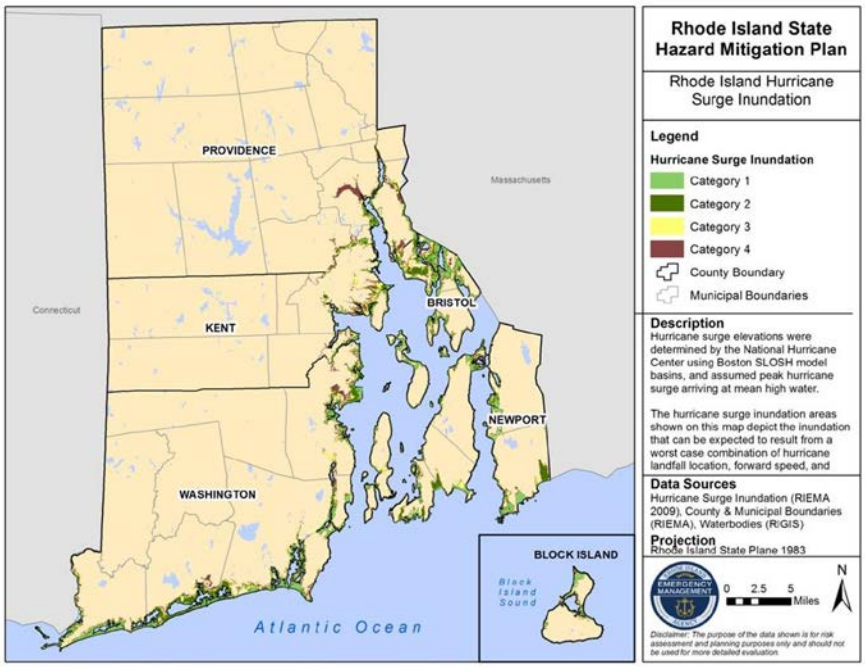
Location

The entire state is vulnerable to hurricanes and tropical storms, depending on the storm's track. The SLOSH model is used to evaluate the potential impact of storm surge. Emergency managers use data from the SLOSH model to identify at-risk populations and determine evacuation areas. Storm surges also affect tidal rivers and creeks, potentially increasing evacuation areas. Figure 8 indicates the potential inland extent of storm surge as a function of hurricane category. Low-lying coastal areas in close proximity to the shore, sounds, or estuaries are exposed to the threat of flooding from storm surge. It is readily apparent from this figure that Rhode Island has significant vulnerability to storm surge. This is particularly true of portions of Bristol and Washington counties. The inundation data was derived by the USACE by overlaying the hurricane surge water surface elevations from the SLOSH model results on top of ground elevations from FEMA Light Detection and Radar (LiDAR) data to show which areas would be flooded by hurricane storm surge.

Figure 8: Storm surge inundation based on hurricane category



Extent

Hurricanes are categorized according to the Saffir-Simpson hurricane wind scale (SSHWS), outlined in Table 32 below, which was developed in the 1970s by Herbert Saffir and Robert Simpson, with ratings determined by wind speed and central barometric pressure. Hurricane categories range from one (1) through five (5), with Category 5 being the strongest (winds greater than 155 mph). The scale is designed to give public officials and the general public usable information on the magnitude of a storm. It gives an indication of the potential flooding and wind damages associated with each hurricane category. A hurricane watch is issued when hurricane conditions could occur within the next 36 hours. A hurricane warning indicates that sustained winds of at least 74 mph are expected within 24 hours or less. The scale rates the intensity and effects of hurricanes based on wind speed and barometric pressure measurements as shown in Table 32.

Table 32: Saffir-Simpson Hurricane Wind Scale. Source: NWS NCDC

Wind Speed	Typical Effects
Category One (1) Hurricane – Weak	
74-95 mph (64-82kt)	Minimal Damage: Damage is primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage occurs in building structures. Some damage is done to poorly constructed signs.
Category Two (2) Hurricane – Moderate	
96-110 mph (83-95kt)	Moderate Damage: Considerable damage is done to shrubbery and tree foliage; some trees typically are blown down. Major structural damage occurs to exposed mobile homes. Extensive damage occurs to poorly constructed signs. Some damage is done to roofing materials, windows, and doors; no major damage occurs to the building integrity of structures.
Category Three (3) Hurricane – Strong	
111-130 mph (96-113kt)	Extensive damage: Foliage torn from trees and shrubbery; large trees blown down. Practically all poorly constructed signs are blown down. Some damage to roofing materials of buildings occurs, with some window and door damage. Some structural damage occurs to small buildings, residences, and utility buildings. Mobile homes are destroyed. There is a minor amount of failure of curtain walls (in framed buildings).
Category Four (4) Hurricane - Very Strong	
131-155 mph (114-135kt)	Extreme Damage: Shrubs and trees are blown down; all signs are down. Extensive roofing material and window and door damage occurs. Complete failure of roofs on many small residences occurs, and there is complete destruction of mobile homes. Some curtain walls experience failure.
Category Five (5) Hurricane – Devastating	
Greater than 155 mph (135kt)	Catastrophic Damage: Shrubs and trees are blown down; all signs are down. Considerable damage to roofs of buildings. Very severe and extensive window and door damage occurs. Complete failure of roof structures occurs on many residences and industrial buildings, and extensive shattering of glass in windows and doors occurs. Some complete buildings fail. Small buildings are overturned or blown away. Complete destruction of mobile homes occurs.

Previous Occurrences

Rhode Island has experienced tropical depressions and tropical storms, as well as hurricanes ranging from Category One (1) to Category Three (3). Hurricanes are rare but devastating events in Rhode Island. Hurricane wind damages can be costly, but storm surge is by far the most destructive force acting on the Rhode Island coast. The highest storm surges recorded at the Newport tide gauge were 9.45 feet and 6.76 feet above mean higher high water (MHHW) during the Great September Hurricane of 1938 and Hurricane Carol, on August 1954, respectively. By comparison, the Providence gauge recorded surges of 12.66 feet and 9.96 feet above MHHW respectively during those events.

The comparison of hurricanes to Nor'easters reveals that the duration of high surge and winds in a hurricane is 6-12 hours, while a Nor'easter's duration can be from 12 hours to three (3) days. The amount of damage resulting from a strong hurricane is often more severe than a Nor'easter, but Rhode Island has historically suffered more damage from Nor'easters because of the greater frequency in which they occur.

Table 33 highlights hurricanes and tropical storms that have resulted in significant damages, injuries, and deaths in Rhode Island. Damages from Hurricane Carol in Westerly are pictured in Figure 9.

Figure 9: Hurricane Carol damages in Westerly. Source: RI National Guard (9/1954)

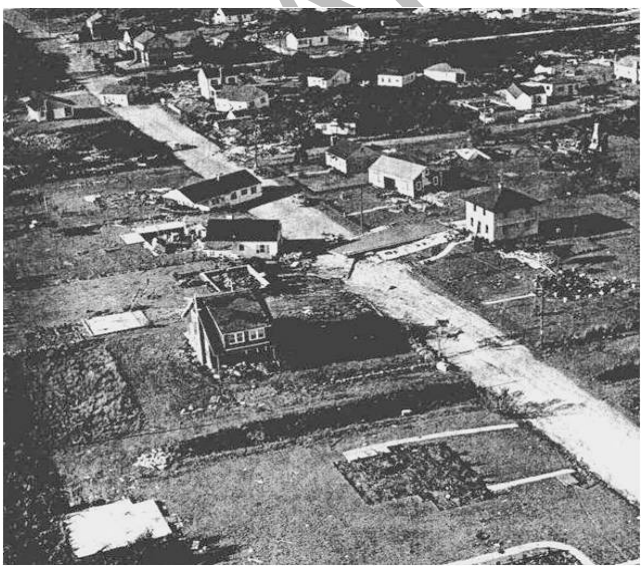


Table 33: Rhode Island Historic Hurricanes

Hurricane	Date	Description
1938	September 21, 1938	The hurricane of September 21, 1938, brought major devastation to the state, with 262 persons losing their lives and damage estimated at $100 million. The coastal area from Westerly to Little Compton experienced the heaviest damage, but there was no tidal wave because the storm hit at ebb tide. Sustained winds of 95 mph recorded; damage estimated at $100 million; 262 fatalities. Tide 15 feet above mean sea level (at USGS gage in Westerly). Virtually all of the state was without power. Ten percent of electric customers still without power 12 days after hurricane.
1944	September 14, 1944	Affected Rhode Island and southeastern Massachusetts; $2 million in property damage; no loss of life.
Carol	August 31, 1954	On August 31, 1954, Hurricane Carol swept into Rhode Island with little warning. The result was 19 deaths and $200 million in property damage. The storm center passed to the west of Providence and came at high tide. The central area of Providence was flooded to a depth of 13 feet, and 3,500 cars were inundated in the downtown areas. Hurricane Edna occurred 12 days after Carol, with heavy rain and major river flooding. There were 19 fatalities in New England, $200 million in property damage, and 13 feet of flooding. In Providence, wind speeds of 90 mph, with 115 mph gusts; nearly 3,800 homes destroyed. Tide 12.2 feet above mean seal level (at USGS gage in Westerly). Most of state without power. Four days after storm, approximately 50 percent had power restored; 90 percent after seven days.
Edna	September 11, 1954	Heavy rain and major flooding in the Blackstone River Valley.
Diane	August 17–20, 1955	In 1955, remnants of the August Hurricane Diane swept over Rhode Island, but its wind velocities were far below hurricane force because of its long inland trip over North Carolina, Virginia, and Pennsylvania. Damage to power lines was high, and at one time 82 percent of Rhode Island's homes were without electricity. Ample warning permitted people to return home from school and work early, and as a result, only two lives were lost. Property damage amounted to $170 million, most resulting from torrential rains, which caused serious river flooding. Blackstone River crests 15 feet above normal; $170 million in property damage. Heavy rain and six-foot tidal surge; $5 million in property damage; 82 percent of electric customers lost power.

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Hurricane	Date	Description
Donna	September 12, 1960	Heavy rain and major flooding in the Blackstone River Valley.
Esther	September 21, 1961	Heavy shore damage at Sakonnet Point in Little Compton and Misquamicut in Westerly.
Gloria	September 27, 1985	Two fatalities in New England; property damage estimated at $19.8 million; 8,596 of electric customers lose power; an estimated 23,700 people evacuated.
Bob	August 18, 1991	Southern New England damage at $1.5 billion; 60 percent of residents across Southeastern New England lost power; six- to 10-foot storm surge in Narragansett Bay; Two (2) unconfirmed tornadoes in Rhode Island. There were 18 fatalities in Southern New England, although none in Rhode Island.
Irene	August 27, 2011	Preliminary damage assessment report from FEMA brings the total public assistance cost to $9,260,898. Irene knocked down trees and power lines, leaving up to half of Rhode Island residents without power. Gusts of wind up to 71 mph were reported, and storm surge in Narragansett Bay caused some coastal damage. However, the majority of damage was caused by wind. The storm surge experienced along the coast was generally in the two- to four-foot range with a high of 4.78 feet at Fox Point in Providence, Rhode Island. The highest sustained wind speed was 54 knots (62 mph) at the Physical Oceanographic Real Time System station at Conimicut Light in Narragansett Bay, Rhode Island.
Sandy	October 29, 2012	Hurricane Sandy swept through the region in October 2012 leaving significant damage all along the coast. Beaches along Westerly, including Misquamicut, were devastated and almost unrecognizable. More than 122,000 people lost power. It is estimated that more than $39.4 million in support from four federal disaster relief programs is helping Rhode Island recover from this disaster, the majority of which is from the NFIP ($31.1 million).

Probability of Future Events

Based on historical frequency of occurrence, Rhode Island is likely, between 10 percent and 100 percent probability, to experience a hurricane in next 12 to 60 months. Table 34 provides the annualized events qualitative ranking used for determining probability of future events. The hazard ranking includes the probability of future events by county. Long-term global climate models under Intergovernmental Panel on Climate Change (IPCC) warming scenarios indicate that it is possible that hurricanes will become more intense, with stronger winds and heavier precipitation throughout the twenty-first century.

Nor'easters are a primary concern for Rhode Island residents; not only because of the damage potential in any given storm, but because there is a frequent rate of recurrence. Nor'easters have an average frequency of one (1) or two (2) per year, with a storm surge equal to or greater than two (2) feet.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined hurricane and tropical storms to be a high priority hazard in Rhode Island. As described in the profile above, hurricane and tropical storm events within the state are likely within the next year to three (3) years. Hurricane and tropical storm events have a medium to large range of impact, accounting for 10 to 40 percent (medium impact) and 40 to 100 percent (large impact) of the jurisdictional boundaries. Hazard magnitude ranges and is considered to have negligible to limited magnitude, including some injuries and short duration shutdown of critical facilities and infrastructure. There is a range of scattered incidental to less than 10 percent of residential and commercial structure damages from these events. Table 34 outlines the hazard rankings for each of the hazard priority criteria related to hurricane and tropical storms.

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Table 34: Hurricane and Tropical Storms Hazard Priority

<table>
<tr><th rowspan="2">Jurisdiction</th><th rowspan="2">Likelihood of Hazard Occurrence</th><th rowspan="2">Likely Range of Impact</th><th colspan="3">Probable Hazard Magnitude</th><th rowspan="2">Composite Hazard Index</th></tr>
<tr><th>Injuries and Deaths</th><th>Infrastructure</th><th>Structures</th></tr>
<tr><td>Bristol County</td><td rowspan="5">Likely
Between 10% and 100% probability in next 12-60 months and one incident during the next ten years.</td><td rowspan="2">Medium
10% to 40% of the total jurisdictional boundaries</td><td rowspan="5">Limited
Some injuries</td><td rowspan="5">Limited
Short shutdown of critical infrastructure and facilities</td><td>Negligible
Scattered incidental residential and commercial structure damages</td><td rowspan="5">High</td></tr>
<tr><td>Kent County</td><td rowspan="4">Limited
Less than 10% of residential and commercial structure damages</td></tr>
<tr><td>Newport County</td><td>Large
40% to 100% of the total jurisdictional boundaries</td></tr>
<tr><td>Providence County</td><td>Medium
10% to 40% of the total jurisdictional boundaries</td></tr>
<tr><td>Washington County</td><td>Large</td></tr>
</table>

Vulnerability and Impact to People and Property

Rhode Island, as with other New England states, is particularly vulnerable to hurricanes and tropical storms. One reason is due to the geography of southern New England in relation to the Atlantic seaboard. Historically, most hurricanes that have struck the New England region re-curved northward on tracks, which paralleled the eastern seaboard, maintaining a slight north-northeast track direction. The fact that the states of Connecticut, Rhode Island, and Massachusetts geographically project easterly into the Atlantic and have southern exposed shorelines places them in direct line of any storm that tracks in this manner. Therefore, even though New England is a relatively far distance from the tropics, its susceptibility to hurricane strikes can statistically be greater than other states closer to the tropics.

Further evidence of New England's unique vulnerability to hurricanes is the fact that hurricanes that eventually strike the region undergo significant increases in forward speed. Historically, hurricanes tend to lose their strength and accelerate in a forward motion after passing the outer banks of Cape Hatteras, North Carolina. The increase in forward speed that usually occurs as the hurricane weakens with further northward movement can often compensate for any discounting in hurricane intensity. Surge flooding, wave effects, and wind speeds accompanying a faster moving, weaker hurricane may exceed conditions caused by more intense hurricanes. This means that for some locations, depending on the meteorology of the storm, the effects of a Category Two (2) hurricane traveling at 60 mph might be worse than those of a Category Four (4) hurricane moving at 20 mph.

Rhode Island may experience a hurricane every four (4) years, or 22.8 percent annually. Estimated NCDC annualized damages range from negligible amounts up to $10,390 statewide. These estimates are believed to underrepresent actual losses experienced due to hazards as there are losses from events that go unreported or that are difficult to quantify.

There are primarily three components of statewide vulnerability from the impact of a hurricane: (1) storm surge (coastal flooding); (2) ability to evacuate in a timely manner; and (3) shelter capacity. Storm surge has the potential to create a very serious problem in many Rhode Island coastal communities because in most cases, water will rise to extremely high levels and cover roads and bridges. These roads are hurricane evacuation routes and the only way out of danger.

The vulnerability of Rhode Island to hurricane surges is further increased by the presence of Narragansett Bay. The bay's configuration can exhibit a funneling phenomenon on tidal surges as they flood the East and West Passages and the Sakonnet River. Ocean waters entering these inlets become more restricted, causing higher flood levels with continued movement into the upper reaches of the bay. The funneled ocean waters along the shores of the bay's northernmost points tend to result in higher storm surge elevations, causing a greater amount of coastal and tidal riverine flooding. The northern reaches of Narragansett Bay are the most urbanized and densely developed areas in the state.

Electrical utilities, communications, and transportation infrastructure are vulnerable to significant coastal events. Damage to power lines or communication towers has the potential

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to cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Furthermore, downed wires and lightning strikes have been known to spark fires.

A structure's vulnerability to significant coastal event hazards is based in large part on building construction and standards, and its location in relation to potential storm surge inundation zones. In general, mobile homes and wood-framed structures are more vulnerable to damage from wind during significant coastal events than steel framed structures. Other factors, such as location and condition and maintenance of trees also plays a significant role in determining vulnerability.

Human vulnerability is based on the availability, reception, and understanding of early warnings of coastal hazard events (i.e., Hurricane Watches and Warnings issued by the NWS), as well as access to substantial shelter and a means and desire to evacuate if necessary. In some cases, despite having access to technology (such as computer, radio, television, and outdoor sirens) that allows for the reception of a warning, individuals may not understand the warning due to language barriers. Once warned of an impending significant coastal hazard event, sheltering in a substantial indoor structure that is wind resistant and outside of storm surge zones is recommended as the best protection against bodily harm.

5.6 Extreme Cold

Description

Extreme cold typically indicates temperatures are well below zero for an extended period of time. Specifically, extreme cold is characterized by temperatures falling to -22°F (or -30°C) or less. Excessive cold may accompany winter storms, be left in their wake, or can occur without storm activity. Extreme cold can lead to hypothermia and frostbite, which are both serious medical conditions.

Location

Rhode Island's location in the northeastern United States makes it susceptible to extreme cold. In addition, coastal counties, specifically Kent, Newport, and Washington counties, have stronger winds coming off the Atlantic Ocean and are more likely to have higher wind chills, which can significantly lower the overall temperature.

Extent

In relation to extreme cold, the wind chill index attempts to quantify the cooling effect of wind with the actual outside air temperature to determine a wind chill temperature that represents how cold people and animals feel, based on the rate of heat loss from exposed skin. The NWS uses a Wind Chill Temperature Index to measure the current wind chill in the atmosphere and the speed at which frostbite will set in. A wind chill index of -5°F indicates that the effects of wind and temperature on exposed flesh are the same as if the air temperature alone were five (5) degrees below zero, even though the actual temperature

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could be much higher. The NWS issues a wind chill advisory when wind chill temperatures are potentially hazardous and a wind chill warning when the situation can be life-threatening.

Previous Occurrences

Rhode Island's location on the coast makes the state susceptible to not only weather systems that harbor cold weather, but also include significant wind chills that drop temperatures to well below freezing. Table 35 shows days in 2013–2016 when the minimum temperatures were 20°F and below. Additionally, in the same time period, there were 112 days with a wind chill between 20°F and zero, and 68 days when the wind chill was below zero. The wind chill was estimated using the minimum temperature and the average wind speed and temperature.

Table 35: Number of Days 20°F and Below

Year	Date	Min Temp	Total # of Days	Year	Date	Min Temp	Total # of Days
2013	1/2/2013	14	39	2014	1/1/2014	16	54
	1/3/2013	8			1/2/2014	10	
	1/4/2013	17			1/3/2014	1	
	1/5/2013	20			1/4/2014	-6	
	1/8/2013	19			1/5/2014	10	
	1/18/2013	18			1/7/2014	7	
	1/19/2013	19			1/8/2014	5	
	1/21/2013	20			1/9/2014	11	
	1/22/2013	13			1/10/2014	12	
	1/23/2013	7			1/21/2014	12	
	1/24/2013	1			1/22/2014	6	
	1/25/2013	9			1/23/2014	1	
	1/26/2013	8			1/24/2014	5	
	1/27/2013	8			1/25/2014	13	
	1/28/2013	15			1/26/2014	14	
	2/2/2013	17			1/27/2014	19	
	2/3/2013	19			1/28/2014	11	
	2/4/2013	19			1/29/2014	13	
	2/7/2013	17			1/30/2014	5	
	2/9/2013	16			1/31/2014	14	
	2/10/2013	9			2/4/2014	15	
	2/11/2013	13			2/6/2014	16	

Year	Date	Min Temp	Total # of Days	Year	Date	Min Temp	Total # of Days
	2/17/2013	17			2/7/2014	9	
	2/18/2013	15			2/8/2014	10	
	2/19/2013	17			2/9/2014	16	
	3/18/2013	19			2/10/2014	14	
	11/25/2013	17			2/11/2014	7	
	11/30/2013	16			2/12/2014	2	
	12/11/2013	20			2/13/2014	20	
	12/12/2013	14			2/17/2014	9	
	12/13/2013	14			2/18/2014	6	
	12/14/2013	14			2/19/2014	14	
	12/16/2013	17			2/25/2014	18	
	12/17/2013	8			2/26/2014	13	
	12/18/2013	17			2/27/2014	6	
2013	12/19/2013	20	39	2014	2/28/2014	8	54
	12/25/2013	17			3/1/2014	7	
	12/26/2013	19			3/3/2014	13	
	12/31/2013	16			3/4/2014	6	
2015	1/1/2015	17	60		3/5/2014	19	
	1/5/2015	20			3/6/2014	11	
	1/6/2015	12			3/7/2014	11	
	1/7/2015	5			3/13/2014	15	
	1/8/2015	0			3/14/2014	12	
	1/9/2015	12			3/17/2014	17	
	1/10/2015	7			3/18/2014	15	
	1/11/2015	6			3/24/2014	16	
	1/13/2015	16			3/25/2014	14	
	1/14/2015	14			3/27/2014	20	
	1/16/2015	17			11/19/2014	20	
	1/17/2015	9			11/22/2014	18	
	1/18/2015	20			11/29/2014	18	
	1/21/2015	18			12/30/2014	19	
	1/23/2015	19			12/31/2014	14	
	1/26/2015	16		2016	1/4/2016	17	27
	1/27/2015	14			1/5/2016	8	
	1/28/2015	9			1/6/2016	12	

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Year	Date	Min Temp	Total # of Days	Year	Date	Min Temp	Total # of Days
	1/29/2015	0			1/7/2016	17	
	1/30/2015	18			1/12/2016	16	
	1/31/2015	11			1/14/2016	18	
	2/1/2015	9			1/18/2016	20	
	2/2/2015	13			1/19/2016	17	
	2/3/2015	4			1/20/2016	20	
	2/4/2015	4			1/21/2016	19	
	2/5/2015	10			1/22/2016	16	
	2/6/2015	-2			1/24/2016	19	
	2/7/2015	10			1/25/2016	16	
	2/8/2015	19			1/26/2016	20	
	2/9/2015	17			1/28/2016	19	
	2/10/2015	17			2/6/2016	14	
	2/11/2015	18			2/9/2016	19	
	2/12/2015	10			2/10/2016	16	
	2/13/2015	4			2/11/2016	14	
	2/14/2015	-6			2/12/2016	6	
	2/15/2015	1			2/13/2016	1	
	2/16/2015	-4		2016	2/14/2016	-9	27
	2/17/2015	9			2/15/2016	-5	
	2/18/2015	12			2/19/2016	17	
	2/19/2015	9			2/27/2016	18	
	2/20/2015	-1			3/3/2016	20	
	2/21/2015	-8			4/6/2016	19	
2015	2/23/2015	7	60				
	2/24/2015	-6					
	2/25/2015	7					
	2/26/2015	15					
	2/27/2015	3					
	2/28/2015	6					
	3/1/2015	3					
	3/3/2015	7					
	3/6/2015	6					
	3/7/2015	6					
	3/8/2015	20					

Year	Date	Min Temp	Total # of Days	Year	Date	Min Temp	Total # of Days
	3/9/2015	18					
	3/13/2015	20					
	3/19/2015	17					
	3/20/2015	17					
	3/23/2015	16					
	3/24/2015	19					
	3/25/2015	19					

Probability of Future Events

Extreme cold in Rhode Island is projected to continue as extreme weather events experience an upswing due to climate change. The specific likelihood of extreme cold is unpredictable, as days of frigid, arctic air and below freezing temperatures may be followed by days of mild temperatures in the 40s or 50s. Based on history and climatic conditions, there is a likely probability that extreme cold will continue to occur and impact Rhode Island. Within the next 12–60 months there is a 10- to 100-percent chance of extreme cold affecting Rhode Island.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined extreme cold to be a high priority hazard in Rhode Island. As described in the profile above, extreme cold events within the state are likely within the next year to three (3) years. Extreme cold events have a large range of impact, accounting for 40 to 100 percent of the jurisdictional boundaries. Hazard magnitude for extreme cold is considered to have negligible magnitude including minor injuries, no shutdown of critical facilities and infrastructure, and scattered incidental residential and commercial structure damages from the events. Table 36 outlines the hazard rankings for each of the hazard priority criteria related to extreme cold.

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Table 36: Extreme Cold Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Likely** *Between 10% and 100% probability in next 12-60 months and one incident during the next ten years*	**Large** *40% to 100% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structure damages*	**High**

Vulnerability and Impact to People and Property

Extreme cold presents the greatest danger to people. Prolonged exposure to the cold can cause frostbite or hypothermia and may become life threatening. The risk of hypothermia due to exposure greatly increases during episodes of extreme cold. Infants and elderly people are most susceptible. Certain medications, medical conditions, or the consumption of alcohol can also make people more susceptible to the cold. House fires and carbon monoxide poisoning are also possible as people use supplemental heating devices.

All state buildings, critical facilities, and infrastructure are vulnerable to extreme cold. Probable hazard magnitude related to extreme cold is negligible in terms of minor injuries, no significant impact to critical facilities, infrastructure, or residential and commercial damages.

Exposure to cold temperatures can lead to serious or life-threatening health problems, such as hypothermia, cold stress, or frostbite. Extreme cold temperatures often accompany a winter storm, which can cause power failures and icy roads. Heating systems in homes may not be adequate for the weather and can lead to the use of space heaters and fireplaces, increasing the risk of household fires and carbon monoxide poisoning. Vulnerable populations include the homeless, elderly, low income, linguistically isolated populations, people with life-threatening illnesses, and people living in areas that are isolated from major roadways.

As mentioned above, extreme cold events can lead to power interruption or failure. Increased demand for utilities, such as electricity and natural gas, may result in shortages and higher costs for these resources. Businesses may be faced with an increased financial burden due to unexpected repairs, such as pipes bursting and higher utility bills, and business interruption due to power failure.

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5.7 Thunderstorms

Description

Thunderstorms are formed when the right atmospheric conditions combine to provide moisture, lift, and warm and unstable air that can rise rapidly. Thunderstorms occur any time of the day and in all months of the year, but are most common during summer afternoons and evenings, and in conjunction with frontal boundaries. The NWS classifies a thunderstorm as severe if it produces hail at least one inch in diameter, winds of 58 mph or greater, or a tornado. About 10 percent of the estimated 100,000 annual thunderstorms that occur nationwide are considered severe.[17] Thunderstorms affect a smaller area compared with winter storms or hurricanes, but they can be dangerous and destructive for a number of reasons. Storms can form in less than 30 minutes, giving very little warning; they have the potential to produce lightning, hail, tornadoes, powerful straight-line winds, and heavy rains that produce flash flooding.

Lightning

All thunderstorms produce lightning, and therefore all thunderstorms are dangerous. Lightning often strikes outside of areas where it is raining, and may occur as far as 10 miles away from rainfall. It can strike from any part of the storm, and may even strike after the storm has passed. Hundreds of people across the nation are injured annually by lightning, most commonly when they are moving to a safe place but have waited too long to seek shelter. Lightning strike victims often suffer long-term effects such as memory loss, sleep disorders, weakness and fatigue, chronic pain, depression, and muscle spasms. Lightning also has the potential to start both urban fires and wildfires. Lightning causes an average of 55-60 fatalities, 400 injuries, and over $1 billion in insured losses annually nationwide.

Hail

Hail is formed in towering cumulonimbus clouds (thunderheads) when strong updrafts carry water droplets to a height at which they freeze. Eventually, these ice particles become too heavy for the updraft to hold up, and they fall to the ground at speeds of up to 120 mph. Hail falls along paths called swaths, which can vary from a few square acres to up to 10 miles wide and 100 miles long.[18] Hail larger than three-quarters-inch in diameter can do great damage to both property and crops, and some storms produce hail over two (2) inches in diameter. Hail causes about $1 billion in damages annually in the U.S.

Location

Bristol, Kent, Newport, Providence, and Washington are vulnerable to risks and hazards associated with major thunderstorm systems based on meteorological movement of storm systems. Based on NCDC data, Providence County has experienced the most thunderstorm

[17] National Oceanic and Atmospheric Administration, http://www.nws.noaa.gov/om/severeweather/resources/ttl6-10.pdf.
[18] University Corporation for Atmospheric Research, http://www.ucar.edu/communications/factsheets/Hail.html.

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events, accounting for 47.6 percent of the thunderstorm events between 1956 and 2016. The specific number and location of events according to NCDC data is outlined below in Table 37.

Table 37: NCDC Thunderstorm Events

County	Number of Events (1956-2016)
Bristol	17
Kent	48
Newport	15
Providence	100
Washington	30

Extent

The National Oceanic and Atmospheric Administration (NOAA) classifies types of thunderstorms as any of the following: single-cell, multi-cell, squall line, supercell, bow echo, mesoscale convective system, mesoscale convective complex, mesoscale convective vortex, and derecho, which are defined below:[19]

- **Single-cell thunderstorms** are small, brief, weak storms that grow and die within an hour or so. They are typically driven by heating on a summer afternoon. Single-cell storms may produce brief heavy rain and lightning.
- **A multi-cell storm** is a common, garden-variety thunderstorm in which new updrafts form along the leading edge of rain-cooled air (the gust front). Individual cells usually last 30 to 60 minutes, while the system as a whole may last for many hours. Multi-cell storms may produce hail, strong winds, brief tornadoes, and/or flooding.
- **A squall line** is a group of storms arranged in a line, often accompanied by "squalls" of high wind and heavy rain. Squall lines tend to pass quickly and are less prone to produce tornadoes than are supercells. They can be hundreds of miles long but are typically only 10 or 20 miles wide.
- **A supercell** is a long-lived (greater than one hour) and highly organized storm feeding off an updraft (a rising current of air) that is tilted and rotating. This rotating updraft—as large as 10 miles in diameter and up to 50,000 feet tall—can be present as long as 20 to 60 minutes before a tornado forms. Scientists call this rotation a mesocyclone when it is detected by Doppler radar. The tornado is a very small extension of this larger rotation. Most large and violent tornadoes come from supercells.
- **A bow echo** is a radar signature of a squall line that "bows out" as winds fall behind the line and circulations develop on either end. A strongly bowed echo may indicate high winds in the middle of the line, where the storms are moving forward most quickly. Brief tornadoes may occur on the leading edge of a bow echo. Often the north side of a bow echo becomes dominant over time, gradually evolving into a comma-shaped storm complex.

[19] http://www.nssl.noaa.gov/education/svrwx101/thunderstorms/types/

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- **A Mesoscale Convective System (MCS)** is a collection of thunderstorms that act as a system. An MCS can spread across an entire state and last more than 12 hours. On radar one of these monsters might appear as a solid line, a broken line, or a cluster of cells. This all-encompassing term can include any of the following storm types:
    - **A Mesoscale convective complex (MCC)** is a large, circular, long-lived cluster of showers and thunderstorms identified by satellite. It often emerges out of other storm types during the late-night and early-morning hours. MCCs can cover an entire state.
    - **Mesoscale convective vortex (MCV)** is a low-pressure center within an MCS that pulls winds into a circling pattern, or vortex. With a core only 30 to 60 miles wide and one to three miles deep, an MCV is often overlooked in standard weather analyses. But an MCV can take on a life of its own, persisting for up to 12 hours after its parent MCS has dissipated. This orphaned MCV will sometimes then become the seed of the next thunderstorm outbreak. An MCV that moves into tropical waters, such as the Gulf of Mexico, can serve as the nucleus for a tropical storm or hurricane.
    - **A derecho** is a widespread, long-lived wind storm that is associated with a band of rapidly moving showers or thunderstorms. Although a derecho can produce destruction similar to that of tornadoes, the damage typically is in one direction along a relatively straight swath. As a result, the term "straight-line wind damage" sometimes is used to describe derecho damage. By definition, if the wind damage swath extends more than 240 miles (about 400 kilometers) and includes wind gusts of at least 58 mph (93 km/h) or greater along most of its length, the event may be classified as a derecho

Any one of these types can be severe, which is defined by wind speeds of 58 mph or greater and/or hail 1.0 inches or greater in diameter.[20] Thunderstorms also carry the risk of lightning that is categorized as cloud-to-ground flashes. In 2014, Rhode Island experienced 311 flashes, with the average of 2.3 flashes per square mile.[21] The cloud-to-ground description comes from differences in charges between the cloud and ground which creates a major electrical discharge. When hail is produced by the storm, the initial criterion to determine severity is based on the diameter produced by the storm. The diameter has to be one inch or greater to be considered severe.

Previous Occurrences

Rhode Island is not known for experiencing the same frequency of severe thunderstorms as the Midwest and Southeast, but the state has observed a number of very destructive hail and lightning events over the years. The NCDC has recorded 151 significant (those causing injury, fatalities, and/or damage) lightning and hail events. One (1) death as a result of lightning was recorded on August 11, 2004, in Washington County. Eleven additional injuries have been recorded since 1956 due to lightning. Some of the most significant wind and lightning

[20] http://www.nssl.noaa.gov/education/svrwx101/thunderstorms/types/
[21] http://www.lightningsafety.noaa.gov/stats/05-14_Flash_Density_State.pdf

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events in the state's history are listed in Table 38. Hail and wind events are shown in Figure 10.

Table 38: Significant NCDC Lightning Events

Date	County	Property Damage (Inflated to 2016 dollars)
8/5/1994	Providence County	$774,605
6/22/1997	Kent County	$357,621
6/17/2001	Providence County	$194,460
6/25/2012	Providence County	$150,000
6/25/2012	Washington County	$25,000
7/1/2012	Providence County	-
10/20/2012	Kent County	$100,000
7/20/2012	Providence County	$5,000
9/1/2013	Washington County	$2,000
6/23/2015	Providence County	$5,000
7/28/2015	Newport County	$5,000
8/4/2015	Providence County	$2,000

Probability of Future Events

Based on historical frequency of occurrence using NCDC data, a reasonable determination of probability of future thunderstorms can be made. Thunderstorm events are highly likely to occur within the next one (1) to three (3) years. Thunderstorm events have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. The hazard ranking shown in Table 39 includes the probability of future events by county.

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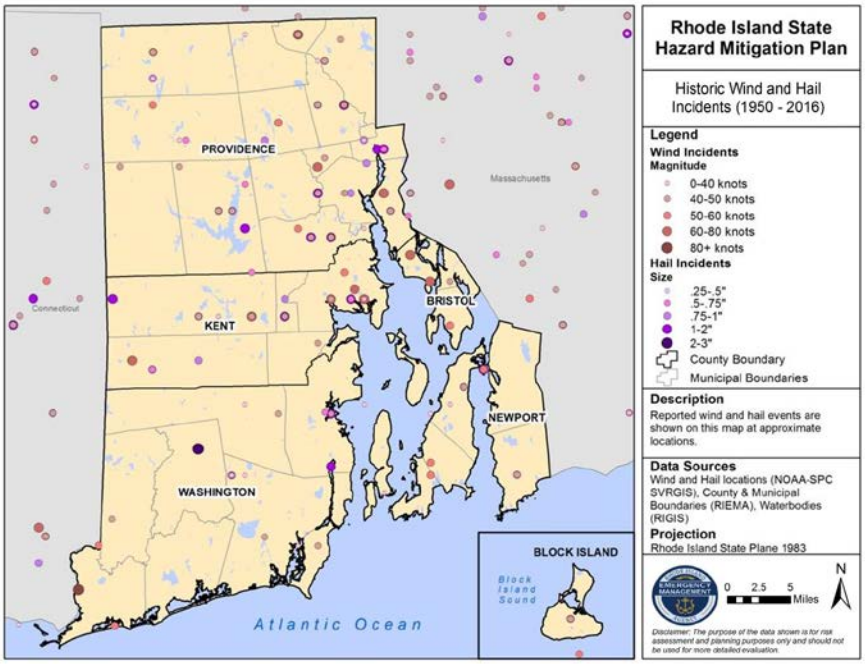
Figure 10: Rhode Island Historic Wind and Hail Incidents



Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined thunderstorm events to be a high priority hazard in Rhode Island. As described in the profile above, thunderstorm events within the state are highly likely within the next year to three (3) years. Thunderstorm events have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Hazard magnitude ranges and is considered to have negligible to limited magnitude, including some injuries, no shutdown of critical facilities and infrastructure, and scattered incidental, residential, and commercial structure damages from the events. Table 39 outlines the hazard rankings for each of the hazard priority criteria related to thunderstorms.

Table 39: Thunderstorm Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Highly Likely** *Near100% probability in next 12-60 months and one incident during the next ten years.*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structure damages*	**High**

Vulnerability and Impact to People and Property

The impact of thunderstorms (including lightning and hail) can be measured in financial terms, as well as fatalities and injuries. An examination of NCDC data shows that wind events contributed to at least 20 injuries. Wind vulnerability is based in large part on building construction and standards. Other factors, such as location, condition, and maintenance of trees also plays a significant role in determining vulnerability.

Historical data indicates that Rhode Island is highly likely to experience between one (1) and four (4) wind events in a given year. Annualized damages range from $22,824 in Bristol County to $76,784 in Providence County. Within Providence County, Scituate and Pawtucket have experienced multiple hail and wind events of increased size and magnitude, followed by Cranston and Providence. Richmond in Washington County is vulnerable to large hail events and may see $45,343 in annualized damages due to wind related events.

All facilities within Rhode Island are considered equally vulnerable to thunderstorms with negligible impacts to facilities, infrastructure, and residential and commercial properties. The location and construction of a facility plays a role in how it will be affected by lightning and hail incidents. If a tall structure is located on a hilltop, near other tall structures, or has large exposed windows, it may be damaged during a thunderstorm. Communications and power supplies may be compromised during thunderstorms, and some critical facilities may not be well equipped with a backup power source. As the facilities data sets are expanded to include construction and value information, analysis of thunderstorms should be reconsidered.

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Building construction, location, and nearby trees or other tall structures will have a large impact on how vulnerable an individual facility is to a lightning strike. A rough estimate of a structure's likelihood of being struck by lightning can be calculated using the structure's ground surface area, height, and striking distance between the downward-moving tip of the stepped leader (negatively charged channel jumping from cloud to earth) and the object.[22] In general, buildings are more likely to be struck by lightning if they are located on high ground or if they have tall protrusions, such as steeples or poles, which the stepped leader can jump to. Electrical and communications utilities are also vulnerable to direct lightning strikes. Damage to these lines has the potential to cause power and communications outages for businesses, residences, and critical facilities.

Structure vulnerability to hail is determined mainly by construction and exposure. Metal siding and roofing is better able to stand up to the damages of a hailstorm than many other materials, although it may also be damaged by denting. Exposed windows and vehicles are also susceptible to damage. Crops are extremely susceptible to hailstorm damage, as even the smallest hail stones can rip apart unsheltered vegetation.

The potential damages resulting from lightning strikes are primarily loss of life, business interruption, fire, and minor structural damage. A false sense of security often leads people to believe that they are safe from a lightning strike because it may not appear to be near their location. However, lightning can strike 10 miles away from a rain column, which puts people that are still in clear weather at risk. The amount of cover obtained during a hail storm can greatly reduce the risk to human health during these events. Agricultural crops and structures have significant exposure and are at risk.

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5.8 Dam Failure

Description

Dam failures can result from natural events, human-induced events, or a combination of the two. Failures due to natural events, such as prolonged periods of rainfall and flooding, can result in overtopping, which is the most common cause of dam failure. Overtopping occurs when a dam's spillway capacity is exceeded and portions of the dam that are not designed to convey flow begin to pass water, erode away, and ultimately fail. Other causes of dam failure include design flaws, foundation failure, internal soil erosion, inadequate maintenance, or misoperation. Complete failure occurs if internal erosion or overtopping results in a complete structural breach, releasing a high-velocity wall of debris-laden water that rushes downstream, damaging or destroying everything in its path. An additional hazard concern is the cascading effect of one dam failure causing multiple dam failures downstream due to the sudden release of flowing water.

While dam failures that occur during flood events compound an already tenuous situation and are certainly problematic, the dam failures that occur on dry days are the most dangerous. These "dry day" dam failures typically occur without warning, and downstream

[22] Hasbrouck, P.E. *Determining the Probability of Lightning Striking a Facility*, National Lightning Safety Institute, http://lightningsafety.com/nlsi_lhm/prbshort.html (April 2004).

property owners and others in the vicinity are more vulnerable to being unexpectedly caught in life threatening situations than failures during predicted flood events.

Dams are classified by size and hazard ratings. The size classification provides a relative description of small, medium, or large, based on the storage capacity and height of the impounded water. The hazard classification relates to the probable consequences of failure or misoperation of the dam; however, it does not relate to the current condition or the likelihood of failure of the dam. The hazard classifications are defined in the Rhode Island Dam Safety Regulations as follows:

- High Hazard: When dam failure or misoperation will result in a probable loss of human life.
- Significant Hazard: When dam failure or misoperation results in no probable loss of human life, but can cause major economic loss, disruption of lifeline facilities, or detrimental concern to the public's health, safety, or welfare.

Location

There are 96 high hazard dams, 81 significant hazard dams, and 490 low hazard dams, for a total inventory of 667 dams (Table 40). In addition, one of the Rhode Island Department of Environmental Management's (DEM) responsibilities in the Dam Safety Program is to inspect and identify unsafe dams and take appropriate action to return the dams to a safe condition. An unsafe dam is a high or significant hazard dam whose condition is such that an unreasonable risk of failure exists.

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Table 40: DEM Dam Inventory (Source: 2015 RI Dam Safety Report List)

County	Municipality	High	Significant	Low	Total
Bristol	**County Total**		3	6	9
	Barrington			2	2
	Bristol		1	2	3
	Warren		2	2	4
Kent	**County Total**	12	9	112	134
	Coventry	6	6	48	60
	East Greenwich		1	13	14
	East Greenwich/North Kingstown			1	1
	Warwick	2	1	15	19
	West Greenwich			27	27
	West Warwick	4	1	8	13
Newport	**County Total**	8	7	20	35
	Jamestown		2	4	6
	Little Compton	1	2	8	11
	Middletown	3		3	6
	Portsmouth	3	1	4	8
	Tiverton	1	2	1	4

County	Municipality	High	Significant	Low	Total
Providence	**County Total**	56	41	242	336
	Burrillville	5	6	30	40
	Cranston	5	1	18	24
	Cranston/Warwick			1	1
	Cumberland	3	3	11	19
	Cumberland/Lincoln			3	
	East Providence	2		8	10
	Foster	2	1	24	27
	Foster/Scituate			1	1
	Glocester	6	10	35	51
	Glocester/Smithfield	1			1
	Johnston	5	6	13	24
	Johnston/North Providence			2	2
	Johnston/Providence			1	1
	Lincoln	9		10	19
	Lincoln/North Smithfield	1			1
	North Providence	2		4	6
	North Providence/Johnston	1			1
	North Smithfield	3	2	15	20
	North Smithfield/Smithfield	1			1
	Pawtucket			6	6
	Providence		2	7	9
	Scituate	1	7	20	28
	Smithfield	6	2	23	31
	Woonsocket	2	1	10	13
Washington	**County Total**	20	20	108	158
	Charlestown		1	6	7
	Charlestown/Richmond	1		2	3
	Charlestown/Hopkinton			1	1
	Exeter	5	1	31	37
	Hopkinton	2	6	27	35
	Hopkinton/Richmond	1	2	2	5
	Hopkinton/Westerly			1	1
	Narragansett		1	4	5
	New Shoreham		2		2
	North Kingstown	6	3	13	22
	Richmond	1	1	10	11
	South Kingstown	4	3	18	25
	Westerly			3	3
	Westerly/CT			1	1

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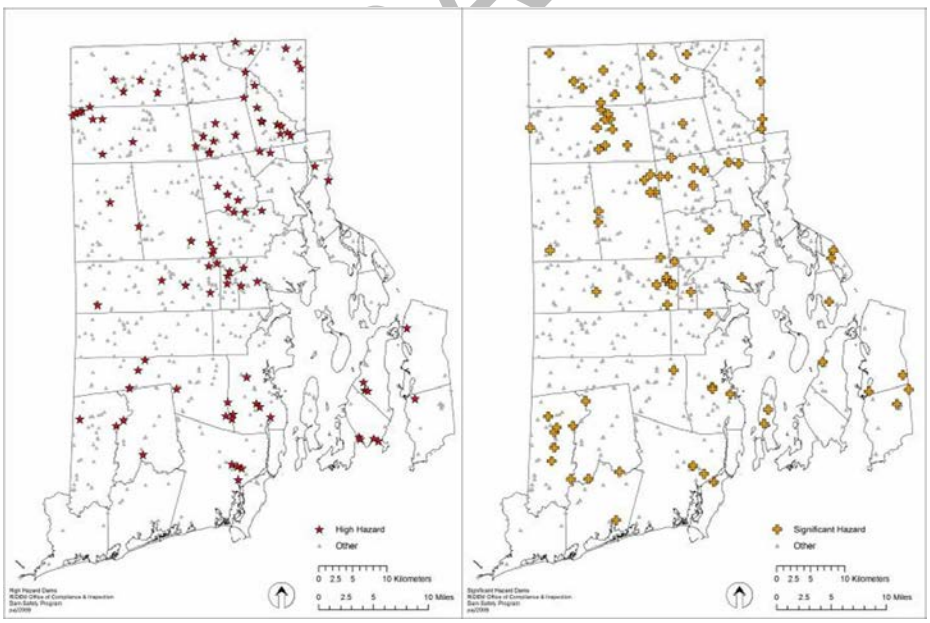
Extent

According to the Federal Guidelines for Dam Safety, two factors influence the severity of a dam failure: (1) the amount of water impounded, and (2) the density, type, and value of development and infrastructure located downstream. Most dam failures are described by their potential point of inundation; their hazard profile ranking goes from low, significant, to high:

- Low hazards potential represents those dams where, if failure occurred, would result in no probable loss of human life and low economic/environmental losses.
- Significant can be categorized by those failures that result in economic loss, environmental damage, or disruption of lifeline facilities, but not in loss of life.
- High hazard potential signifies those dams that will result in loss of life if they fail.[23]

Dams have been an important part of Rhode Island's water infrastructure for centuries. In addition to the historic economic benefits provided by dams, they are used for flood control, water supply, power generation, recreation, and for mitigating the impact of increased runoff typically caused by land use changes associated with property development. The United States Army Corps of Engineers maintains a national inventory of dams that lists dams in Rhode Island, but also those in proximity to Rhode Island. Additional risks exist based on proximity of Rhode Island counties to other states where dam failures may occur.

Figure 11: High and significant dams in Rhode Island



Previous Occurrences

Rhode Island has experienced many dam failures, mainly resulting from major flood events. Historically, however, the consequences of dam failures have not been well documented. Descriptions of previous dam failure events provided in this section are based on data available from the National Performance of Dams Program (NPDP) at Stanford University, the Association of State Dam Safety Officials, and NCDC.

Over 111 dam incidents have been recorded in Rhode Island, of which seven (7) resulted in dam failure. The most recent documented event was in Glocester during May 2002 at Sweet's Mill Dam in Providence County.

Table 41: National Performance of Dams Program Rhode Island Reported Dam Incidents

Incident Date	Dam Name	Incident Type
8/25/1889	Spring Lake Dam	Piping
3/11/1901	Randall's Pond (Lower)	Inflow Flood - Hydrologic Event
1991	Burton Pond Dam	Concrete Deterioration
1991	Unnamed Dam (RIS00003)	Not Known
2/18/1998	Peace Dale Pond Dam	Inflow Flood - Hydrologic Event
8/6/2000	Mill Pond Dam	Embankment Erosion
5/8/2002	Sweet's Mill Dam	Biological Attack (i.e., bush, tree growth); Embankment Erosion

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Probability of Future Events

While generally considered an unlikely occurrence, the potential for dam failure in Rhode Island is a significant concern given the large number of dams across the state and the fact that there have been dam failure events in the past. The probability of future occurrence or annualized events shown in Table 42 illustrates a potential to likely probability of occurrence across the state, depending on the county. Specifically, Bristol and Newport Counties have a potential probability (one to 10 percent) of having a dam failure within the next 12-60 months. The remaining Rhode Island counties (Washington, Kent, and Providence) have a likely probability (10 to 100 percent) of dam failure occurring within the next 12-60 months.

The probability of future dam failure events is not easily measured, but correlates to some extent with the probability of future major flood events coupled with preventative measures, including the routine inspection, maintenance, repair, and proper operation of dams by their owners, and as regulated by DEM's Dam Safety Section.

[23] http://www.fema.gov/media-library-data/20130726-1516-20490-7951/fema-333.pdf

The Dam Safety Section through DEM is tasked with monitoring the routine inspection and maintenance of those dams that present the greatest risk or are in need of structural repair. State regulations require that over 600 dams in Rhode Island must be inspected annually, with priority placed on those dams which pose the greatest potential threat to downstream persons and properties. Other structures are inspected as time and funding permit, and upon notification of potentially significant deficiencies or emergency conditions. Dam owners are responsible for complying with maintenance and repair requirements, and developing Emergency Action Plans (EAPs) that are required for high and significant hazard dams.

Dams that receive construction permits for repair and/or reconstruction are designed to pass at least the one percent annual rainfall event with one foot of freeboard (a factor of safety against overtopping). The most critical and hazardous dams are required to meet a spillway design standard much higher than passing the runoff from a one percent annual chance rainfall event. Although not all of the dams have been shown to withstand the one percent annual chance rainfall event, most of the dams meet this standard due to original design requirements or recent spillway upgrades. If smaller rainfall events, such as 10-year and 25-year events, occur more frequently there will be little impact on the ability of the dams to operate safely.

As more and more state-owned and privately owned dams are repaired, the number of dams that will not meet the state minimum requirements for spillway design diminishes. Nonetheless, the average age of all the dams continues to increase. Therefore, the state must remain vigilant in administering its dam safety regulations and related programs.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined dam failure to be a moderate priority hazard in Rhode Island. As described in the profile above, dam failure events within the state range from potential to likely within the next year to three (3) years. Dam failure events have a small to large range of impact, accounting for less than 10 percent to 100 percent of the jurisdictional boundaries. Hazard magnitude ranges and is considered to have negligible to limited magnitude including minor injuries, no shutdown of critical facilities and infrastructure, and less than 10 percent of residential and commercial structures damaged from the events. Table 42 outlines the hazard rankings for each of the hazard priority criteria related to dam failure.

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Table 42: Dam Failure Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Potential** *1% to 10% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Limited** *Less than 10% of residential and commercial structures damaged*	**Moderate**
Kent County	**Likely** *10% to 100% probability within next 12-60 months*	**Large** *40% to 100% of the total jurisdictional boundaries*		**Limited** *Short shutdown of critical infrastructure and facilities*		**High**
Newport County	**Potential** *1% to 10% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*		**Negligible** *No shutdown of critical infrastructure and facilities*		**Moderate**
Providence County	**Likely** *10% to 100% probability within next 12-60 months*	**Large** *40% to 100% of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*		**High**
Washington County		**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*			

Vulnerability and Impact to People and Property

Dam failures may be caused by structural defects from poor design, construction materials, lack of maintenance, or gradual weakening of the dam. Factors attributing to dam failure include debris blocking the spillway, flooding, earthquakes, or improper operation.

Dam failure can significantly impact residential, business, and government property and infrastructure, with potential loss of life. Several factors affect the severity of the damage caused by a dam failure. These include: the amount and type of development located downstream, amount of water released, speed at which the failure occurred, and if the failure was partial or complete.

If a dam failure were to occur, it would result in the evacuation of downstream residences and businesses. Depending on the severity of the dam failure, structures may be uninhabitable from flooding and there may be a need to rebuild or relocate. Businesses

would have to do the same and may have to close their doors for good. If utilities and infrastructure are damaged, residents would have to look for supplemental power. Roadways could become flooded, resulting in essential facilities becoming isolated or emergency services rerouted in response to calls. A catastrophic dam failure, without ample warning and evacuation, could lead to injury and death.

The DEM maintains dam inundation data and maps; however, this data is for state use only. As a result, dam inundation mapping with critical and state facilities was not possible for this HIRA update. The state may consider conducting internal analysis between dam inundation layers and critical and state facilities, and reporting on the number of facilities within the dam inundation zone for future Rhode Island Hazard Mitigation Plan updates.

Dam inspections may also reflect dam vulnerability. High hazard dam inspections are required to be performed every two (2) years, while significant hazard and low hazard dam inspections are required every five (5) years. A visual inspection is performed whenever DEM has cause to believe that an unsafe dam exists, or upon request by any person who has cause to believe that an unsafe dam exists. In 2015, 11 high hazard dams and one significant dam were inspected.

Summaries of the visual inspections are provided in the *Rhode Island 2015 Annual Report to the Governor,* prepared by the Office of Compliance and Inspection within DEM. Table 43 summarizes the unsafe dams in Rhode Island. A summary of each of these dams and the reason they were deemed unsafe can be found in the above referenced *Annual Report to the Governor* on the activities of the Dam Safety Program. During 2015, DEM addressed 42 unsafe dams and by the end of 2015, seven (7) of the dams were returned to a safe condition. Johnston in Providence County has four (4) high hazard dams considered unsafe, followed by Coventry in Kent County with four (4) significant hazard dams considered unsafe, and Smithfield in Providence County with three (3) high hazard dams considered unsafe.

Table 43 summarizes the unsafe dams in Rhode Island. A summary of each of these dams and the reason they were deemed unsafe can be found in the above referenced *Annual Report to the Governor* on the activities of the Dam Safety Program.

No potential losses or specific vulnerabilities could be estimated due to the lack of inundation mapping. Providence County has a higher risk of dam failure due to the number of dams in the county and previous events resulting in deaths and injuries.

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Table 43: RI Department of Environmental Management (DEM) Unsafe Dams. Source: Rhode Island 2015 Annual Report to the Governor on the Activities of the Dam Safety Program, prepared by the Office of Compliance and Inspection

County	Municipality	Dam Number	Dam Name	Hazard Class	Unsafe Conditions
Bristol	Barrington	N/A			
	Bristol	N/A			
	Warren	480	Warren Upper	Significant	Vegetation prohibited inspection, spillway location unknown, low level outlet operability unknown
Kent	Coventry	175	Quidnick	Significant	Vegetation prohibited inspection, low section of embankment, debris blocked low level outlet channel
		186	Upper	Significant	Seepage and sediment transport, embankment section low, spillway discharge flowed along base of dam
		498	Hopkins Farm	Significant	Raised spillway crest, auxiliary spillway partially filled
		645	Centre of New England #1	Significant	Vegetation prohibited inspection, spillway movement and debris impacting flow
	East Greenwich	N/A			
	Warwick	N/A			
	West Greenwich	N/A			
	West Warwick	455	Bouchar Farm	Significant	Vegetation prohibited inspection
Newport	Jamestown	575	Jamestown Lower	Significant	Vegetation prohibited inspection, low level outlet could not be located
	Little Compton	N/A			
	Middletown	N/A			
	Newport	N/A			
	Portsmouth	N/A			
	Tiverton	742	Creamer	High	Vegetation prohibited inspection
Providence	Burrillville	027	Sucker	Significant	Vegetation prohibited inspection, plywood blocked spillway, low level outlet inoperable, auxiliary spillway modified
	Burrillville	565	Ross	Significant	Vegetation prohibited inspection, low level outlet inoperable
	Central Falls				
	Cranston	198	Curran Lower	High	Vegetation prohibited inspection, vegetation in spillway inhibited flow, low level outlet inoperable

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County	Municipality	Dam Number	Dam Name	Hazard Class	Unsafe Conditions
	Cumberland	N/A			
	East Providence	N/A			
	Foster	N/A			
	Glocester	727	Bowdish Lower	High	Vegetation prohibited inspection, debris obstructing spillway, low level outlet operability unknown
	Glocester	111	Waterman	High	Vegetation/debris prohibited inspection, drainage trench clogged
	Johnston	169	Almy	High	Vegetation prohibited inspection, spillway not functioning properly, low level outlet inoperable
		170	Simmons Upper	High	Vegetation prohibited inspection, low level outlet inoperable
		171	Simmons Lower	High	Vegetation prohibited inspection, severe embankment erosion, spillway not functioning properly, low level outlet inoperable
		313	Hughesdale Upper	High	Low section of embankment, low level outlet inoperable
	Lincoln	097	Butterfly	High	Low level outlet inoperable
		104	Bleachery	High	Low level outlet inoperable
	North Providence	084	Wenscott	High	Low level outlet inoperable
	North Smithfield	067	Todd's	Significant	Vegetation prohibited inspection, low level outlet inoperable
	Pawtucket	N/A			
	Providence	093	Canada Upper	Significant	Low level outlet inoperable
	Scituate	N/A			
	Smithfield	111	Waterman	High	Vegetation/debris prohibited inspection, drainage trench clogged
		109	Stillwater	High	Vegetation prohibited inspection, vegetation inhibited spillway flow, low level outlet inoperable
		123	Hawkins	High	Vegetation prohibited inspection, low level outlet inoperable
	Woonsocket	073	Harris	High	Vegetation prohibited inspection, low level outlet operability unknown
Washington	Charlestown	N/A			
	Exeter	219	Boone	High	Vegetation prohibited inspection, debris in spillway affected flow, leakage with sediment transport through spillway
		238	Edward's	Significant	Vegetation prohibited inspection
		239	Slocum	High	Low level outlet inoperable

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County	Municipality	Dam Number	Dam Name	Hazard Class	Unsafe Conditions
	Hopkinton	440	Hoxie Farm	Significant	Vegetation prohibited inspection
		216	Wyoming Upper	High	Embankment soil missing and displaced, sinkholes, sediment at the downstream toe, possible spillway leakage, low level outlet inoperable
	Narragansett	N/A			
	New Shoreham (Block Island)	424	Rod & Gun Club	Significant	Vegetation prohibited inspection, auxiliary spillway not present
	North Kingstown	553	Belleville	Significant	Vegetation prohibited inspection, low section and large area of erosion on embankment, sediment transport through spillway
		710	Slocum Road Upper	High	Vegetation prohibited inspection, spillway stop log operability unknown
	Richmond	216	Wyoming Upper	High	Embankment soil missing and displaced, sinkholes, sediment at the downstream toe, possible spillway leakage, low level outlet inoperable
	South Kingstown	425	Wakefield	High	Vegetation prohibited inspection, low level outlet inoperable
	Westerly	N/A			

5.9 Fire

Description

Fire is a combustion or burning, in which substances combine chemically with oxygen from the air and typically give out bright light, heat, and smoke. For the purposes of the 2016 HIRA, fire is distinguished into two primary categories: urban fire and wildfire.

Urban Fire

Urban fires in cities or towns involve buildings with the potential for spreading to adjoining structures. Although statistics show a decline in fire casualty rates in recent years, the U.S. rate remains much higher than the yearly reported fire death and damage rates for other developed areas of the world, such as Western Europe.

The urban fire hazard in Rhode Island involves areas where single family homes, multi-family occupancies, and/or business facilities are clustered close together, increasing the possibility of a rapid spread to another structure. Other areas are characterized by adjoining buildings. Adjoining buildings are found in the downtown region of the city or include other

closely spaced wood frame structures. The cause of fires in urban areas usually includes one of the following:

- Criminal acts (arson, illegal explosive devices, acts of terrorism);
- Residential accidents (improper use of electrical appliances, faulty connections, grease fires, smoking, heating appliances, or improper disposal of wood ashes);
- Industrial accidents (hazardous material incidents, explosions, transportation accidents); or
- Acts of nature (lightning strikes, earthquake byproduct).

Wildfire

Wildfires are fueled by natural cover, including native and non-native species of trees, brush and grasses, and crops along with weather conditions and topography. While available fuel, topography, and weather provide the conditions that allow wildfires to spread, most wildfires are caused by people through criminal or accidental misuse of fire.

Location

Urban fires can occur in any building, facility, or infrastructure. Small urban fires occur routinely and are resolved expediently by first responders with minimal incident. Similarly, small wildfires are common throughout the state. When drought or near-drought conditions warrant, the potential for spreading wildfires is real. Forests cover more than half of Rhode Island's land area and the state's woodlands are increasingly being developed. Figure 13 portrays the state's Wildland Urban Interface (WUI), the area where structures and human development meet and intermingle with undeveloped wildland, creating an environment in which fire can move readily between structural and vegetative fuels. Providence and Washington Counties have the large total square mile area combined, which could lead to great devastation should large wildfire occur. Intermix WUI are areas where housing and vegetation intermingle (48 percent of Rhode Island land area), whereas interface WUI are areas with housing in the vicinity of contiguous wildland vegetation (nine percent of Rhode Island land area).[24]

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Figure 12: Wildland Urban Interface area by county and zone

County	Intermix Area (Square Mile)	Interface Area (Square Mile)	Total Area (Square Mile)
Bristol	2.85	0	24.72
Kent	78.85	8.49	173.96
Newport	41.02	8.27	107.49
Providence	213.48	34.57	429.95
Washington	185.77	41.13	341.86
Total	521.97	92.46	1077.98

[24] Radeloff, V. C., R. B. Hammer, S. I Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. 2005. The Wildland Urban Interface in the United States. Ecological Applications 15:799-805.

Extent

According to the National Weather Service, the elements that make up the criteria of a "Red Flag Warning" for New England are a combination of current meteorological conditions (winds, relative humidity), longer term dryness (rainfall amounts, Keetch-Byram Drought Index) and the vegetation status. Keetch-Byram Drought Index (KBDI) is an index used to determine forest fire potential. The drought index is based on a daily water balance, where a drought factor is balanced with precipitation and soil moisture (assumed to have a maximum storage capacity of eight inches) and is expressed in hundredths of an inch of soil moisture depletion. The drought index ranges from 0 to 800, where a drought index of 0 represents no moisture depletion, and an index of 800 represents absolutely dry conditions.

The accurate prediction of the potential risk of a fire and the forewarning of dangerous wildfire conditions can help reduce the incidence and seriousness of wildland fires. It can also provide firefighters the critical time needed for important preparation and readiness for wildfire suppression, as well as assist decision makers in the appropriate uses and activities for the public at large during times of extreme fire danger to aid in the prevention efforts.

Wildfires pose serious threats to human safety and property in rural and suburban areas. They can destroy crops, timber resources, recreation areas, and habitat for wildlife. Wildfires are commonly perceived as hazards in the western part of the country; however, wildfires are a growing problem in the wildland/urban interface of the eastern United States, including Rhode Island. In addition, wildfires are dependent upon the quantity and quality of available fuels. Fuel quantity is the mass per unit area. Fuel quality is determined by a number of factors, including fuel density, chemistry, and arrangement. Arrangement influences the availability of oxygen. Another important aspect of fuel quality is the total surface exposed to heat and air. Fuels with large area-to-volume ratios, such as grasses, leaves, bark, and twigs, are easily ignited when dry.

Climatic and meteorological conditions that influence wildfires include solar insulation, atmospheric humidity, and precipitation, all of which determine the moisture content of wood and leaf litter. Dry spells, heat, low humidity, and wind increase the susceptibility of vegetation to fire. In Rhode Island, common factors leading to large fires include short-term drought, humidity below 20 percent, and fuel type.

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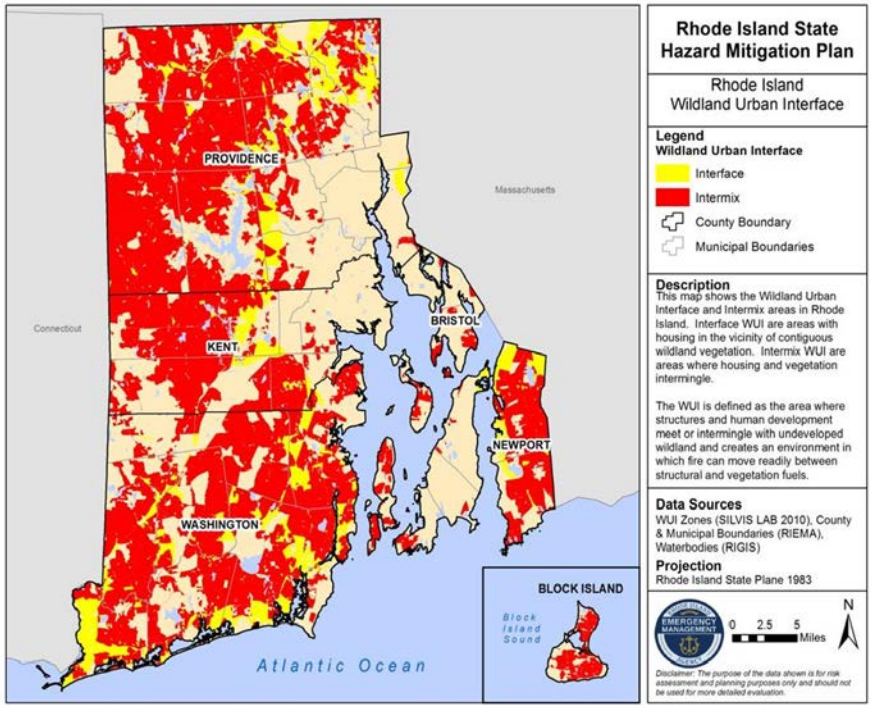
Figure 13: Wildland Urban Interface zones



Previous Occurrences

The largest wildfire in Rhode Island was the Coventry Fire, occurring from April 30, 1942, to May 2, 1942, in which 18,000 acres were burned. The most intense fire was the Wood River Fire on May 2, 1951, in which 7,400 acres burned. The worst year for fires was 1930, when 37,400 acres burned. Figure 14 outlines areas burned during these periods.

Figure 15 highlights the five-year average for wildfires in Rhode Island. Early spring and fall appear to be peak wildland fire seasons. While dated, this information was the best available provided for the 2014 Rhode Island Hazard Mitigation Plan Update by the Rhode Island Division of Forest. As members of the SIHMC, Division of Forest Environment will be in contact with RIEMA during plan implementation and maintenance to discuss data needs and collection for the Hazard Mitigation Plan update.

Figure 14: Wildfire occurrence, 1930 through 1955

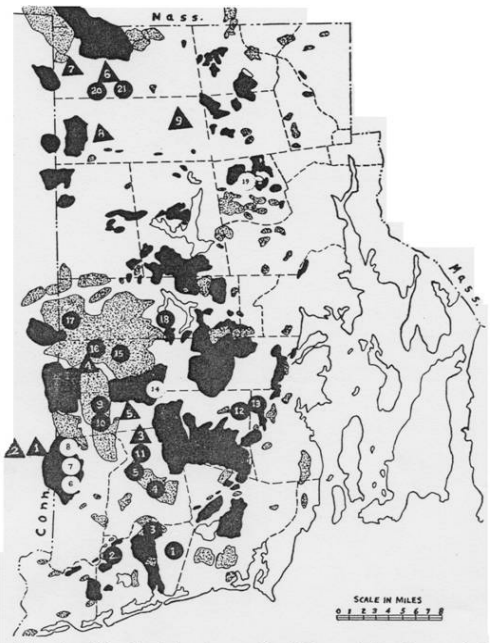


FIG. 1. Rhode Island woodland burned in the period from 1930 to 1940 (solid black area) and from 1940 to 1955 (dotted area). Circles indicate locations of plots in burned stands; triangles indicate locations of plots in unburned stands.

Drought conditions and other natural disasters increase the probability of wildfires by producing fuel in both urban and rural settings. Using historical NCDC records, it can be estimated that Rhode Island will experience one wildland type or natural vegetation fire event every 10 years, or a 10 percent occurrence annually, which can be related to a low probability of occurrence. Table 44 provides the annualized events qualitative ranking used for determining probability of future events.

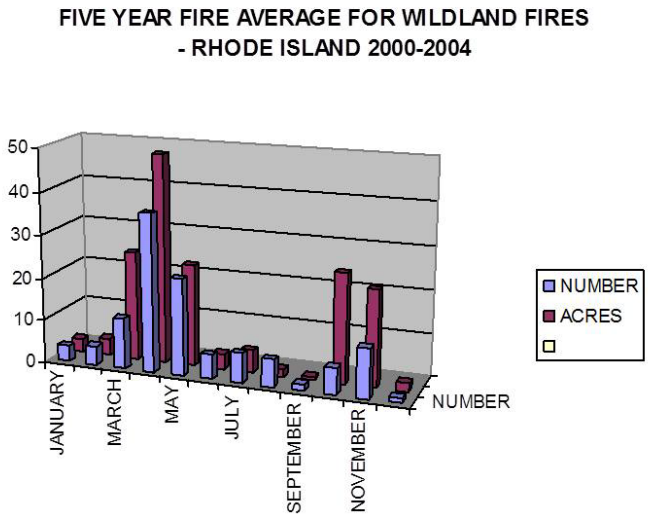
The most significant urban fire event was the nightclub fire at The Station. The Station nightclub fire occurred on February 20, 2003, in West Warwick, Rhode Island. The conditions produced by the fire, and the lack of sufficient exits in the club resulted in 100 deaths and several injuries. This incident prompted a major overhaul in the NFPA policies and standards regarding occupying spaces.[25]

Probability of Future Events

[25] http://www.nfpa.org/public-education/by-topic/property-type-and-vehicles/nightclubs-assembly-occupancies/the-station-nightclub-fire

Bristol, Kent, and Providence Counties have a potential probability (one to 10 percent) of experiencing a fire within next 12-60 months. The remaining Rhode Island counties (Newport and Washington) have a likely probability (10 to 100 percent) of fire occurring within the next 12-60 months.

Figure 15: Five-year average for wildland fire (2004). Rhode Island Department of Forestry



Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined fire to be a moderate priority hazard in Rhode Island. As described in the profile above, fire events within the state range from potential to likely within the next year to three (3) years. Fire events have a medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Hazard magnitude is considered to have limited magnitude including some injuries, short shutdown of critical facilities and infrastructure, and less than 10 percent of residential and commercial structures damaged from the events. Table 44 outlines the hazard rankings for each of the hazard priority criteria related to fire.

Table 44: Fire Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Potential** *1% to 10% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Limited** *Less than 10% of residential and commercial structures damaged*	**Moderate**
Kent County						
Newport County	**Likely** *10% to 100% probability within next 12-60 months*					**High**
Providence County	**Potential** *1% to 10% probability within next 12-60 months*					**Moderate**
Washington County	**Likely** *10% to 100% probability within next 12-60 months*					**HIgh**

Vulnerability and Impact to People and Property

Wildfires can affect any type of asset and may threaten major population centers when they break on the rural-urban fringe. Timber loss and environmental damage frequently result from wildfires. Wildfire poses a significant threat to nearby buildings and populations. Forest damage from fires may block interior access roads and fire breaks, pull down overhead power lines, or damage pavement and underground utilities, thereby creating heavy fire load and making suppression and response more difficult.

Buildings without fire suppression (i.e., sprinkler systems) are more vulnerable to building fires. If a residential or commercial property were to burn to the ground this would cause significant upheaval in the community. Residents would need to rebuild or relocate. If businesses were significantly damaged, employees would have to search for new employment.

Current geographic information system (GIS) structure data from the RIGIS does not include attribute fields related to fire suppression systems; this information would be ideal to identify vulnerable structures based on if fire suppression systems exist and the type of system in place. Based on past events, Newport County and Washington County have a higher hazard priority compared to Bristol, Kent, and Providence counties.

The WUI is where houses meet or intermingle with wildland vegetation. The WUI poses the biggest risk to human lives and structures.[26] Intermix WUI are areas where housing and vegetation intermingle, whereas interface WUI are areas with housing in the vicinity of contiguous wildland vegetation. Table 45 summarizes the facilities and structures, with a 30-foot buffer, located within WUI zones.

Table 45: Facilities located within Wildland Urban Interface (WUI). Source Silvis Lab

County	Number within Interface WUI	Number within Intermix WUI
Bristol	0	544
Kent	5,135	7,851
Newport	5,482	5,085
Providence	24,314	21,640
Washington	23,459	22,269
Grand Total	58,390	57,389

The 2013 Annual Fire District Survey (released March 2014) was prepared by the Department of Revenue Division of Municipal Finance and provides a report on Rhode Island fire districts[27]. The survey and report provides an examination of the fire districts to better understand the delivery of fire protection services. There are currently 42 fire districts; 33 of the districts have fire stations, fire trucks and equipment, and fire fighters. The fire districts provide fire services to nearly 50 percent of the state's land area. Five of the districts have financial agreements with neighboring districts for fire protection, including: Lake Shores, Quonochontaug, Shady Harbor, Shelter Harbor, and Weekapaug.

The Rhode Island Division of the State Fire Marshall is tasked with creating a fire-safe atmosphere and culture throughout the State. As part of the Comprehensive Fire Safety Act of 2003, the State Fire Marshall and several agencies have created a five-year work plan to provide local fire departments proper coordination to ensure fire safety and fire prevention activities are offered in every community.

5.10 Sea Level Rise

Description

Sea level rise is the level of the sea's surface related to the level of the continental crust. Relative sea level changes can be caused by absolute changes of the sea level and/or by absolute movements of the continental crust. Sea level rise (SLR) presents a hazard that should be considered in long-term land use, development, and critical infrastructure planning. Rhode Island has large exposure to the potential impacts of SLR, with approximately 400 miles of shoreline, 21 coastal communities, and significant areas of low

[26] Radeloff, V. C., R. B. Hammer, S. I Stewart, J. S. Fried, S. S. Holcomb, and J. F. McKeefry. 2005. The Wildland Urban Interface in the United States. Ecological Applications 15:799-805.
[27] http://www.municipalfinance.ri.gov/documents/resources/2013_RI_Fire_Districts.pdf

elevation.[28] Climate change, including the continued increase in global temperature, is projected to result in an acceleration of observed rates of SLR. Projections of global increases in sea level rise by 2100 range from one to two feet[29] up to 6.6 feet.[30]

Although SLR is a gradual process, impacts may be experienced in the short term. Some examples include increased frequency of low-level inundation, exacerbated flood elevations during storm events, increased rates of coastal erosion, and increased saltwater intrusion into groundwater.

The Sentinel Monitoring for Climate Change in Long Island Sound Program is a multidisciplinary scientific approach to provide early warning of sea level rise impacts to Long Island Sound ecosystems, species and processes to facilitate appropriate and timely management decisions and adaptation responses.[31] It has been such a successful collaborative project that Sentinel Monitoring is being scaled up for the entire northeast and Gulf of Maine region through the joint Ecosystem Heath Committee of Northeast Regional Ocean Council (NROC) and Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS). With a scaled up Sentinel Monitoring program, Rhode Island and regional efforts can be leveraged to support key monitoring for discernible climate signals and impacts, as well as inform adaptation strategies to keep our ocean and coastal resources as healthy as possible. Data from this effort will be available on their data clearinghouse and will contain SLR data and trends.

Heat waves, coastal flooding due to SLR, marine transgression, and river flooding due to more extreme precipitation events will pose a growing challenge to Rhode Island. This will increase the vulnerability of the region's residents, especially those already disadvantaged. While several municipalities have already begun to incorporate the risk of SLR, implementation of adaption measures is still at early stages.[32] Since Rhode Island is a "home rule" state and nearly all land use decisions are made at the municipal level, planning and implementation of actions to reduce the impacts of SLR in general must happen at the local level.

Location

In northeastern United States, signs of the planet's changing climate have become increasingly apparent. Over the past 30 years, average winter temperatures in the region have risen 3.8°F,[33] the largest increase in extreme precipitation events in the country. New

[28] NOAA Office of Science and Technology webpage. New England summary of communities. July 2013.
[29] IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E.Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
[30] Pfeffer, W.T. et al, 2008: Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. Science 321, 1340.
[31]Sentinel Monitoring for Climate Change in Long Island Sound Program http://longislandsoundstudy.net/research-monitoring/sentinel-monitoring/
[32] Global Change. Assess the US Climate. National Climate Assessment (NSA) Draft report Chapter 16 for the Northeast. V11 Jan 2013.
[33] Union of Concerned Scientists, 2006

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England as a whole has experienced a 61 percent increase in like storm events over the past 59 years, while Rhode Island in particular has witnessed an 88 percent rise over the same period.[34]

Additionally, data from the Newport tide gauge suggests a relative rate of SLR equal to 10.2 inches (± 0.75 inches) over the last century (1930-2006) in Rhode Island, in which 1989-2007 displays an even higher average rate of SLR with approximately 0.157 inches per year.[35] If this linear trend continues, Newport's sea level in 2100 will be 15 inches higher than today; however, most model predictions are non-linear. These models anticipate sea levels to be approximately 1.6 feet to 4.6 feet higher by 2100. Higher sea levels will mean that coastal flood zones will move inland, encroaching on areas that currently are not in high risk flood zones.[36] A one-foot SLR is possible in the next 25 years, with a five feet or higher rise by 2100 no longer being considered the worst case scenario.[37]

The Rhode Island Sea Grant (RISG) College Program, working with numerous state, institutional, and federal partners, compiled SLR inundation scenarios that represent conditions under average conditions at high tide as measured from the Newport tide gauge using tide data collected between 1983 and 2001 (National Tidal Datum Epoch). However, tide levels can vary by more than a foot above or below average conditions due to gravitational forces from the alignment of the earth, the moon, and the sun. In addition, water levels at high tide become increasingly higher as you travel north through Narragansett Bay. Mean higher high water (MHHW) at the Providence tide gauge is about seven (7) inches higher than at the Newport tide gauge. Newport tide data is a reasonable representation of tides in North Kingstown, the site of one of the pilot communities. The inundation zones do not include wave heights or consider obstructions to water flow, such as dikes and culverts. It should be noted that the data is intended for planning purposes only and not to be used as regulatory or jurisdictional capacity. The following bullets explain the five (5) SLR inundation scenarios for Rhode Island that have been utilized for this HIRA update vulnerability assessment:

- MHHW - The mean elevation of the higher of the two daily high tides over a 19-year period, in comparison to the mean high water (MHW), which is the average elevation of all high tides over the same period. MHHW is the chosen baseline for the RI SLR study since it reflects a realistic average tidal elevation that communities will experience regularly.
    - MHW = average of all high tides over 19-year tidal epoch
    - MHHW = average of the highest daily tide over a 19-year tidal epoch
- MHHW Plus One-foot SLR – Sea level has already risen about 11 inches in the past 100 years. A rise of nine inches has been noted at North Kingstown based on data since 1930 when the Newport tide gauge was installed. With accelerated SLR already

[34] Madsen and Figdor, 2007
[35] National Oceanic and Atmospheric Administration, NOAA, 2007
[36] CRMC Metro Bay SAMP, 2009
[37] Veemer and Rahmstorf, 2009; USACE, 2009

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being observed in Rhode Island, models show that global sea levels are likely to rise one foot in the next 20 to 50 years. MHHW Plus one-foot SLR scenario depicts:
    - Areas inundated at mean high tide levels with one foot of SLR, or
    - Areas inundated at spring high tide today.
- MHHW Plus One-foot SLR and Three-foot Storm Surge – Extra-tropical storms, often referred to as Nor'easters, typically have storm surges of three feet above the predicted tide height in Rhode Island. MHHW plus one-foot SLR and three-foot Storm Surge scenario depict:
    - Areas inundated during extra-tropical storms with a one-foot SLR, or
    - Areas inundated during extra-tropical storms that strike at spring tide today.
- MHHW Plus Five-foot SLR – Models show that global sea levels may rise as much as five (5) feet by 2100. MHHW plus five-foot SLR scenario depicts:
    - Areas inundated at mean high tide at 2100 or beyond, or
    - Areas inundated during extra-tropical storms that strike at spring high tide with a one-foot SLR.
- Hurricane 1938 Surge Height – This inundation surface estimates flood elevations of the 1938 hurricane, as recorded at the Newport tide gauge. Elevations do not include wave heights or run-up. It should be noted that inundation levels were higher in the upper bay coastal communities as the storm surge traveled north into Narragansett Bay.

There are several models that project accelerated rates of SLR. Table 46 shows the differences in planning horizons depending on the scenario and the specific scientific study.

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Table 46: Sea level change studies

Study Name	1-foot SLR	3-foot SLR	5-foot SLR	Hurricane 1938 surge height
Vermeer and Rahmstorf, 2009	20 – 40 years	60 – 90+ years	80 – 90+ years	One percent change of occurrence every year
USACE Circular No. 1165-2-211, 2009	20 – 60 years	60 – 110+ years	90 – 110+ years	

Each of Rhode Island's 21 coastal communities are subject to impacts from SLR. Table 47 summarizes, in square miles, the inundation of each of the counties in Rhode Island. Washington and Newport counties represent the largest portion of inundation areas within the state.

Table 47: SLR scenarios shown in square miles of inundation area

County	Hurricane 1938	MHHW	+1' SLR	+3' SLR	+1 SLR and 3' Surge	+5' SRL
Bristol County	2.67	0.68	0.55	1.07	0.56	0.66
Kent County	1.23	0.30	0.23	0.37	0.20	0.24

County	Hurricane 1938	MHHW	+1' SLR	+3' SLR	+1 SLR and 3' Surge	+5' SRL
Newport County	3.51	2.10	1.43	1.97	0.91	0.82
Providence County	1.31	0.29	0.16	0.23	0.11	0.17
Washington County	6.03	5.10	1.42	2.64	1.37	1.42
Total	14.75	8.47	3.79	6.28	3.15	3.31

In addition, Rhode Island established a working group in August 2013 to meet and coordinate SLR and Climate Change Assessments across state agencies. This working group is currently working on details on how to coordinate efforts, as well as having in-depth discussions of static versus dynamic modeling of SLR and inundation risk. Many members of this working group are active participants on the SIHMC and will be key in the implementation, maintenance, and update of this HIRA over the next three (3) to five (5) years.

Extent

Sea level rise will result in wide scale systematic changes in the terrestrial and marine environments. Future increases in relative sea level will displace coastal populations, threaten infrastructure, intensify coastal flooding and ultimately lead to the loss of recreation areas, public space, and coastal wetlands. Coastal infrastructure will become increasingly susceptible to complications from rising sea levels, as the upward trend continues. Residential and commercial structures, roads, and bridges will be more prone to flooding.

SLR will also reduce the effectiveness and integrity of existing seawalls and revetments, designed for historically lower water levels. Higher sea levels will result in changes in surface water and groundwater characteristics. Salt intrusion into aquifers will contaminate drinking water supplies and higher water tables will compromise wastewater treatment systems in the coastal zone.

The most recent findings of the IPCC reports that global air and ocean temperatures are rising due to recent anthropogenic forcing. As global temperatures continue to increase, thermal expansion of seawater and accelerated melting of glacial ice leads to an increase in the total volume of global ocean waters. Over the last 100 years, sea levels have risen 6.7 inches globally. By 2100, greenhouse gas concentrations are predicted to reach levels greater than or equal to those observed during the last interglacial period when sea levels were between 13.1 feet and 19.7 feet higher than present levels.[38] Moreover, it has been reported that the occurrence of severe storm events is increasing almost everywhere in the contiguous United States.[39] Climate change may increase both the frequency and the severity of these events. Finally, as sea temperatures increase, the associated changes in species composition and ecosystem dynamics will alter our estuaries, fisheries, and wetlands, with

[38] Overpeck, et al., 2006
[39] Madsen and Figdor, 2007

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the potential to increase the presence of invasive species.[40] Due to the timescales associated with climate processes and feedbacks, anthropogenic warming and SLR will continue for centuries, regardless of steps taken to curb greenhouse gas emissions.[41]

Future increase in relative sea level will increase the extent of flood damage over time. Lower elevations will become increasingly susceptible to flooding as storm surge reaches further inland due to SLR in concert with a probable increase in the frequency and intensity of predicted storms. As a result, more coastal lands will be susceptible to erosion. Barriers, if unimpeded by development, will tend to over wash and move landward. Increased frontal erosion and retreat of the barriers will cause Rhode Island's south shore to migrate continuously landward with rising sea levels.

Previous Occurrences

Sea level in Rhode Island has increased by an average of one inch per decade since 1930. Over the past half century, sea levels in the Northeast have been increasing three (3) to four (4) times faster than the global average rate, resulting in a six (6) inch rise since 1970. With accelerating rates, sea level is projected to increase by three (3) to five (5) feet above 1990 levels in Rhode Island by 2100, with a potential for one foot of SLR by 2050.[42] This is the policy for CRMC, three to five feet by 2100.

SLR presents a hazard that should be considered in long-term land use, development, and critical infrastructure planning. Rhode Island has large exposure to the potential impacts of SLR, with over 400 miles of shoreline and significant areas of low elevation. Climate change, including the continued increase in global temperature, is projected to result in an acceleration of observed rates of SLR. Projections in global increases in sea level by 2100 range from one to two feet[43] up to 6.6 feet.[44]

Probability of Future Events

It is difficult to assign quantitative probabilities to projections of sea level rise. Climate planning is being completed in an adaptive approach to allow for best available science to be continually updated. Based on Table 49 there is a potential likelihood of one to 10 percent probability within the next 12-60 months of a sea level rise incident. The issue with creating more quantitative probabilities is that no widely accepted method is currently available for probabilistic projections at the regional or local level. Multiple scenarios allow for experts

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[40] CRMC Metro Bay SAMP, 2009
[41] IPCC, 2007
[42] Sea Level Rise in Rhode Island. Trends and Impacts Fact Sheet. http://seagrant.gso.uri.edu/z_downloads/climate_SLR_factsheet2013.pdf
[43] IPCC, 2007: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E.Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.
[44] Pfeffer, W.T. et al, 2008: Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. Science 321, 1340.

and decision makers to consider future conditions and develop responses based on the information that may reduce future impacts and vulnerabilities.[45]

The scenarios shown in Table 48 are based on four (4) estimates of global SLR that reflect different degrees of ocean warming and ice sheet loss ranging from 0.2 meters (8 inches) to 2.0 meters (6.6 feet) by 2100. These scenarios provide a set of plausible trajectories of global mean SLR for use in assessing vulnerability, impacts, and adaptation strategies. None of the scenarios should be used in isolation, and experts and coastal managers should factor in locally and regionally specific information on climatic, physical, ecological, and biological processes and on the culture and economy of coastal communities.[46]

Table 48: Global SLR scenarios

Scenario	SLR by 2100 (in meters)	SLR by 2100 (in feet)
Highest	2.0	6.6
Intermediate-High	1.2	3.9
Intermediate-Low	0.5	1.6
Lowest	0.2	0.7

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Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined SLR to be a low priority hazard in Rhode Island. As described in the profile above, SLR within the state has a potential (one to 10 percent probability) within the next year to three (3) years. SLR has a small to medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Hazard magnitude is considered to have negligible magnitude, including minor injuries, no shutdown of critical facilities and infrastructure, and scattered incidental residential and commercial structures damaged from the events. Table 49 outlines the hazard rankings for each of the hazard priority criteria related to SLR.

[45] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.
[46] Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp.

Table 49: SLR Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Potential** *1% to 10% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Moderate**
Kent County		**Small** *10% or less of the total jurisdictional boundaries*				**Low**
Newport County		**Medium** *10% to 40% of the total jurisdictional boundaries*				**Moderate**
Providence County		**Small** *10% or less of the total jurisdictional boundaries*				**Low**
Washington County		**Medium** *10% to 40% of the total jurisdictional boundaries*				**Moderate**

Vulnerability and Impact to People and Property

SLR vulnerability is restricted to the coastal communities and shoreline in Rhode Island. Washington County has the largest inundation area with potential vulnerability and losses in North Kingstown, Narragansett, South Kingstown, Charlestown, and Westerly. All municipalities within Newport County are vulnerable to inundation and losses; these include Jamestown, Newport, Middletown, Portsmouth, Tiverton, and Little Compton. Barrington, Warren, and Bristol within Bristol County are also vulnerable, with the entire extent of Barrington and Warren at eminent risk due to the elevation of the community in relation to the potential inundation.

Risk to State-owned and critical facilities was evaluated for each SLR risk class by facility category. Exposed State-owned and critical facilities were tabulated by county. Facilities data did not have building contents or exposure value and, as a result, this analysis does not include total exposure or monetary loss estimates. Welfare state facility in Newport County and Block Island state facility in Washington County intersected with the MHHW. Twelve critical facilities intersected with the MHHW plus five (5) ft. SLR scenario and include:

- Striper Marina (Bristol County);
- Angel's Marina (Kent County);
- Pawtuxet Reservoir Lower Dam (Kent County);
- Christie's Restaurant (Newport County);
- Newport Yacht Club, Harbour Court (Newport County);
- Newport Fire Department Station 1 (Newport County);
- Old Harbor Marina (Providence County);
- Rhode Island Yacht Club (Providence County);
- Avondale Boatyard Inc.(Washington County);
- Kenport Marina.(Washington County); and
- Wickford Yacht Club (Washington County).

Rhode Island Statewide Planning Program, in collaboration with CRMC, OHCD-DR, DEM, Sea Grant/CRC are currently working on a two (2) phase project to determine the socioeconomics of SLR. Phase I focus included the vulnerability of transportation assets to SLR using infrastructure and SLR projections. Phase II identified the socioeconomics of SLR by identifying populations located within the inundation scenario areas. The key goal of the project was to identify the socioeconomic and demographic makeup of the estimated population residing in each coastal inundation zone, based on the number of occupied residential units located within each inundation zone. Critical steps in the project included:

- Utilizing the sea level rise inundation zones developed by Coastal Resources Management Council (CRMC) in GIS

- Overlaying the Rhode Island Geographic Information System (RIGIS) "Sites – E-911" data with the sea level rise inundation zones to identify the number and types of residential units within each inundation zone

- Applying Census data to calculate an estimated number of occupied residential units, and develop estimates for social, economic, demographic and housing variables

Identifying the number of residential units in each inundation zone served as a foundation for the socioeconomics of SLR project. The following data (Table 50) pertains to the total number of residential units located in each sea level rise inundation zone scenario, without calculations for the percent occupied or vacant applied.

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As the sea level rise inundation zone height increases, the number of residential units identified within each inundation zone increases as well. The greatest percent change between the number of units identified and the sea level rise inundation zones occurs between the 3FT sea level rise scenario and 1FT sea level rise scenario at a 2,927.27% increase (11 residential units at 1FT, 333 residential units at 3FT). Subsequent percent changes decrease between the 5FT and 3FT scenario (467.87%), and between the 7FT and 5FT inundation zones (117.82%). As the sea level rise inundation zones increase, the number of residential units located within the inundation zones increase as well.

Seven (7) of the 11 residential units located within 1FT scenario are located within South Kingston; of which, 19 people are considered vulnerable at 1FT. Narragansett, Westerly, and South Kingston each have more than 50 structures located within the 3FT scenario; of which, 585 people are considered vulnerable at 3FT. Newport, South Kingston, and Westerly each have more than 300 structures located within the 5FT scenario; of which, 3,539 people are considered vulnerable at 5FT. Narragansett, South Kingston, Newport, Warwick, and Westerly have more than 400 structures located within the 7FT scenario; of which, 7,904 people are considered vulnerable at 7FT.

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Table 50: E911 Residential Structures within SLR scenarios.

Codes: R1 = Single Family Residential Unit, R2 = Multi-Family Residential Unity, R3 = Mobile Home

Town	1ft			1FT Total Residential Units	3ft			3FT Total Residential Units	5ft			5FT Total Residential Units	7ft			7FT Total Residential Units
	R1	R2	R3		R1	R2	R3		R1	R2	R3		R1	R2	R3	
Barrington	-	-	-	-	19	-	-	19	85	-	-	85	255	8	-	263
Block Island - New Shoreham	-	-	-	-	3	-	-	3	10	-	-	10	19	-	-	19
Bristol	-	-	-	-	10	-	-	10	54	5	-	59	100	19	-	119
Charlestown	-	-	-	-	39	-	-	39	185	-	-	185	396	-	-	396
Cranston	-	-	-	-	1	-	-	1	8	-	-	8	22	-	-	22
East Greenwich	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
East Providence	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	5
Jamestown	-	-	-	-	-	-	-	-	8	-	-	8	26	2	-	28

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Town	1ft			1FT Total Residential Units	3ft			3FT Total Residential Units	5ft			5FT Total Residential Units	7ft			7FT Total Residential Units
	R1	R2	R3		R1	R2	R3		R1	R2	R3		R1	R2	R3	
Little Compton	-	-	-	-	-	-	-	-	5	-	-	5	12	-	-	12
Middletown	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	3
Narragansett	-	-	-	-	55	-	1	56	147	5	1	153	406	14	1	421
Newport	-	-	-	-	8	6	-	14	163	62	-	225	312	126	-	438
North Kingstown	-	1	-	1	6	1	-	7	77	7	-	84	209	26	-	235
Pawtucket	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portsmouth and Prudence Island	-	-	-	-	11	-	2	13	92	-	11	103	202	1	13	216
Providence	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
South Kingstown	6	-	1	7	55	1	6	62	217	2	10	229	412	5	12	429

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Town	1ft			1FT Total Residential Units	3ft			3FT Total Residential Units	5ft			5FT Total Residential Units	7ft			7FT Total Residential Units
	R1	R2	R3		R1	R2	R3		R1	R2	R3		R1	R2	R3	
Tiverton	2	-	-	2	19	-	6	25	41	-	20	61	67	1	21	89
Warren	-	-	-	-	6	2	-	8	88	93	-	181	209	159	-	368
Warwick	-	-	-	-	14	1	-	15	164	15	-	179	458	39	-	497
Westerly	1	-	-	1	54	7	-	61	302	14	-	316	530	26	-	556
Total	**9**	**1**	**1**	**11**	**300**	**18**	**15**	**333**	**1,646**	**203**	**42**	**1,891**	**3,642**	**430**	**47**	**4,119**

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In addition to the E911 residential facility analysis, E911 commercial facilities within inundation scenarios were also identified for the socioeconomics of SLR project (Table 51). Westerly, Providence, and Newport have the largest number of commercial structures located within the SLR scenarios.

Table 51: E911 Commercial Structures within SLR scenarios.

Town	1ft	3ft	5ft	7ft
Barrington		1	5	7
Block Island - New Shoreham		6	12	31
Bristol		3	13	27
Charlestown		1	1	3
Cranston	1	2	3	6
East Greenwich			1	4
East Providence				4
Jamestown		2	8	10
Little Compton			2	5
Middletown				6
Narragansett		13	28	39
Newport	3	23	103	196
North Kingstown		9	42	65
Pawtucket		1	6	11
Portsmouth and Prudence Island	1	1	19	161
Providence		1	8	12
South Kingstown		5	9	12
Tiverton		4	27	48
Warren		8	17	37
Warwick		24	64	123

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Town	1ft	3ft	5ft	7ft
Total	5	104	368	807

5.11 Epidemic

Description

An epidemic is defined as a disease that spreads rapidly through a demographic segment of the human population, such as everyone in a given geographic area, a military base, or similar population unit, or everyone of a certain age or sex, such as the children or women of a region.

Many potential devastating diseases are spread through physical contact, ingestion, insects, and inhalation. Airborne diseases and those spread through physical contact pose higher risks to the community because they are difficult to control. Diseases such as influenza, pertussis, tuberculosis, and meningitis are all spread through these methods and pose a threat to all communities. Health agencies closely monitor for diseases with the potential to cause an epidemic and seek to develop immunizations.

Location

Rhode Island's geographic location and demographic characteristics make it vulnerable to importation and spread of infectious diseases. The state has experienced the effects of disease outbreak, including influenza. Although the entire state is susceptible to an epidemic event, disease spreads particularly rapidly in areas with high population density, such as crowded urban areas where people are in routine, close contact with one another. For example, Central Falls in Providence County, which is the smallest and most densely populated city in Rhode Island, is likely to experience more rapid spreading of disease. In addition, Providence, the capital of Rhode Island in Providence County, is susceptible as it is a major city center where foot traffic is heavier thus increases the likelihood of a contagion spreading quickly. Additionally, the county's abundance of waterbodies and forested land provide breeding ground for infected mosquitos and ticks.

Extent

Epidemics have the propensity to do significant damage, to include the widespread contraction of illness and, depending on the disease, death in populations more vulnerable to disease—such as children, the elderly, and pregnant women. Rhode Island, along with the rest of the United States, faces a near annual flu outbreak during "flu season," which typically occurs between October until May.

However, a flu epidemic is not the same as the annual flu season. Flu epidemic is caused by a new, much more serious and contagious virus to which humans have little or no natural resistance. If a new highly contagious strain of influenza began to infect humans, it would probably cause widespread illness and death within a matter of months, and the outbreak

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could last up to two years. The Centers for Disease Control and Prevention (CDC) predicts that as much as 25-30 percent of the U.S. population would become ill, with many requiring hospitalization and the potential for many deaths. Historically, communicable disease outbreaks have claimed more lives than any other type of disaster.

Previous Occurrences

The Rhode Island Department of Health (RIDOH) collects annual data on infectious disease cases. These outbreaks are outlined in Table 52 below.

Table 52: Infectious Disease Outbreaks Cases (2010-2014)

Disease	2010	2011	2012	2013	2014
Chlamydia	3480	4146	4313	4312	4349
Cryptosporidiosis	18	12	16	12	16
Shiga-toxin positive E. coli	3	8	2	3	4
Giardiasis	83	79	58	41	45
Gonorrhea	291	360	507	454	590
Haemophilus Influenzae, invasive	15	15	19	13	16
Hepatitis A	9	8	3	4	8
HIV (Human Immunodeficiency Virus)	106	97	78	74	97
Legionnellosis	43	29	31	46	28
Listeriosis	3	3	2	4	10
Lyme Disease	181	159	219	724	905
Malaria	15	6	17	14	22
Measles	0	1	0	1	0
Meningococcal Disease	1	1	0	1	1
Mumps	0	5	2	3	0
Pertussis	44	62	113	160	108
Pneumococcal Disease	123	97	73	76	73
Rocky Mountain Spotted Fever	2	2	13	2	0
Rubella	0	0	0	0	0
Salmonellosis	176	194	108	128	140
Shigellosis	16	9	15	267	34
Streptococcus, Group A	35	22	25	23	35
Streptococcus, Group B	61	47	62	61	56
Syphilis (primary, secondary, early latent)	61	66	68	67	120
Syphilis (late)	18	18	25	21	41
Tuberculosis	26	27	23	27	21
Varicella	46	42	80	39	54

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Disease	2010	2011	2012	2013	2014
Vibriosis	4	2	11	19	6
West Nile Virus	1	0	4	1	0

A key example of an epidemic was the outbreak of a new flu virus called H1N1 that was first detected in people in the United States in April 2009. The virus was found all over the world and spread from person to person, probably in the same way that more common seasonal influenza viruses spread. This virus was first referred to as swine flu because testing showed it was similar to flu viruses in pigs. The CDC estimates that more than one million people were infected with the virus and it was eventually elevated to a pandemic, in which a disease is pinpointed in multiple countries.

Probability of Future Events

Although it is impossible to predict the next disease outbreak, there is recent history that shows these epidemic outbreaks with significant impacts is low. The probability of such a reoccurrence though is considered unlikely with less than one percent probability within the next 12-60 months. Additionally, growing population and population density in Rhode Island have the potential to increase exposure and susceptibility of residents to epidemics. Infected mosquitos and ticks will continue to inhabit and impact the state as well.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined epidemic to be a low priority hazard in Rhode Island. As described in the profile above, epidemic events within the state are unlikely within the next year to three (3) years. Epidemics have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude ranges from negligible to limited magnitude including some injuries, no shutdown of critical infrastructure and facilities, and scattered incidental residential and commercial structures damaged from the events. Table 53 outlines the hazard rankings for each of the hazard priority criteria related to epidemic.

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Table 53: Epidemic Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial*	**Low**

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Washington County					*structures damaged*	

Vulnerability and Impact to People and Property

Depending on the scale of outbreak and type of disease, a localized infectious disease outbreak could impact the State of Rhode Island significantly. An event could overwhelm health systems, especially the 20 hospitals and health centers serving Rhode Island.

In the event residents and workers became infected from an epidemic, employee absenteeism would increase and the length of time necessary to recoup and regain lost time and money could be six (6) months or longer. Areas with high population density such as Providence, Warwick, and Cranston are most vulnerable to the spread of an influenza virus. Other parts of the state with lower densities, such as West Greenwich, Richmond, Scituate, and Warren, are not as susceptible to an outbreak; however, the virus can still spread in schools and workplaces.

Rhode Island Department of Health (RIDOH) tracks infectious disease outbreaks in the state.[47] The following list of diseases includes the five-year median number of cases from 2010 through 2014, starting with the highest occurring disease:

- Chlamydia (4,312: 5-yr median of cases)
- Gonorrhea (454: 5-yr median of cases)
- Lyme Disease (219: 5-yr median of cases)
- Salmonellosis (140: 5-yr median of cases)
- Campylobacteriosis (136: 5-yr median of cases)
- Pertussis (113: 5-yr median of cases)
- Ehrlichiosis / Anaplasmosis (107: 5-yr median of cases)
- HIV (Human Immunodeficiency Virus) (97: 5-yr median of cases)

The RIDOH provides detailed information and protocol for citizens to protect themselves and also provides services related to decreasing vulnerability on their website. The RIDOH website notes that disease prevention, specifically related to infectious diseases, includes: vaccinating and using medicines properly; proper hand washing and awareness of food preparation; protection from disease carriers by being aware of surroundings and avoiding areas with disease threats (ticks, mosquitoes); avoiding others when sick; safer sex practices; and not using intravenous drugs or sharing syringes.

[47] Rhode Island Department of Health Data for Diseases/Conditions http://www.health.ri.gov/data/

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The top two infectious diseases in Rhode Island are sexually transmitted diseases (STDs). As described above, the RIDOH advocates safer sex practices. These include but are not limited to abstinence, discussions with a healthcare provider, family planning, use of a condom consistently and correctly, and regular STD testing.

5.12 Drought

Description

Drought is characterized as a continuous period of time in which rainfall is significantly below the norm for a particular area. The American Meteorology Society defines drought as a period of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance. Drought differs from other natural hazards in that it is not something that occurs suddenly. Rather, a drought evolves over months or even years and, while causing very little structural damage, can have profound economic, environmental, and social impacts.

Four methods are used to define the severity of drought: meteorological, hydrological, agricultural, and socioeconomic. Meteorological drought refers to a reduction in the normal rainfall for a given geographic area. This needs to be area-specific, as the average rainfall can vary greatly in different areas. Hydrological drought is based on the amount of surface and groundwater relative to normal levels. Agricultural drought deals with the amount of moisture in soils available for plants. The last, socioeconomic drought, measures the impact that any or all of the first three have on people and businesses.

Characteristics and impacts of drought differ in many ways, so it is difficult to quantify drought. Drought levels are measured using several major hydrologic indices; precipitation, groundwater, and surface water are evaluated in terms of departure from normal. Normal is defined as the statistical average of the data for the period of record. It is important to note that time of year may influence the process considerably. In the fall and winter months, the crop moisture index (CMI) and the Palmer drought index (PDI) may react slowly but decline rapidly once the spring "green-up" occurs. The lag between surface water levels and groundwater levels could similarly skew the relative importance and number of indicators that are critical to determining the level of drought. In the final two stages, groundwater and reservoir data particular to the supplier will be used in conjunction with statewide data to determine drought levels.

1. PDI: An index that reflects soil moisture and weather conditions, including temperature. It is compiled by the NWS and the NCDC.

2. CMI: An index that reflects short-term soil moisture conditions, particularly as it pertains to agriculture. The agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water, which can be rapidly depleted in extended dry periods.

3. Precipitation: Data is collected by the NWS at eight (8) data points and reported by county. A drought phase determination is based on conditions relative to normal in three-, six-, and 12-month intervals.

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4. Groundwater Levels: These are monitored by the USGS from 38 observation wells. A drought phase determination is based on the number of months groundwater levels are below normal (lowest 25 percent of period of record). Local water suppliers also monitor public wells in order to make seasonal water availability comparisons.

5. Stream Flow: Conditions are monitored by the USGS from 21 near-real-time stations with 30 or more years of record. A drought phase determination is based on the number of months that stream flow levels are below normal compared to historical trend data.

6. Surface Water Reservoir Levels: Data is typically reported by water suppliers, relative to normal conditions or percent "full". A drought phase determination considers historic monthly averages of small, medium, and large index reservoirs.

The Rhode Island Drought Steering Committee assigns drought levels, for the seven (7) designated drought regions in the state based on hydrological indices, such as precipitation, groundwater, stream flow, and the PDI, as well as local supply indices, such as static groundwater levels and reservoir levels (Table 34). The Normal, Advisory, and Watch levels are issued statewide. The Warning and Emergency levels are issued on a regional basis and consider local conditions, source of water supply, and water storage capacity issues.

Economic impacts can result from a drought itself or, more indirectly, through conservation measures implemented because of a drought. Farmers can lose livestock or crops, or pay substantially more to produce a year's production. Water suppliers may lose income if they impose restrictions or face increased costs for developing alternate water supplies. Economic impacts to industries can include loss of production due to use restrictions or increased costs for alternate water supplies, such as cooling. In addition, Rhode Island relies heavily on tourism. Restricting access to beaches, restricting water recreation activities such as fishing and boating, and restricting golf course water supply could reduce the state's appeal to visitors, causing reduced revenues from tourism.

According to the Rhode Island's Department of Administration (DOA), Division of Planning, *Rhode Island Water 2030 (2012),* 92 percent of the state's resident population is served public water by 28 major water suppliers and 458 small public systems. The remaining population is served by private wells; the total number of persons on private wells varies by each region with the highest percent, nearly 30 percent, in the southern region. The quantities of water used by small systems and private wells are estimates as there is no reporting system to record this type of water use. Much of the public drinking water in the central and southern parts of the state comes from wells relying on groundwater aquifers, and it is this surface water provides the majority of water for the other regions in the state. Some of the surface water supplies in the north and east come from out of the state as well.[48]

According to the Rhode Island DEM's Section 305(b) *State of the State's Waters Report (2006),* the primary use of water in Rhode Island by the general population is for domestic uses, sanitation, and drinking water. Domestic water use includes water for normal

[48] Rhode Island Water 2030. RIDOA Division of Planning. 6/14/2012.

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household purposes such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens. There are 647 public wells in Rhode Island according to the Rhode Island Department of Health's (RIDOH's) Center for Drinking Water Quality (DWQ), with 170 of these wells being community wells serving residential populations of 25 persons or more. The remaining 477 wells are non-community wells that supply places such as schools and businesses. It is estimated that there are an additional 127,000 people served by an on-site water supply source.

Prior to the creation of the *Rhode Island Drought Management Plan (2002),* there was no mechanism for coordinating responses to drought by water suppliers throughout the state because of the decentralized nature of water suppliers and the variability of water supply sources.

In 2002, the Water Allocation Program Advisory Committee was launched to develop a water allocation program for the state and in 2004/2005 an implementation team identified water resources and developed a pilot study for the lower Blackstone River basin. Although these committees have been established, Rhode Island has not formally developed a systematic regulatory procedure for the allocation of water on a statewide or regional basis. Water allocation is currently based on riparian rights, traditional usage, and *ad hoc* permit approvals. Each water supplier imposes use restrictions when necessary based on the limitations of their system. Generally, this has worked because water supply has traditionally exceeded demand throughout most of the state's history. However, when drought conditions occur, shortages develop which may affect water suppliers and individual wells (private or community) differently because of regional hydrology, water demand, differing water supply sources, and infrastructure. For example, southern Rhode Island relies on extensive groundwater aquifers for water supply, while much of the rest of the state relies on surface water reservoirs for water supply.

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Location

Current drought conditions in Rhode Island and the nation are tracked by the U.S. Drought Monitor, a partnership between the University of Nebraska-Lincoln, as well as various federal and state agencies and other experts. Graphic and text summaries of current and projected drought conditions are updated on a weekly basis and are available through the Drought Monitor[49] website.

[49] http://droughtmonitor.unl.edu

Table 54: Drought indices and phases

Drought Indices and Phases						
Drought Level	**PDI**	**CMI**	**Precipitation**	**Ground Water**	**Stream Flow**	**Surface Water Reservoirs**
Normal	-1.0 to -1.99	0.0 to -1.0 Slightly dry	1 month below normal	1 month below normal	2 consec. months below normal	Reservoir levels at or near normal for the time of year
Advisory	-2.0 to 3.99	-1.0 to -1.9 Abnormally dry	2 month cumulative below 65% of normal	At least 2 out of 3 months below normal	3 consec. months below normal	Small index Reservoirs below normal
Watch	-3.0 to 3.99	-2.0 to -2.9 Excessively dry	1 of the following criteria met: 3 month cum. <65% or 6 months cum <70% or 12 months cum. <70%	4-5 consecutive moths below normal	At least 4 out of 5 consec. months below normal	Medium index Reservoir normal
Warning	-4.0 and below	>-2.9 Severely dry	2 out 3 of the above criteria met: 3 months cum. <65% **and** 6 months cum <65% **and** 12 months cum. <65% **or** 3 months cum. <65% **and** 12 months cum <65%	6-7 consecutive months below normal	At least 6 out of l7 consec. months below normal	Large index reservoir below normal
Emergency	-4.0 and below	>-2.9 Severely dry	Same criteria as Warning and Previous month was Warning Emergency	7 months below normal observation wells recording monthly record lows	>7 months below normal	Cont. of previous month's conditions
NOTES: PDI and CMI are short-term indicators. Local triggers will also be considered in assessing drought, such as water storage capacity and other water supply system management considerations, particularly in the later phases of drought.						

Extent

According to the NWS, the average annual rainfall in the state is between 39 inches to 54 inches. In contrast, the average annual precipitation for the United States is 29.53 inches. Even though the state receives more rain annually than the average for the United States, Rhode Island does experience extended periods of dry weather. Summer dry spells, during which crops and lawns may require irrigation, are fairly common. Thus, droughts, while not frequent, do occur.

An existing index called the Palmer Drought Severity Index (PDSI)[50] Table 55 uses temperature and precipitation levels to determine dryness, measuring a departure from the normal rainfall in a given area. The advantage of the PDSI is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or

[50] https://www.drought.gov/drought/content/products-current-drought-and-monitoring-drought-indicators/palmer-drought-severity-index

rainfall conditions. A monthly PDSI value below -2.0 indicates moderate drought, and a value below -3.0 indicates severe drought.

Table 55: Palmer Drought Severity Index

Severity	Index Value
Extreme Drought	-4 or less
Severe Drought	-4 to -3
Moderate Drought	-3 to –2
Mild Drought	-2 to –1
Incipient Dry Spell	-1 to –0.5

In addition, Keetch-Byram Drought Index (KBDI)[51] was developed to assess fire risk and in concert with current drought conditions. This index is detailed in the discussion of the fire hazard.

Previous Occurrences

Considering just the PDSI, severe droughts have occurred periodically in Rhode Island; periods of two or more months of severe or extreme drought were documented in 1911, 1925, 1930, 1943-1944, 1947, 1949-1950, 1957, 1965-1967 and 1985. The lowest PDSI was April 1966, with an index of -4.60.[52]

For the major historical drought events, the NWS noted that the precipitation during the preceding fall and winter months was below normal (which is typically defined as 90 percent and 75 percent less than levels through the spring) and led to the most severe drought episodes, including the 1965-67 long-term droughts (Table 56). The 1965-1967 drought episodes lasted for three summers and included long periods of below normal precipitation through the winter, spring, and summer months. This drought period serves as the classic model of a long-term drought in Rhode Island. Though short-term droughts, such as in 1999, may not have a significant impact on the state's public water systems; no water system will be immune to periods of long-term drought. Extended droughts, though not common, require statewide monitoring of climactic conditions.

Table 56: Rhode Island historical droughts and locations of impacts

Date	Area Affected	Remarks
1930-31	Statewide	Estimated stream flow about 70% of normal
1941-45	Statewide. Particularly severe in the Pawtuxet and Blackstone Rivers	Estimated stream flow about 70% of normal

[51] https://www.drought.gov/drought/content/products-current-drought-and-monitoring-wildfire/keetch-byram-drought-index
[52] Source of historic data for droughts consisting of a two or more-month period of severe or extreme drought is: http://www.nrcc.cornell.edu/drought/RI_drought_periods.html.

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1949-50	Statewide	Estimated stream flow about 70% of normal
1963-67	Statewide	Water restrictions and well replacements common
1980-81	Statewide. Groundwater deficient in eastern part of state	Considerable crop damage in 1980
1987-88	Southern part of state	Crop damage, $25 million

In addition to the events above, two drought events have been documented by NCDC since 1993, both in the spring and summer of 2012, impacting each county during this time. The U.S. Drought Monitor declared a severe drought across Rhode Island. A meteorological drought was documented by precipitation that had been approximately one half of normal from January 2012 through April 2012. Rivers and streams were most affected as most ran at record low levels during the spring run-off season. No southern New England state issued drought declarations, as reservoirs were at normal levels due to above normal precipitation falling between August 2011 and November 2011. The main impact of the meteorological drought was periods of very high fire danger. In addition, small pond levels were reduced. While soil moisture was well below normal, this drought occurred prior to the beginning of the growing season. Thus, no agricultural impacts were noted. From January 1 through April 15, precipitation levels were six (6) to eight (8) inches below normal across Rhode Island.

Annual average PDSI values have been recorded for Rhode Island since 1895.[53] Historically, Rhode Island has ranged from near-normal moisture conditions to moderate and severe droughts throughout the past century (Figure 16).

A noticeable trend in the PDSI is the lowering frequency of moderate to severe droughts (PDSI at or below -1.0) since the late 1960s. This corresponds very closely to a similar trend in the annual rainfall in Providence (Figure 17), which shows the majority of dry years, experiencing less than 36 inches of rainfall, all occurring prior to 1970. The majority of very wet years, experiencing greater than 54 inches of rainfall, have occurred since 1970.

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[53] NOAA NCDC, http://www.ncdc.noaa.gov/temp-and-precip/time-series/index.php?parameter=pdsi&month=5&year=2012&filter=ytd&state=37&div=0 (June 2013)

Figure 16: Average annual Palmer Drought Severity Index for Rhode Island

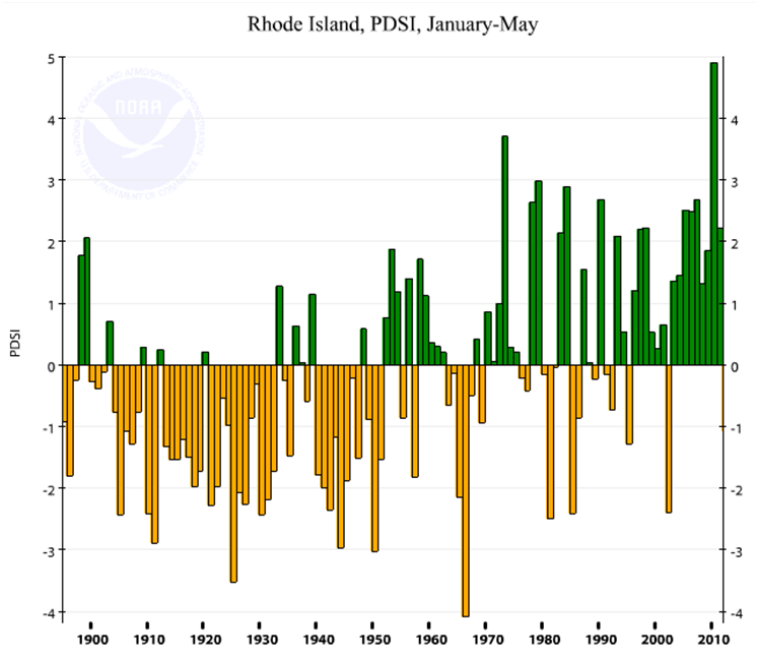

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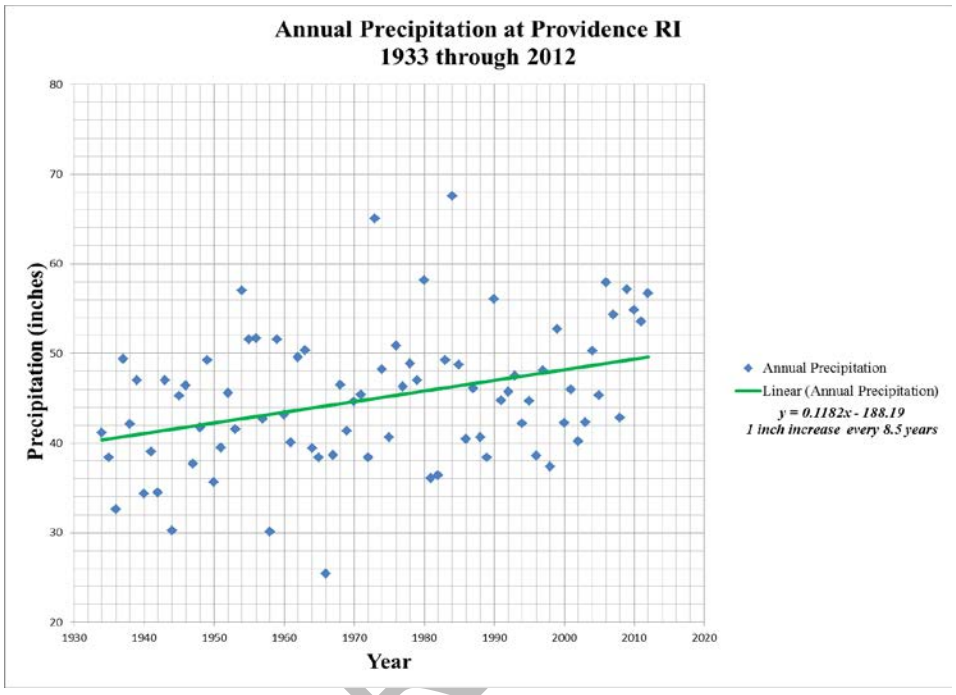
Figure 17: Annual Precipitation at Providence, RI (1933 – 2012).



Probability of Future Events

Extended periods of dry weather with significant negative impacts on crops, livestock, and people have occurred in the past and should be expected to occur into the future. Since drought is highly unpredictable and may be localized, assessing probability of its occurrence is difficult. Calculation of annualized drought risk as a function of probability and impact has not been performed for this analysis. Quantifying drought in terms of historical frequency also proves to be a difficult task because of the variations in drought definition and the very limited and curtailed historical reports.

Using the hazard ranking criteria, drought is deemed unlikely to occur in Rhode Island within the next 12-60 months. Table 7 provides the annualized events qualitative ranking used for determining probability of future events. The hazard ranking shown in Table 57 includes the probability of future events by county.

Other factors may also contribute to the degree of droughts and their impacts on Rhode Island. These include projections of humidity levels (decrease), hotter temperatures and increased heat wave occurrences, transpiration rates, and increased water demands by the general population and industry sectors. A review of the limited amount of data available suggests that a drought will occur about every 10 years in Rhode Island.

Recent climate change studies[54] have indicated that although precipitation is projected to increase throughout this century, it will be in the form of short duration, intense, and less frequent events. In addition, it is projected by the Northeast Climate Impacts Assessment Group (NECIA) and the New York City Panel on Climate Change (NPCC) that most of this increased precipitation may occur during colder times of the year, such as winter, in the form of snow or ice. Furthermore, it is projected that the frequency and intensity of both long-term and short-term droughts throughout the Northeast will increase throughout the century with the impacts beginning to occur with a greater degree of frequency beginning in the mid-century (2050s).

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined drought to be a low priority hazard in Rhode Island. As described in the profile above, drought events within the state are unlikely within the next year to three (3) years. Droughts have a medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Hazard magnitude is considered to have negligible magnitude including minor injuries, no shutdown of critical infrastructure and facilities, with scattered incidental residential and commercial structures damaged from the events. Table 57 outlines the hazard rankings for each of the hazard priority criteria related to drought.

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Table 57: Drought Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Low**
Kent County						
Newport County						
Providence County						
Washington County						

[54] Information derived from two recent studies: *Confronting Climate Change in the Northeast*, by the Northeast Climate Impacts Assessment Group, July 2007, and *Climate Risk Information*, by the New York City Panel on Climate Change, 2/17/09.

Vulnerability and Impact to People and Property

The entire state is susceptible and vulnerable to the occurrence of a drought event. The vulnerability of the state to drought is increasing as water use and land use change. People tend to assume that plentiful water is the norm for Rhode Island, when, in fact, occasional droughts of at least moderate intensity and duration have occurred in the state. Impacts from droughts can be moderated through mitigation planning and preparedness. Because droughts are a normal part of any climate, it is important to have a plan in place, providing for response actions. Rhode Island is vulnerable to a drought occurrence, whether short- or long-term in duration. Impacts will be costly in both social and economic terms. The responsibility for drought planning lies with the Rhode Island Water Resources Board. It is recommended that future updates of the *Rhode Island Drought Management Plan* include:

- Assessment of vulnerability aspects (social and economic) of the state;
- Identification of primary and secondary impacts that may arise from a drought (both long-term and short-term droughts), including underlying issues that may increase the state's or a particular sector's vulnerability to a drought;
- Inclusion of risk assessment and recommendation work performed by the Governors Steering Committee on Climate Change; and
- Proposed mitigation measures and implementation of educational outreach, which may be performed to reduce the impacts from both short-term and long-term droughts.

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Even though there is minor variation throughout the state in terms of areas more prone to experience drought conditions, it is assumed that the drought hazard would impact buildings in a fairly uniform and negligible manner. It is assumed therefore that state-owned and critical facility buildings would sustain very minor, if any, direct physical damage from exposure to drought conditions.

Economic impacts from a drought event may affect both elderly populations and families with children under 18 years of age. In addition, if current economic data are also taken into consideration at the time of a long-term drought, the economic and social impacts from such an event could be significant for Rhode Island. It is assumed that the drought hazard would impact the general population in a fairly uniform and negligible manner related to estimated damages.

A drought will produce different impacts in Rhode Island depending on the extent and geographic location of the drought (i.e., affecting a local area or region, or occurring statewide). The *Rhode Island Water 2030* plan details the anticipated demands versus the available water in 2030. The water data within the plan includes the system's safe yields, total volume of water consumed, the available water to the systems, and anticipated future demands. Based on the analysis in the *Rhode Island Water 2030* plan, four (4) suppliers are predicted to have a deficit of current available water and seven (7) are predicted to be close to source capacity.

In highly developed areas, drought impacts tend to be dominated by economic losses, possible potable water shortages, and health threats. In less densely populated areas of the state, the potential impacts from a drought are distinct, but equally high. They include:

- Increased potential of brush and forest fire occurrences. Potential loss of natural resources, in addition to the impacts to people living within or near heavily forested areas, who are at a higher risk for the impacts which can come from fires. Barriers to safe access/evacuation routes from the affected area, loss of personal belongings and economic losses, potential physical injury, and/or loss of life.

- Potential threat to levels and quality of municipal public water supplies, and impacts to small community and private potable water wells.

- Reduction of available fresh water resources of existing wells, including increased threat of well contamination (bacterial or chemical), and increased need to drill deeper wells to adequately provide fresh water resources for the resident population and natural resource and agriculture management.

5.13 Earthquake

Description

An earthquake is caused by a sudden displacement within the earth. Strong and destructive earthquakes usually result from the rupturing or breaking of great masses of rocks far beneath the surface of the earth. The ultimate cause of these deep ruptures has not been established. All earthquakes produce both vertical and horizontal ground shaking. This ground movement begins at the focus or hypocenter, deep in the earth, and spreads in all directions. The felt motion is the result of several kinds of seismic vibrations. The primary waves (P waves) are compressional. The secondary waves (S waves) have a shear motion. These body waves radiate outward from the fault to the ground surfaces where they cause ground shaking.

The fast moving P waves are the first waves to cause the vibrations of a building. The S waves arrive next and may cause a structure to vibrate from side to side. Rayleigh and Love waves (surface waves), which arrive last, cause low-frequency vibrations and are more likely than P and S waves to cause tall buildings to vibrate. Surface waves decline less rapidly than body waves, so as the distance from the fault increases, tall buildings located at relatively great distances from the epicenter can be damaged.

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Geologists have found that earthquakes tend to reoccur along faults, which reflect zones of weakness in the earth's crust. *A fault* is a fracture in the earth's crust along which two (2) blocks of the crust have slipped with respect to each other. Faults are divided into three main groups, depending on how they move. *Normal faults* occur in response to pulling or tension; the overlying block moves down the dip of the fault plane. *Thrust (reverse) faults* occur in response to squeezing or compression; the overlying block moves up the dip of the fault plane. *Strike-slip (lateral) faults* occur in response to either type of stress; the blocks move horizontally past one another. Most faulting along spreading zones is normal, along subduction zones is thrust, and along transform faults is strike-slip. Even if a fault zone has recently experienced an earthquake there is no guarantee that all the stress has been relieved.

The *focal depth* of an earthquake is the depth from the earth's surface to the region where an earthquake's energy originates (the *focus).* Earthquakes with focal depths from the surface to about 70 kilometers (43.5miles) are classified as shallow. Earthquakes with focal depths from 70 to 300 kilometers (43.5 to 186 miles) are classified as intermediate. The focus of deep earthquakes may reach depths of more than 700 kilometers (435 miles). The focuses of most earthquakes are concentrated in the crust and upper mantle. The depth to the center of the earth's core is about 6,370 kilometers (3,960 miles), so even the deepest earthquakes originate in relatively shallow parts of the earth's interior. The *epicenter* of an earthquake is the point on the earth's surface directly above the focus. The location of an earthquake is commonly described by the geographic position of its epicenter and by its focal depth.

Earthquakes beneath the ocean floor sometimes generate immense sea waves or tsunamis. These waves travel across the ocean at speeds as great as 960 kilometers per hour (597 miles per hour) and may be 15 meters (49 feet) high or higher by the time they reach the shore.

Liquefaction, which happens when loosely packed, water-logged sediments lose their strength in response to strong shaking, causes major damage during earthquakes.

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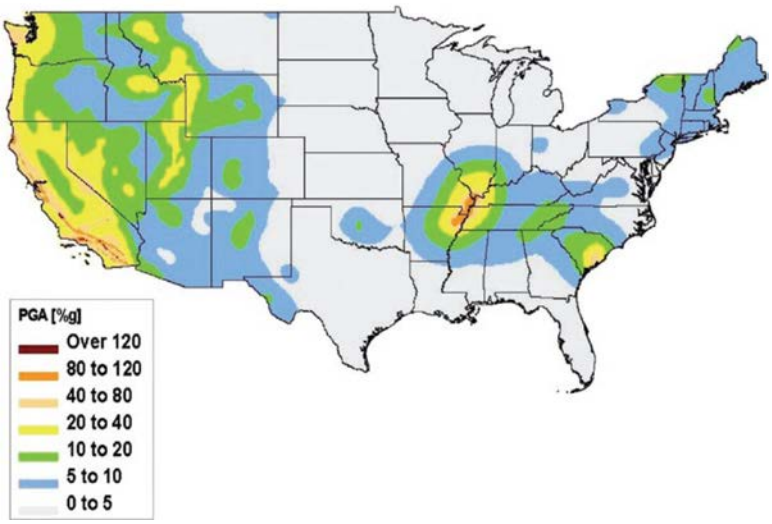
Location

Rhode Island is located in the North Atlantic tectonic plate and is in a region of historically low seismicity. Only three (3) or four (4) earthquakes of Modified Mercalli Intensity Scale (MMI) V or greater have been centered in Rhode Island, including the 1951 South Kingstown earthquake of magnitude 4.6 on the Richter scale. Other past earthquakes centered in Narragansett Bay, which most significantly impacts Newport, Bristol, and Providence counties. Because of this low seismic level there is a general perception that the state has very little risk of sustaining any earthquake-induced damage. However, areas geographically close to Rhode Island have had moderate seismic activity historically. For example, the area off Cape Ann, Massachusetts, has had several MMI VIII or greater events within the past 300 years. An earthquake of that location and intensity has the possibility to cause damage to structures in Rhode Island not designed to withstand seismic loadings.

In addition, an examination of the regional geology of Rhode Island yielded the potential for amplification of ground motions in significant areas in the state. Most of the region is generally characterized by till plains. Till is generally composed of unsorted rocks of varying sizes and is considered to be a stable geological formation not susceptible to amplification. However, the area around Narragansett Bay is characterized by outwash deposits. These deposits are typically sorted sand and gravel under dynamic loading; they tend to amplify the intensity of the bedrock motion so that the surface intensity is greater than that of the bedrock. This phenomenon has been known to cause extensive damage to structures. The City of Providence (in Providence County) is located at the head of Narragansett Bay, within the outwash region, and is the zone of potential amplification. In this region of outwash deposits, the bedrock intensity will be increased by one intensity level to account for the possibility of amplification. The region identified as Charlestown and New Shoreham Moraine within Washington County will be increased by a 0.5 intensity level.

Probabilistic ground motion maps are typically used to assess the magnitude and frequency of seismic events. These maps measure the probability of exceeding a certain ground motion, expressed as percent peak ground acceleration (%PGA), over a specified period of years. The severity of earthquakes is site specific, and is influenced by proximity to the earthquake epicenter and soil type, among other factors. Average PGA, for the 1000-year return period, has been used in the hazard ranking as the geographic extent parameter (Figure 18). The average PGA values for the state would result in no felt shaking or potential damage. Although California is widely known for its seismic activity, earthquakes, mostly with a magnitude of < 3.0, occur in a large frequency within the Northeastern United States.[55] In fact, the Northeast States Emergency Consortium notes that from 1538 to 1989, 1,215 earthquakes occurred in New England.[56]

Figure 18: USGS seismic hazard map for the 1,000-year return period. Source: USGS and FEMA



Extent

The severity of an earthquake can be expressed in terms of both *intensity* and *magnitude. Intensity* is based on the observed effects of ground shaking on people, buildings, and natural features. It varies from place to place within the disturbed region, depending on the location of the observer with respect to the earthquake epicenter. Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the one currently used in the United States is the MMI Scale. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.

Magnitude is related to the amount of seismic energy released at the hypocenter of the earthquake. It is based on the amplitude of the earthquake waves recorded on instruments that have a common calibration. The magnitude of an earthquake is thus represented by a single, instrumentally determined value. The magnitudes of seismic waves are recorded on instruments called seismographs, using the Richter Magnitude Scale. The Richter scale is not used to express damage. An earthquake in a densely populated area that results in many deaths and considerable damage may have the same magnitude as a shock in a remote area that does nothing more than frighten the wildlife. Large magnitude earthquakes that occur beneath the oceans may not even be felt by humans.

Impacts from earthquakes can be severe and cause significant damage. Ground shaking can lead to the collapse of buildings and bridges and disruption of gas and electric lines, phone service, and other critical utilities. Deaths, injuries, and extensive property damage may result from earthquakes. Some secondary hazards caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure.

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Table 58: Richter Magnitude Scale and Modified Mercalli Intensity Scale Comparison

Richter Magnitude Scale	Modified Mercalli Intensity Scale
1.0 to 3.0	I
3.0 to 3.9	II to III
4.0 to 4.9	IV to V
5.0 to 5.9	VI to VII
6.0 to 6.9	VII to IX
7.0 and Higher	VIII or Higher

Table 59: Modified Mercalli Intensity Scale

Defined Modified Mercalli Intensity Scale Rating	
I	Not felt except by a very few under especially favorable conditions
II	Felt only by a few persons at rest, especially on upper floors of buildings

Defined Modified Mercalli Intensity Scale Rating	
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors, disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Total damage. Lines of sight and level are distorted. Objects thrown into the air.

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Previous Occurrences

The USGS National Earthquake Information Center maintains a national database of significant earthquake epicenters from 1568–present.[57] USGS defines significant earthquakes as those that caused deaths, property damage, or geological effects, or that were experienced by populations in the epicentral area. The Weston maintains the history of earthquakes in the Northeast. Previous earthquakes that occurred in and near Rhode Island are presented in Table 60, compiled from several northeast earthquake catalog files.

Table 60: Rhode Island Historic Earthquakes. Source: USGS and Weston Observatory

Year	Month	Magnitude	Epicenter Location
1766	August	Unknown	Newport (Near Middletown)
1849	February	Unknown	RI
1849	March	Unknown	Newport
1876	September	Unknown	Newport
1883	February	Unknown	Newport

[57] http://earthquake.usgs.gov/earthquakes/eqinthenews/

Year	Month	Magnitude	Epicenter Location
1888	January	Unknown	Fall River, MA
1925	November	Unknown	Fall River, MA
1925	December	Unknown	Wareham/Taunton, MA
1926	January	Unknown	Voluntown, CT
1940	January	Unknown	Block Island
1948	May	Unknown	Westerly
1949	April	Unknown	N Kingstown
1951	June	4.6	Kingstown RI
1956	September	Unknown	Swansea, MA
1962	August	Unknown	East Greenwich
1965	December	2.6	Warwick
1967	February	3	Narragansett Bay
1974	October	2.5	West Warwick
1976	March	1.8	Portsmouth
1976	March	2.9	Portsmouth
1976	March	2.7	New Bedford, MA
1978	September	2.8	RI Sound
1978	April	1.7	Block Island Sound
1978	October	1.9	South of Dartmouth, MA
1981	April	2.7	Portsmouth
1982	November	1.8	West of Providence
1983	February	2.2	NW of Newport
1983	February	1.8	SW of New Bedford, MA
1989	May	Unknown	Island Park
2000	June	Unknown	East Greenwich
2005	November	Unknown	Newport
2003	November	Unknown	Near North and South Kingstown
2007	November	Unknown	West of Warwick, RI
2011	August	0.9	Near South Kingstown, RI
2012	December	1.0	Near Exeter, RI

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New England has had a history of earthquakes, including those recorded by the first settlers, and by the Plymouth Pilgrims in 1630. Over 34 earthquakes have been recorded in or near Rhode Island between 1568 to present with no significant earthquake activity since 1951. Several significant earthquake events are highlighted below:

- A February 27, 1883, earthquake that was centered in Rhode Island was felt from New London, Connecticut, to Fall River, Massachusetts. Within Rhode Island, it was felt (MMI V) from Bristol to Block Island.
- A large area, estimated at over 5,000,000 square kilometers of eastern Canada and the United States (south to Virginia and west to the Mississippi River) was affected by a magnitude 7.0 shock on February 28, 1925. The epicenter was in the St. Lawrence River region; minor damage was confined to a narrow belt on both sides of the river. Intensity effects were felt on Block Island and at Providence; intensity MMI IV, at Charlestown.
- The major submarine earthquake (magnitude 7.2) in the vicinity of the Grand Banks of Newfoundland on November 18, 1929, was felt throughout the New England states. Moderate vibrations were felt on Block Island and at Chepachet, Newport, Providence, and Westerly.
- Another widely felt earthquake occurred on November 1, 1935, near Timiskaming, Quebec, Canada. Measured at magnitude 6.25, the shock was felt (MMI IV) on Block Island and at Providence and Woonsocket. The total area affected was about 2,500,000 square kilometers of Canada and the United States.
- The strong earthquakes centered near Lake Ossipee, New Hampshire, on December 20 and 24, 1940, caused some damage in the epicenter area and effects were felt in Newport, Rhode Island. Additional reports included intensity MMI IV effects in Central Falls, Pascoag, Providence, and Woonsocket, and intensity MMI I-III effects in Kingston, New Shoreham, and Wakefield.
- Minor intensities were also reported from a September 4, 1944, shock in the Massena, New York, and Cornwall, Ontario, area. Kingston, Lonsdale, Providence, Wakefield, and Woonsocket reported intensity I-III. In addition, a magnitude 4.5 earthquake on October 16, 1963, near the coast of Massachusetts caused some cracked plaster (MMI V) at Chepachet, Rhode Island.
- A small earthquake was felt in the Narragansett Bay region on December 7, 1965, with a MMI V. Both windows and doors were reported to be shaking slightly. Moreover, some fourteen months later, another small earthquake (MMI V) was felt in the lower bay area.
- A magnitude 5.2 earthquake in western Maine on June 14, 1973, caused some damage in the epicenter region and was reportedly felt over an area of 250,000 square kilometers of New England and Quebec. The intensities in Rhode Island were MMI IV at Charlestown and MMI I-III at Bristol, East Providence, Harmony, and Providence.
- The last earthquake in Rhode Island with a magnitude of 4.0 or greater was near North Kingstown on June 10, 1951, with a magnitude of 4.6.

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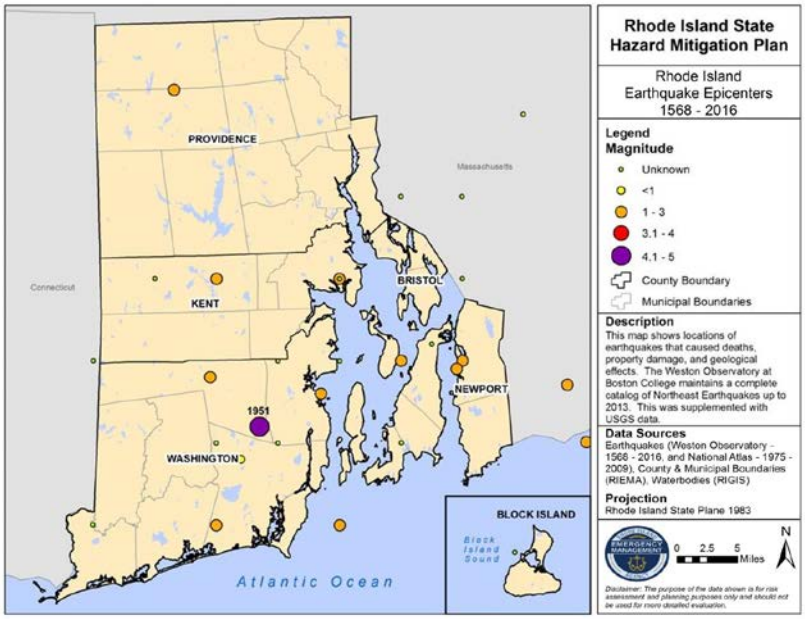
Earthquake events do occur in the state, though with much less intensity than elsewhere in the region or on the west coast. Additionally, earthquake events are more likely to be felt as a result of an earthquake that occurs in the surrounding region rather than originating within Rhode Island.

Probability of Future Events

Seismologists and geologists agree that earthquakes are impossible to predict with any degree of accuracy. Rhode Island is located in an area of moderate seismicity and high risk. Figure 19 shows earthquake epicenters near Rhode Island. Seismic risk applies to the seismic hazard, location demographics, and regional economics to the vulnerabilities of the structure or lifeline on the site. Seismologists have estimated that there is about a 50 percent probability of a very damaging magnitude 5.0 earthquake occurring anywhere in New England in a 50-year period. Using the hazard ranking criteria, probability of future occurrence has been related to an unlikely probability in Bristol, Providence, and Washington, and a potential (one to 10 percent) probability in Kent and Newport County within the next 12 to 60 months.

Figure 19: Earthquake epicenters near Rhode Island (1568 – 2016). Source: Weston earthquake center



Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined earthquakes to be a low priority hazard in Rhode Island. As described in the profile above, earthquake events within the state range from potential to unlikely occurrence within the next year to three (3) years. Earthquake events have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude for earthquake ranges from negligible to limited magnitude including minor injuries, no shutdown of critical infrastructure and facilities, and a range of scattered incidental damages to less than 10 percent of residential and commercial structures damaged from the events. Table 61 outlines the hazard rankings for each of the hazard priority criteria related to earthquakes.

Table 61: Earthquake Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries & Deaths	*Infrastructure*	*Structures*	
Bristol County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structure damages*	**Low**
Kent County Newport County	**Potential** *Between 1% and 10% probability within next 12-60 months*				**Limited** *Less than 10% of residential and commercial structures damaged*	**Moderate**
Providence County Washington County	**Unlikely** *Less than 1% probability within next 12-60 months*				**Negligible** *Scattered incidental residential and commercial structure damages*	**Low**

Vulnerability and Impact to People and Property

Earthquakes are low probability, high-consequence events. Although earthquakes may occur infrequently, they can have devastating impacts. Ground shaking can lead to the collapse of buildings and bridges, and disrupt gas, life lines, electric, and phone service. Deaths, injuries, and extensive property damage are possible vulnerabilities from this hazard. Earthquakes have the potential to trigger secondary hazards such as fire, flash flooding, hazardous materials release, slope failure, dam failures, and tsunamis—all potentially devastating to the environment. Moderate and even very large earthquakes are inevitable; consequently,

buildings in these regions are extremely vulnerable, as they are seldom designed to deal with an earthquake threat.

Despite the low probability of a high impact earthquake, physical characteristics in Rhode Island may increase earthquake vulnerability:

1. Hard Rock: Due to the geological makeup of New England's base rock, seismic energy is conducted on a greater scale (four to 10 times that of an equivalent Richter magnitude earthquake in California)
2. Soft Soil: Many coastal regions of New England are made up of soft soils. These soils can magnify an earthquake as much as two times.
3. Structures: The New England region, being one of the first settled areas of the United States, has an abundance of older, unreinforced masonry structures that are inherently brittle and very vulnerable to seismic forces.
4. Low Public Awareness of Vulnerability: There is little public recognition of earthquake threat, and no established system of educating or informing the public of the threat or how to prepare for or respond during an earthquake. Therefore, higher losses will occur here than in other regions of the country.

The entire State of Rhode Island is exposed to earthquakes. Certain areas, buildings, and infrastructure are at increased risk due to soils and the manner of construction. An earthquake risk assessment is difficult because it is challenging to monetize the potential damages accurately. Currently, the Rhode Island Building Code follows the Building Official and Code Administrators International (BOCA) code which has very basic earthquake provisions. Thus, even a moderate earthquake could cause severe damage to aged structures and unreinforced masonry buildings. In addition, these codes are only for new structures and do not take into account past structures like the "mill building." New England has a high seismic vulnerability because of the built environment, despite being considered to have moderate seismic risk.

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All critical facilities in the planning areas are exposed to the earthquake hazard. In addition, increased risk is associated with hazardous materials releases, which have the potential to occur during an earthquake from fixed facilities, transportation-related incidents, and pipeline distribution. Transportation corridors and pipelines can be disrupted during an earthquake, leading to the release of materials to the surrounding environment, and disrupting services well beyond the primary area of impact.

In addition to the physical characteristics of the soil and built environment, one of the most critical factors of vulnerability is low public awareness. In Rhode Island, there is little public recognition of earthquake threat, and no established system of educating or informing the public of the threat or how to prepare for or respond during an earthquake. Therefore, higher losses will occur than in other regions of the country.

5.14 Tornado

Description

A tornado is a violently rotating column of air in contact with and extending between a cloud and the surface of the earth. Winds in most tornadoes are 100 mph or less, but in the most violent and least frequent tornadoes, wind speeds can exceed 250 mph. Tornadoes typically track along the ground for a few miles or less and are less than 100 yards wide, though some can remain in contact with the earth for well over fifty miles and exceed one mile in width.

Several conditions are required for the development of tornadoes and the thunderstorm clouds with which most tornadoes are associated. Abundant low level moisture is necessary to contribute to the development of a thunderstorm, and a "trigger" (perhaps a cold front or other low level zone of converging winds) is needed to lift the moist air. Once the air begins to rise and becomes saturated, it will continue rising to great heights and produce a thunderstorm cloud, if the atmosphere is unstable. An unstable atmosphere is one where the temperature decreases rapidly with height. Finally, tornadoes usually form in areas where winds at all levels of the atmosphere are not only strong, but also turning with height in a clockwise, or veering, direction.

Tornadoes can appear as a traditional funnel shape, or in a slender rope-like form. Some have a churning, smoky look to them, while others contain "multiple vortices"—small, individual tornadoes rotating around a common center. Others may be nearly invisible, with swirling dust or debris at ground level as the only indication of the tornado's presence.

A tornado begins in a severe thunderstorm called a supercell. A supercell can last longer than a regular thunderstorm. The wind coming into the storm starts to swirl and forms a funnel. The air in the funnel spins faster and faster and creates a very low pressure area which sucks more air (and possibly objects) into it. The severe thunderstorms that produce tornadoes form where cold dry polar air meets warm moist tropical air.

The Storm Prediction Center issues tornado and severe thunderstorm watches. A tornado watch defines an area shaped like a parallelogram, where tornadoes and other kinds of severe weather are possible in the next several hours. A tornado watch does not indicate an imminent tornado; rather, a tornado watch is an advisory for citizens to be alert and prepared to go to safe shelter if tornadoes do develop or if a tornado warning is issued.

Local NWS offices are responsible for issuing tornado warnings. Tornado warnings indicate that a tornado has been spotted, or that Doppler radar detects a thunderstorm circulation capable of spawning a tornado.

Location

Nationally, the tornado season lasts from March to August, with peak tornado activity normally occurring in April, May, and June. Tornados in Rhode Island have occurred July through October with August representing the month that has the most recorded incidents. The highest concentrations of tornadoes have been in the central U.S. (in an area referred to as “Tornado Alley” composed of South Dakota, Nebraska, Kansas, Oklahoma, and Texas) and portions of the Gulf Coast states. While Rhode Island is far from Tornado Alley, tornadoes do occur in the state, and though not frequent, they may occur anytime and anywhere in Rhode Island (and the rest of New England). This situation may be more dangerous than states in

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Tornado Alley because Rhode Island residents do not expect severe tornadoes and are ill-prepared to respond to a tornado strike.

Tornadoes are considered to be low frequency, high-impact events. All areas of Rhode Island face nearly uniform susceptibility to tornadoes. The only area most susceptible, based on historical evidence would be Providence County which suffered nine (9) tornadoes between 1972 and 2012. See Table X.

Extent

The Fujita (F) scale, introduced in 1971 by Dr. Ted Fujita, provided a way to characterize tornadoes based on the damage they produced and relating that damage to the fastest quarter-mile wind at the height of a damaged structure. An Enhanced Fujita (EF) scale became operational in 2007 and improves upon the original scale by including more damage indicators, taking into account construction quality and variability, and providing a more definitive correlation between damage and wind speed (Table 62).

Table 62: Fujita Scale and Enhanced Fujita Scale

Fujita Scale			Enhanced Fujita Scale	
F Number	Fastest 1/4-mile (mph)	3-Second Gust (mph)	EF Number	3-Second Gust (mph)
0	40-72	45-78	0	65-85
1	73-112	79-117	1	86-110
2	113-157	118-161	2	111-135
3	158-207	162-209	3	136-165
4	208-260	210-261	4	166-200
5	261-318	262-317	5	Over 200

Electrical utilities and communications infrastructure are vulnerable to tornadoes. Damage to power lines or communication towers has the potential to cause power and communication outages for residents, businesses, and critical facilities. Downed wires and lightning strikes have been known to spark fires. In addition to lost revenues, downed power lines present a threat to personal safety.

A structure's tornado vulnerability is based in large part on building construction and standards. In general, mobile homes and wood-framed structures are more vulnerable to damage in a tornado than steel framed structures. Other factors, such as location, condition, and maintenance of trees play a significant role in determining vulnerability.

Human vulnerability is based on the availability, reception, and understanding of early warnings of tornadoes, such as Tornado Warning issued by the NWS, and access to shelter. In some cases, despite having access to technology (computer, radio, television, or outdoor

sirens) that allows for the reception of a warning, language differences are sometimes a barrier to full understanding of the risk. Once warned of an impending tornado hazard, seeking shelter indoors on the lowest floor of a building away from windows is recommended as the best protection against bodily harm. Table 63 gives a breakdown of injuries and fatalities by county that are the result of tornadoes since 1950.

Previous Occurrences

Twenty tornadoes have touched down in Rhode Island since 1950, with almost half impacting Providence County. Based on previous occurrence, Providence County has a slightly higher vulnerability compared to the other counties in Rhode Island. Burrillville, Lincoln, Glocester, and Cranston have experienced tornado events and are considered to be vulnerable to future events and damages. The majority of the damages ($6.7 million) has occurred within these municipalities; they are estimated to experience $107,101 in damages in any given year due to tornadoes. Warren and Bristol within Bristol County and Warwick in Kent County have experienced tornado events and are vulnerable to them in the future.

Table 63, shown below, was derived from the NOAA NCDC. Rhode Island has had 20 tornadoes since 1972 with property damages amounting to $7.28 million, the majority (over $5.2 million) resulting from an F-2 tornado in Providence County in 1986. There were 20 reported injuries due to tornadoes, with no fatalities. Figure 20, shows the locations of tornadoes in and around Rhode Island.

Table 63: NCDC Historic Tornadoes (1972-2016)

Event Date	County	Length	Width	F-Scale	Fatalities	Injuries	Property Damages (Adjusted for Inflation)
9/14/1972	Bristol County	2	33	0	0	0	$0
8/26/1985	Providence County	1	100	1	0	0	$0
8/7/1986	Providence County	0.5	100	1	0	0	$523,707
8/7/1986	Providence County	4	1000	2	0	20	$5,237,067
8/8/1986	Providence County	6	1000	1	0	0	$523,707
9/23/1989	Providence County	0.2	40	0	0	3	$462,889
10/18/1990	Kent County	4.5	73	1	0	0	$439,160
8/13/1994	Kent County	0.5	50	0	0	0	$0
8/4/1995	Washington County	0	0		0	0	$0
7/13/1996	Washington County	0	0		0	0	$0
8/29/1997	Newport County	0	0		0	0	$0
8/6/1997	Newport County	0	0		0	0	$0

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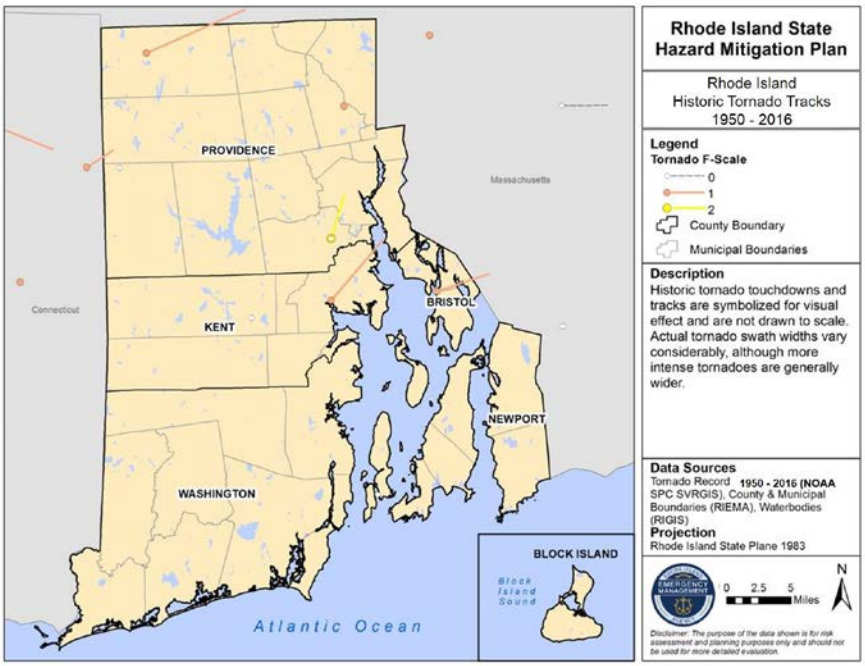
Event Date	County	Length	Width	F-Scale	Fatalities	Injuries	Property Damages (Adjusted for Inflation)
8/20/1997	Kent County	0	0		0	0	$0
8/20/1997	Providence County	0	0		0	0	$0
8/20/1997	Providence County	0	0		0	0	$0
8/20/1997	Providence County	0	0		0	0	$0
8/16/2000	Providence County	0.2	15	0	0	0	$0
8/7/2004	Kent County	0	0		0	0	$0
7/23/2008	Bristol County	3	40	1	0	0	$47,987
8/10/2012	Washington County	4	20	0	0	0	$50,000

Figure 20: Tornado touchdowns and tracks. Source: NOAA NWS NCDC



Probability of Future Events

Based on historical frequency of occurrence using NCDC data, a reasonable determination of probability of future tornado events can be made. Although relatively infrequent, tornadoes have had significant impacts on Rhode Island in the past and are likely to impact the state in the future. An examination of NCDC data suggests that on an annual basis, approximately 0.03 to 0.14 tornadoes occur in any particular Rhode Island county. The hazard ranking shown in Table 64 includes the probability of future events by county. As a whole, Rhode Island has an unlikely probability of less than one percent to have a tornado incident within the next 12 to 60 months. Table 7 provides the annualized events qualitative ranking used for determining probability of future events.

A tornado may happen anywhere in Rhode Island, given the right climatic conditions. Based on past events, as depicted in the above map, it appears that the areas at greatest risk for touchdowns run from northwestern to northeastern Rhode Island.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined tornado to be a low priority hazard in Rhode Island. As described in the profile above, tornado events within the state are unlikely within the next year to three years. Tornado events have a small to medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Probable hazard magnitude is negligible magnitude to include minor injuries, no shutdown of critical infrastructure and facilities, and scattered incidental residential and commercial structures damaged from the events. Table 64 outlines the hazard rankings for each of the hazard priority criteria related to tornadoes.

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Table 64: Tornado Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Low**
Kent County		**Small** *10% or less of the total jurisdictional boundaries*				
Newport County						
Providence County						
Washington County						

Vulnerability and Impact to People and Property

Tornadoes are high-impact, low-probability hazards whose effect is dependent on its intensity and the vulnerability of development in its path. Tornado vulnerability is based on building construction and standards, the availability of shelters or safe rooms, and advanced warning capabilities. Even well-constructed buildings are vulnerable to the effects of a stronger (generally EF-2 or higher) tornado. Due to the relatively low incidence and risk for tornado, traditional "Tornado Alley" mitigation methods such as tornado safe rooms may not be economically feasible in Rhode Island.

Vulnerability to tornadoes is dependent on the geographic extent and magnitude of the event. Damages from lower intensity tornadoes (EF-0) can range from chimney damage to uprooted shallow trees. A significant tornado (EF-2) would cause considerable damage to roofs on frame houses, complete destruction of mobile homes and large trees and utility lines snapping. A devastating tornado (EF-4) would result in well-constructed houses being leveled, weak foundations blown to a distance, and cars thrown. Mobile homes within the state are especially vulnerable.

It should be noted that the entire state population is considered uniformly vulnerable to tornadoes. The type and age of construction plays a role in the vulnerability of facilities to tornadoes. In general, concrete, brick, and steel-framed structures tend to fare better in tornadoes than older, wood-framed structures.

As evidence in property loss figures obtained from NCDC, tornadoes have the potential to be very destructive. The NCDC estimates are believed to be an underrepresentation of the actual losses experienced due to hazards, as losses from events that go unreported or that are difficult to quantify are not likely to appear in the NCDC database.

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6.0 Hazard Profile: Human-Caused Hazards

6.1 Cybersecurity Incident

Description

A cybersecurity incident is an incident that threatens the confidentiality, reliability, or accessibility of an information system or the information systems processes, which constitutes a violation of security policies or procedures, causing a direct impact on critical infrastructure and the economic vitality of Rhode Island and resources within the state. A significant cybersecurity incident will require effective incident response to minimize the disruption of services and loss of critical information, while ensuring continuity of services and security throughout the state. While cyber threats happen daily, such as the delivery of electronic junk mail clogging a personal mailbox, potentially overloading mail servers, and impacting network performance, the sophistication of these threats varies considerably. Cybersecurity threats can be classified into three distinct categories:

- **Unstructured Threat**: Constitute the vast majority of cyber-attacks on the Internet, typically conducted by single individuals or small unaffiliated groups. These attacks exploit unprotected targets with known vulnerabilities and can be completely automated, using little technical skill and sophistication.
- **Structured Threat**: Target a specific person or entity for financial gain, intellectual property, or blackmail. These attacks tend to be more organized and planned, and often rely on insider knowledge. Structured attacks include: distributed denial of service (DDoS), botnets, zero-day exploits, and social engineering tactics.
- **Highly Structured**: Although fewest in number, these attacks are conducted over long periods of time, with extreme preparation and organization. The goal of a highly structured threat is to disrupt the way of life for any given economy. These attackers use multiple methods of reconnaissance and multiple attack techniques to achieve their goal. Highly structured attackers are considered to be nation states or cyber terrorists, and may combine a physical attack with a cyber incident (such as the Stuxnet worm).

While these cybersecurity threats are different by nature, they all possess the ability to impact Rhode Island's critical infrastructure and potentially the public health of its citizens, if and when an incident occurs. Examples of risks associated with cybersecurity incidents in Rhode Island include:

- The "Internet of Things" presents unique security challenges due to the number of interconnected devices and systems present in the state. As this concept was not created with security in mind, many hackers will compromise these connections. Whether it be the healthcare industry or the energy sector, all infrastructure is vulnerable to these compromises, placing Rhode Island businesses and citizens' data and personally identifiable information (PII) at risk.

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- Cyber theft has become an increasingly lucrative business for cyber criminals. For instance, while the Target breach was not an isolated incident in Rhode Island, many Rhode Island citizens fell victim to this act of cyber theft. Cyber thieves hacked as many as 40 million accounts, stealing customer names, credit and debit card numbers, encrypted personal identification number (PIN) data, and card expiration dates, which affected as many as 110 million people. This incident highlights the financial risks posed against citizens and the economy.
- Advanced Persistent Threats (APTs) are of significant concern as hacktivists are gaining unauthorized access to computer systems as a means of carrying out various disruptive actions to achieve political or social objectives. Deploying a targeted, long-term pattern of complicated attacks, sophisticated threat actors, typically nation-states, conduct malicious network activity for purposes of cyber espionage, cyber terrorism, or cyber warfare. While this activity would be a rarity in Rhode Island, if it were to happen, such as an incident similar to Stuxnet, the risk would be detrimentally crippling to the state.

Location

The entire state is vulnerable to a cybersecurity incident. As most day-to-day activities rely on the Internet in one aspect or another, any person or infrastructure is susceptible to cybersecurity threats. For example, virtual systems, such as Supervisory Control and Data Acquisition (SCADA) systems, are used to operate critical infrastructure across the state. These systems, which provide remote monitoring and control operating with coded signals over communication channels, place any number of critical facilities at risk if the appropriate informational security safeguards are not properly implemented. The City of Providence is particularly vulnerable to cybersecurity incidents, given its status as state capital—with many state buildings, businesses, and a dense population.

Extent

As Rhode Island relies on cybersecurity networks and assets to provide security, public safety, and economic vitality, state operations depend on information systems that are maintained, protected, and secured from exploitation and attack. Although cybersecurity incidents originate in a virtual environment, the increased sophistication of attacks would have a damaging impact on physical components of critical infrastructure in the state. According to the National Institute of Standards and Technology's (NIST's) National Vulnerability Database, 6,608 new computer vulnerabilities were recorded in 2006. With an increasing rate of 11 vulnerabilities published per day, that number has more than quadrupled in 2016. As attack sophistication increases, so will vulnerabilities. For example, if Rhode Island were to experience unscheduled power outages impacting a large number of customers, such as that of the cybersecurity attack against Ukrainian critical infrastructure, the state would be incapacitated and unable to provide essential services to citizens. This incident would leave people without power, causing the inability to run water, flush a toilet, or properly operate lifesaving devices for the sick and those with special needs. These basic functions people rely upon would be inoperable if a significant cybersecurity attack were to impact Rhode Island.

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Previous Occurrences

The state has not yet experienced a large-scale cybersecurity incident. However, this should not undermine the potentially devastating impact to critical infrastructure should a significant cybersecurity incident occur. A cybersecurity incident could disable the vast majority of critical infrastructure systems, such as the power grid, traffic control systems, water and wastewater services, and communications systems.

Probability of Future Events

The resilience and sophistication of adversaries indicate that the probability of future events is significant. Although the state alone has not experienced a large scale cybersecurity incident, *USA Today* estimates that 43 percent of businesses were breached in 2015, and that number is projected to increase as threat actors increasingly target critical infrastructure as a means of compromise. By and large, due to the widespread use of electronic devices and the reliance on technology to support daily functions, impacts of a cybersecurity incident are and will continue to be significant in the future.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined a cybersecurity incident to be a moderate priority hazard in Rhode Island. Cybersecurity incidents within the state are likely to occur within the next year to three (3) years, having a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude ranges from limited to significant magnitude including some injuries, short to medium shutdown of critical infrastructure and facilities, and scattered incidental of residential and commercial structures damaged from the events. Table 65 outlines the hazard rankings for each of the hazard priority criteria related to cybersecurity incidents.

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Table 65: Cyber Incident Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County	**Likely** *10% to 100% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of some critical infrastructure and facilities*	**Negligible** *Scattered incidental of residential and commercial structures damaged*	**Moderate**
Kent County						
Newport County				**Significant** *Medium shutdown of some critical*		**High**

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
				infrastructure and facilities		
Providence County				**Limited** *Short shutdown of some critical infrastructure and facilities*		**Moderate**
Washington County						

Vulnerability and Impact to People and Property

Significant cybersecurity incidents typically target traffic pipelines or powerful servers of an information technology (IT) system. Cyber adversaries may seek to compromise their target through service disruption or manipulation, while the attack itself could use destructive worms and viruses, denial of service exploits, or intrusions to disrupt the targeted networks. An adversary can infiltrate many institutions, including banking, medical, education, government, military, and business. Actors inside or outside the asset's organization could carry out acts of sabotage on attractive targets, such as government websites and high-value networks.

Information systems are only as strong as their weakest end user. To this day, it remains difficult to continuously monitor and manage the end user vulnerability. The entire population of Rhode Island is considered to be exposed to the effects of a cybersecurity incident. All populations who directly use a computer or those receiving services from automated systems are vulnerable to cybersecurity incidents. A cybersecurity incident related to power grid failure would impact individuals with medical needs requiring power. The time of year can also play a role in the number and types of vulnerable populations. If an incident were to occur in extreme temperatures, either heat or cold, susceptible populations (e.g., infants, young children, elderly, sick, those with special needs) would be most vulnerable due to the lack of climate control.

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6.2 Chemical Incident

Description

A chemical incident has been defined as an unexpected uncontrolled release of a chemical from its containment. Chemical incidents generally occur at fixed-site facilities that manufacture, store, process, or otherwise handle hazardous materials or along transportation routes like major highways, railways, navigable waterways, and pipelines. In the majority of cases, this is an acute release, where the exposure dose is rising or is likely to rise rapidly. When the release is chronic, the exposure and dose do not rise quickly and public health measures do not have to be taken so rapidly, though the public health concern may emerge suddenly and acutely.

Generally, routes of exposure include inhalation, ingestion, and physical contact, and may lead to respiratory distress, organ failure, burns, or death. The rate of absorption via these paths is different for unlike chemicals, and is also affected by the concentration of the chemical in contact with the body (the concentration may change over time), the length of time that the chemical is in contact with the body, the air temperature, humidity, and the person's age. The severity of a chemical incident depends on the type of material released, the amount of the release, and the proximity to populations or sensitive areas like wetlands or waterways, and environmental factors such as wind velocity and direction and sunlight. The release of materials can lead to injuries or evacuation of thousands of nearby residents.

Injuries vary depending on the chemicals involved. The National Institute for Occupational Safety and Health (NIOSH) pocket guide, Material Safety Data Sheet's (MSDS), the most current Emergency Response Guidebooks (ERG), the Agency for Toxic Substances and Disease Registry (ATSDR) publications, and emergency hotlines such as the Chemical Transportation Emergency Center (CHEMTREC) offer chemical specific injury details and protective measures.

Location

The identification of hazardous sites in the local community is an important means of recognizing possible vulnerabilities to the population. The following facilities have been identified through the vulnerability assessment (Table 66).

Table 66: Identified Chemical Facilities in Rhode Island

Asset Type	Asset Name	Address	County	Jurisdiction
Chemical	Unknown Name Kent County	500 Washington St.	Kent	Coventry
Chemical	Univar	175 Terminal Rd.	Providence	Providence
Chemical	Technic, Inc.	1 Spectacle St.	Providence	Cranston
Chemical	OSAM Sylvania	1193 Broad St.	Providence	Central Falls
Chemical	Evans Plating Corp.	50 Waterman Ave.	Providence	North Providence
Chemical	Rhodes Technologies	498 Washington St.	Kent	Coventry
Chemical	HAB Tool Inc.	50 Colorado Ave.	Kent	Warwick
Chemical	Advanced Chemical Co.	Suite 131B, 131 Bellows St.	Kent	Warwick
Chemical	Metachem Resins Corp.	1505 Main St.	Kent	West Warwick
Chemical	Chemart Co.	11 New England Way	Providence	Lincoln
Chemical	Advanced Chemical Co.	Suite 105B, 105 Bellows St.	Kent	Warwick
Chemical	Mann Chemical LLC	3134 Post Rd.	Kent	Warwick
Chemical	Lincoln Fine Ingredients OilChem Inc.	50 Industrial Circle	Providence	Lincoln
Chemical	Fuji Film Electronics Materials USA Inc.	40 Circuit Dr.	Washington	North Kingstown
Chemical	Roberts Chemical Co. Inc.	258 Pine St.	Providence	Pawtucket

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Asset Type	Asset Name	Address	County	Jurisdiction
Chemical	Truex, Inc.	300 Armistice Blvd.	Providence	Pawtucket
Chemical	Technic, Inc.	300 Park East Dr.	Providence	Woonsocket

Ideally, a local inventory should be collated and kept up to date because chemical use may change frequently. For example, chemicals such as fertilizers, swimming pool disinfectants, and fireworks are only transported and stored locally at certain times of the year.

Extent

Counties with multiple chemical facilities, such as Kent and Providence, experience a greater risk of a chemical incident than other locations. However, almost every community in Rhode Island has at least one facility that stores, produces, or utilizes a hazardous material. Propane installations are located across the state and their presence increases the risk of an incident. Hundreds of thousands of hazardous material shipments move through Rhode Island annually. These shipments can occur at any time, day or night, and by means of road, rail, air and water, and often through areas with urbanized, high traffic volume routes.

Previous Occurrences

DEM has reported 513 oil spills during fiscal year (FY) 2014. The amount of oil products and oil spill debris remediated or removed from the environment during these response activities was estimated to be 3,678 gallons of oil and 1053 tons of oil spill debris.

The following is a list of many chemical incidents that have occurred in Rhode Island in the past:

- Mercury Release at Lawn Terrace Apartment Complex, Pawtucket, 2004
- Pascoag Water Supply Contamination, 1996-2002
- Tugboat Eastern Star Sinking, November 17, 2000
- Route 95 Fuel Spill, July 20, 2000
- Penn 460 Oil Spill, July 5, 2000
- North Cape Oil Spill, January 19, 1996
- World Prodigy Oil Spill, June 23, 1989

Probability of Future Events

As with responses to all types of disasters, careful planning and thorough preparedness are prerequisites for an effective response to a chemical incident. Rhode Island's first line of defense in protecting public health, safety, and welfare in an environmental emergency is the DEM. Like police and fire fighters, DEM's emergency responders are prepared to handle incidents of great variety including everything from a spill of a few gallons to a whole tanker full of petroleum, from a single abandoned drum to biological and chemical weapons. Highly trained first responders are on-call 24-hours a day, seven days a week.

Although major chemical incidents seem most threatening, it is the smaller, more routine accidents and spills that have a greater impact on humans, wildlife, economy, and

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environment. Based on hazard priority data outlined in Table 67, the likelihood of a chemical incident occurring in the next 12 to 60 months is potential, with a 1 to 10% likelihood. Some of the most common spills involve tanker trucks and railroad tankers containing gasoline, chlorine, or other industrial chemicals.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined chemical incident to be a moderate priority hazard in Rhode Island. As described in the profile above, chemical incidents within the state have the potential to occur within the next year to three (3) years. Chemical incidents have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude ranges from negligible to limited magnitude including some injuries, short shutdown of critical facilities and infrastructure, and scattered incidental residential and commercial structures damaged from the events. Table 67 outlines the hazard rankings for each of the hazard priority criteria related to chemical incidents.

Table 67: Chemical Incident Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries & Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Potential** *1% to 10% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Moderate**

Vulnerability and Impact to People and Property

Cities within Rhode Island with dense populations, particularly along major travel routes, are the most vulnerable (with an emphasis on any particularly vulnerable groups, such as infants and young children in day-care centers, children in schools, the elderly in residential facilities, hospital patients, etc.). Factors that affect vulnerability include the amount and quality of shelter, the access into and out of the site, and people's awareness of risks and response measures.

Hazardous materials are widely used in public and private facilities and farms. Numerous facilities in Rhode Island store, use, dispose, or have the capacity and infrastructure to handle hazardous materials on a regular basis; under Title III of the Emergency Planning and Community Right to Know Act, facilities that meet certain requirements must report to

federal, state, and local authorities. These facilities are commonly referred to as "Tier I" or "Tier II" facilities. There are 724 Tier II facilities located in Rhode Island.

Other fixed facilities include water and wastewater treatment facilities, pipelines, and related facilities. RIGIS natural gas transmission lines span the northern and eastern portions of the state in Providence, Bristol, and Newport counties. The Algonquin Gas Transmission pipeline, operated by Spectra Energy, transports 2.74 Billion Cubic Feet Per Day of natural gas through 1,129 miles of pipeline that connects to the Texas Eastern Transmission and Maritimes & Northeast pipelines. Algonquin Gas Transmission pipeline spans New Jersey, Connecticut, Rhode Island, and Massachusetts. Tenneco Gas Transmission is present in Providence County. Algonquin and Tenneco transmission lines total approximately 33 miles each.

Every vehicle carrying hazardous materials is at risk for an accident that could release the materials on board. The vehicles could also be used for malicious activity by their drivers or by hijackers.

The 2014 HMP identified 17 locations as chemical CIKR, including:

- Kent County Facility
- Univar
- Technic, Inc.
- OSAM Sylvania
- Evans Plating Corp.
- Rhodes Technologies
- HAB Tool Inc.
- Advanced Chemical Co.
- Metachem Resins Corp.
- Chemart Co.
- Advanced Chemical Co.
- Mann Chemical LLC
- Lincoln Fine Ingredients OilChem Inc.
- Fuji Film Electronics Materials USA Inc.
- Roberts Chemical Co. Inc.
- Truex, Inc.
- Technic, Inc.

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6.3 Terrorism

Description

Terrorism is generally classified as the use of violence and intimidation in the pursuit of political aims. Specifically, the Federal Bureau of Investigation (FBI) defines terrorism incidents as the "unlawful use of force or violence against persons or property to intimidate, or coerce a government, civilian population, or any segment thereof in the furtherance of political and social objectives."

Acts of terrorism are typically perpetrated by violent extremists. Violent extremist threats come from a range of groups and individuals, including domestic terrorists and homegrown violent extremists in the United States, as well as international terrorist groups like al-Qaeda and Islamic State of Iraq and the Levant (ISIL). Lone offenders or small groups may be radicalized to commit violence at home or attempt to travel overseas to become foreign

fighters. The use of the Internet and social media to recruit and radicalize individuals to violence means that conventional approaches are unlikely to identify and disrupt all terrorist plots.

One of the growing, and arguably most dangerous, trends in the terrorist threat is the use of Improvised Explosive Devices (IEDs). With relatively low-tech skills needed to produce them, IEDs have the potential to make a lethal impact, Specifically, IEDs have been a weapon of choice for acts of terrorism since the first World Trade Center attack in 1993 and for the Oklahoma City bombing in 1995. This threat has expanded to include both Vehicle-borne Improvised Explosive Devices (VBIEDs) and small arms attacks. These kinds of bombs have an enormous potential for influencing public perception and for creating an atmosphere of fear and uncertainty. For example, a car bomb exploding in the middle of a busy urban setting can quickly undermine emergency response efforts to protect the public. In addition, a significant trend in acts of terrorism is the execution of complex coordinated attacks by terrorist groups. Complex coordinated terrorist attacks often involve multiple attacks in different locations perpetrated by multiple individuals with IEDs and high capacity weapons.

Location

The entire State of Rhode Island is vulnerable to terrorism, particularly in densely populated urban areas or crowded venues. Specifically, the Cities of Providence (Providence County) and Newport (Newport County) may be key targets for terrorist activity due to their large tourist populations. However, it is nearly impossible to pinpoint the exact location of the next terrorist attack so all five counties in Rhode Island are vulnerable. Through information and intelligence sharing, public safety personnel at the local, state, and federal level can help identify potential targets for terrorist activity. Although it is impossible to predict for certain where the next terrorist attack will take place, terrorists generally target large, crowded places, such as malls, parks, and other large public or social gatherings, in order to maximize damage. In addition, some acts of terror are conducted against critical infrastructure in an effort to weaken or cripple services on which American daily life depends, such as transportation, communications, and electricity.

Although events such as the World Trade Center Bombing/Destruction (1993 & 2001) and Oklahoma City bombing (1995) did not occur in Rhode Island, the threat, real or implied, to employ terrorism in this state remains. Threats often involve the employment of Weapons of Mass Destruction (WMD), to include bombs, pathogens, or IEDs, and can be directed at targets in both rural and urban-industrial settings.

Extent

In the United States, acts perpetrated by violent extremists can have far-reaching consequences, including structural and infrastructure damage, mass casualty and fatality incidents, environmental harm, decreased national morale, heightened perceived risk and fear by the public, and economic impacts. Large-scale terrorist attacks such as those committed during the September 11, 2001 terrorist attacks in New York City demonstrate the significant catastrophic extent of a terrorist attack.

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Previous Occurrences

Although there has not specifically been a terrorist attack in the State of Rhode Island, this does not underestimate the significance of the threat, nor does it undermine the examples of terrorism on United States soil that have occurred. Outside the World Trade Center attacks in 1993 and 2001 and the Oklahoma City bombing, which have already been discussed, the recent terrorist attacks at the Boston Marathon and in Paris, San Bernardino, and most recently, Orlando, demonstrate the realistic and terrifying consequences of terrorist attacks. While these events all occurred in large, populated areas, the venues, times, and locations of the attacks differ. In addition, there have been no federal declarations directly referred to as terrorism in the past; however, the response to the efforts outlined above required extensive coordination and communication on behalf of the responders, to include extensive logistics and resource support, as well as financial ramifications.

Probability of Future Events

Although it is difficult to precisely predict when and where the next terrorist attack will be, the intelligence community across the local, state, and federal levels is continually gathering information to prevent future events from occurring. Heightened tensions in the Middle East and increased traction by ISIL have heightened the risk of additional terrorist attacks from occurring. Therefore, countering violent extremism has become a key focus of the work of the Department of Homeland Security (DHS) in securing the homeland. Countering violent extremism efforts aim to address the root causes of violent extremism by providing resources to communities to build and sustain local prevention efforts and promote the use of counter-narratives to confront violent extremist messaging online. Building relationships based on trust with communities is essential to this effort. Based on hazard priority data, the likelihood of a chemical incident occurring in the next 12 to 60 months is potential, with a 1 to 10% likelihood.

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Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined terrorism to be a moderate priority hazard in Rhode Island. As described in the profile above, terrorist events within the state have the potential to occur within the next year to three (3) years. Terrorist events have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Hazard magnitude is considered to have limited magnitude including some injuries, short shutdown of critical facilities and infrastructure, and less than 10 percent of residential and commercial structures damaged from the events. Table 68 outlines the hazard rankings for each of the hazard priority criteria related to terrorism.

Table 68: Terrorism Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Potential** *1% to 10% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Limited** *Less than 10% of residential and commercial structures damaged*	**Moderate**

Vulnerability and Impact to People and Property

Rhode Island is vulnerable both to attacks on the jurisdictions within the state and to the residual effects of an attack on surrounding states and metropolitan areas. A WMD attack could kill and injure hundreds to thousands of people, which could overwhelm hospitals in the five counties and the surrounding areas. Because they are so difficult to anticipate and detect, nearly every type of structure is vulnerable to a conventional bomb. Some structures are more likely to be targets of IEDs than others, such as buildings with great political or economic importance.

Bombs can be made of almost anything, so it is relatively easy to obtain the materials necessary to construct an IED. Ammonium nitrate, fuel oil (ANFO) is a typical fertilizer-based explosive, which is readily available in rural areas. DHS proposed legislation to control the sale and transfer of ANFO from production facilities. Petroleum products, such as gas and oil, are available essentially anywhere and can also be used as explosives.

Terrorist activities include bombings, kidnappings, shootings, and hijackings. Eighty percent of terrorist activity is perpetrated through the use of explosives, and the other 20 percent is a combination of arson, vandalism, and assassination. The actual use of terrorist chemical, nuclear, and biological weapons has occurred less than a handful of times in the last 50 years. The common kinds of terrorist situations (explosions, fires, vandalism, and shootings) are the same kind of critical incidents first responders handle on a daily basis. Terrorist activity can be conducted by an active shooter, an individual actively engaging in killing or attempting to kill people in a confined and populated area using a firearm. Targets of an armed attack vary; however, in recent history, schools, office buildings, federal/state-owned buildings, religious institutions, military installations, and large public areas have all been subject to armed attacks. An active shooter may be a disgruntled student or group of students, an employee, or an anti-government/anti-political/extremist citizen or group.

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6.4 Biological Incident

Description

A biological incident includes naturally occurring biological diseases (communicable and non-communicable) in humans as well as terrorist events. Biological agents are organisms or toxins that can kill or incapacitate people, livestock, and crops. A biological attack is the deliberate release of germs or other biological substances that can make a person sick. This definition also includes biological agents found in the environment or diagnosed in animals, which have the potential for transmission to humans (zoonosis).

Location

Bristol, Kent, Newport, Providence and Washington are all vulnerable to biological incidents. However, as with most manmade hazards, areas of higher human movement and urban areas are at greater risk.

Extent

The three basic groups of biological agents that would likely be used as weapons are bacteria, viruses, and toxins. Most biological agents are difficult to grow and maintain. Many break down quickly when exposed to sunlight and other environmental factors, while others, such as anthrax spores, are very long lived. Biological agents can be dispersed by spraying them into the air, by infecting animals that carry the disease to humans, and by contaminating food and water. Delivery methods include:

- Aerosols: Biological agents are dispersed into the air, forming a fine mist that may drift for miles. Inhaling the agent may cause disease in people or animals.
- Animals: Some diseases are spread by insects and animals, such as fleas, mice, flies, mosquitoes, and livestock.
- Food and water contamination: Some pathogenic organisms and toxins may persist in food and water supplies. Most microbes can be killed and toxins deactivated by cooking food and boiling water. Most microbes are killed by boiling water for one minute, longer at higher altitudes.
- Person-to-person: The spread of a few infectious agents is also possible. Humans have been the source of infection for smallpox, plague, and the Lassa viruses.

Diseases that cause widespread human deaths would have an impact on the environment in terms of the disposal of human remains and the handling of bio-hazardous waste. Environmental and regulatory factors would have to be evaluated. Diseases that cause the widespread death of animals, both captive and wild, would have an effect on the environment in terms of disposal of the carcasses. Whether the infected animals are buried, burned or left in place, a large quantity and concentration of carcasses may impact air, soil, and groundwater.

In a biological incident, federal, state, tribal, territorial, and local officials require a highly coordinated response to public health and medical emergencies. A biological incident may

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also affect other countries, or be of international concern, and therefore involve extensive coordination with DOS and the international health community, such as notification to the World Health Organization (WHO) and other international health organizations under the International Health Regulations (IHR). The introduction of biological agents, both natural and deliberate, is often first detected through clinical or hospital presentation. However, there are other methods of detection, including environmental surveillance technologies, such as BioWatch, and medical and syndromic surveillance systems. Early detection of biological agents offers an opportunity to take proactive measures to mitigate the consequences of disease outbreak.

Previous Occurrences

There has not been a significant example of a human-caused biological incident in the State of Rhode Island. Globally, however, bad actors are using biological agents, such as nerve gas or weaponized disease, as a means of warfare. Although it is unlikely (se Probability of Future Events below) that such an instance would occur in the United States, the use of biological agents provides a viable case study about the potential impacts of this hazard.

For more information on natural epidemiological hazards, see the Epidemic section.

Probability of Future Events

Although no major biological incident has occurred within Rhode Island, the ease of foreign travel and other factors increase the risk of a biological incident at any time. There is an unlikely probability of an incident to occur within the next 12-60 months based on the hazard analysis (Table 69).

To ensure the safety of residents and quickly identify and control any biological incident, the Center for Biological Sciences within the RIDOH provides biological testing to ensure the safety of the residents in Rhode Island. Testing services include microbiological testing to assess the safety of the state's food supply. The Center for Biological Sciences laboratories also include the Biomonitoring Laboratory, which follows CDC procedures to test human specimens for the presence of environmental toxic substances, such as lead or mercury, and obtain a more accurate assessment of population exposure to environmental chemicals. The Bioterrorism Response and Special Pathogens Laboratory continues to prepare clinical microbiology laboratories throughout the state to respond rapidly to a large-infectious disease outbreak. The Bioterrorism Response Program is prepared to test clinical specimens and analyze suspicious environmental powders and other evidence for potential agents of bioterrorism.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined biological incidents to be a low priority hazard in Rhode Island. As described in the profile above, biological incidents within the state are unlikely within the next year to three (3) years.

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Biological incidents have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude for biological incidents ranges from negligible to limited magnitude including some injuries, short shutdown of critical infrastructure and facilities, and scattered incidental residential and commercial structures damaged from the events. Table 69 outlines the hazard rankings for each of the hazard priority criteria related to biological incident.

Table 69: Biological Incident Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries & Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Limited** *Some injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Low**

Vulnerability and Impact to People and Property

The entire State of Rhode Island's population is vulnerable to the effects of a biological incident. Vulnerability and impact are similar to what has been outlined in the natural hazard, epidemic, and human-caused, chemical incident, profiles. Areas with dense populations will have a higher exposure to biological incidents, such as contagious diseases. Vulnerable populations including young and elderly are considered at higher risk.

Structures and infrastructure, as shown in the hazard priority, will not be impacted by a biological incident. The economy could be significantly impacted from a biological incident and result in economic impacts due to workforce absenteeism, decreased revenue from tourism, and potential trade losses. In addition, an increase in hospitalization and emergency room visits will take place as a result of the incident, creating greater demand on critical facilities, staff, and resources.

The type of biological incident will determine the severity of the effect on the environment. Diseases that cause widespread human deaths would have an impact on the environment in terms of the disposal of human remains and the handling of bio-hazardous waste. Environmental and regulatory factors would have to be evaluated in the disposal of both human remains and bio-hazardous waste. Diseases that cause widespread deaths of animals, both captive and wild, would have an effect on the environment in terms of disposal of the carcasses. Whether the infected animals are buried, burned, or left in place, a large quantity and concentration of carcasses may impact air, soil, and groundwater.

A contagious biological attack is an attack on a population using a communicable, infectious disease. Effects occur after an incubation period which varies with the biological strain in

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use. They can quickly infect large populations. Bioterrorism can cause mass panic and societal disruption.

6.5 Radiological Incident

Description

A radiological incident can be defined as the uncontrolled release of radioactive material that can harm people or damage the environment. Radiological incidents typically involve nuclear assemblies, research, production, or power reactors and chemical operators. Although all of these sites do not exist within Rhode Island boundaries, sites within neighboring states place the population of Rhode Island potentially in harm's way following an incident.

Following the accident at Three Mile Island in Pennsylvania in 1979, President Carter, through Presidential Executive Order 12148, transferred the lead role for offsite emergency planning and preparedness activities from the Nuclear Regulatory Commission (NRC) to FEMA. While the NRC has jurisdiction within the plant boundaries, FEMA is responsible for ensuring the health and safety of residents living and working in the emergency planning zone outside the plant.

Location

Although Rhode Island does not have any commercial nuclear power plants within its borders, it does fall within the 50-mile Ingestion Exposure Pathway for two nuclear power plants: Millstone Power Station in Waterford, Connecticut, and Pilgrim Nuclear Power Station in Plymouth, Massachusetts. Table 70 shows specific municipality proximity to each of these plants.

The State of Rhode Island's Radiological Emergency Response Plan for the Ingestion Exposure Pathway is a plan to protect the residents and livestock in the state. Predetermined protective action plans are in place to avoid and reduce the potential of ingesting radioactive materials throughout the state.

Extent

A wide-range of possible events that can occur during reactor operations have been analyzed. The impacts on the off-site public range from benign to severe. A nuclear power plant accident can be expected, in the worst-case analysis, to result in a large release of radioactive isotopes into the environment and this release will have a significant impact.

Rhode Island farmers, livestock owners, fruit and vegetable growers, food processors, sod producers, fisherman, or food distributors that are within 50 miles of a Connecticut or Massachusetts nuclear power plant, may be required to protect the food or water supplies in the event of radioactive contamination.

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The chart below identifies municipalities in Rhode Island that are within 50 miles of neighboring state nuclear power plants:

Table 70: Rhode Island Municipalities Nuclear Power Plant Range

Town	Millstone (CT)	Pilgrim (MA)	Town	Millstone (CT)	Pilgrim (MA)
Barrington		X	Newport	X	X
Bristol		X	New Shoreham	X	
Burrillville	X		N. Kingstown	X	X
Central Falls		X	N. Providence		X
Charlestown	X		N. Smithfield		X
Coventry	X		Pawtucket		X
Cranston	X	X	Portsmouth	X	X
Cumberland		X	Providence	X	X
E. Greenwich	X	X	Richmond	X	
E. Providence		X	Scituate	X	
Exeter	X		Smithfield	X	X
Foster	X		S. Kingstown	X	
Glocester	X		Tiverton		X
Hopkinton	X		Warren		X
Jamestown	X	X	Warwick	X	X
Johnston	X	X	Westerly	X	
Lincoln		X	W. Greenwich	X	
Little Compton		X	W. Warwick	X	
Middletown	X	X	Woonsocket		X
Narragansett	X				

Note: X indicates which towns are within the 50-mile Ingestion Pathway Zone for each plant.

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Previous Occurrences

Previous incidents have long-term effects that require years, even decades, of cleanup efforts. Depending on the severity of the incident, areas affected could take decades or even centuries to fully recover. Some may be irreparably altered by the incidents. While no such incidents have occurred at either location during a 15-year period, vulnerabilities with one plant leads to a significant probably of a future radiological event.

Pilgrim has a Mark 1 General Electric (G.E.) Boiling Water reactor that has been in use for several decades. This design was the same as that of Fukushima, which melted down in 2011 causing massive environmental, human, and economic damage in Japan. Should a similar geological event such as Fukushima occur at Pilgrim Nuclear Power Station, it is likely that a high-impact radiological event could occur. While this is a high-impact event, it is also a low probability occurrence as recent reports have confirmed that Pilgrim will be shutting down permanently in 2019, thus reducing the risk to zero.

Probability of Future Events

Millstone Power Station has had periodic shutdown of its Unit 2 and Unit 3 reactors, with its Unit 1 reactor permanently shut down in 1998. The reactor design is a pressurized water reactor with inherent risks of degradation cascading into a potential melt-down event. This would be a high-impact event, as a melt-down could potentially cause significant immediate and long-term damage to the environment and surrounding area. This has an unlikely probability occurrence, as Millstone has only had minor malfunctions that have led to shutdowns for extended periods. Based on this analysis, there is an unlikely probability of an incident occurring within the next 12-60 months.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined radiological incidents to be a low priority hazard in Rhode Island. As described in the profile above, radiological incidents within the state are unlikely within the next year to three (3) years. Radiological incidents have a small range of impact, accounting for less than 10 percent of the jurisdictional boundaries. Probable hazard magnitude ranges from negligible to limited magnitude including minor injuries, short shutdown of critical infrastructure and facilities, and scattered incidental residential and commercial structures damaged from the events. Table 71 outlines the hazard rankings for each of the hazard priority criteria related to radiological incidents.

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Table 71: Radiological Incident Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries & Deaths	*Infrastructure*	*Structures*	
Bristol County	**Unlikely** *Less than 1% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Low**
Kent County						
Newport County						
Providence County						
Washington County						

Vulnerability and Impact to People and Property

Vulnerability and impact for a radiological incident is similar to what has been outlined in the human-caused chemical incident profile. The release of a hazardous material to the environment could cause a multitude of problems. Although these incidents can happen almost anywhere, certain areas of the state are at higher risk, such as roadways that are frequently used for transporting hazardous materials and locations with industrial facilities that use, store, or dispose of such materials. Areas crossed by railways, waterways, airways, and pipelines also have increased potential for mishaps. Hazards can occur during production, storage, transportation, use, or disposal. Communities can be at risk if a chemical is used unsafely or released in harmful amounts into the environment. Hazardous materials can cause death, serious injury, long-lasting health effects, and damage to buildings, the environment, homes, and other property.

The potential danger from an accident at a nuclear power plant is exposure to radiation. This exposure could come from the release of radioactive material from the plant into the environment, usually characterized by a plume (cloud-like) formation. The size of the area affected is determined by the amount of radioactive material released from the plant, wind direction and speed, and weather conditions, which would quickly drive the radioactive material to the ground, causing increased deposition of radionuclides. Contamination could affect areas up to 50 miles from the accident site. Although construction and operation of nuclear power plants is closely monitored and regulated by the NRC, an accident, though unlikely, is possible.

The NRC defines two emergency planning zones around nuclear power plants: a plume exposure pathway zone with a radius of 10 miles (16 km), concerned primarily with exposure to, and inhalation of, airborne radioactive contamination, and an ingestion pathway zone of about 50 miles (80 km), concerned primarily with ingestion of food and liquid contaminated by radioactivity. As described above, Rhode Island is within the 50-mile Ingestion Exposure Pathway of two nuclear power plants: Millstone Power Station in Waterford, Connecticut, and Pilgrim Nuclear Power Station in Plymouth, Massachusetts. Table 70 provides a summary of the municipalities located with the ingestion pathway for each plant. Eleven municipalities are located within both of the 50-mile ingestion pathways.

Millstone Power Station, Unit 2 is operated by Dominion Nuclear Connecticut, Inc. The facilities are pressurized water reactors with Combustion Engineering reactor vendor/type. The facility was licensed in 1975 and renewed in 2005. Millstone Power Station, Unit 3 is also operated by Dominion Nuclear Connecticut, Inc. The facilities are pressurized water reactors with Westinghouse Four-Loop reactor vendor/type. The facility was licensed in 1986 and renewed in 2005. Pilgrim Nuclear Power Station is operated by Entergy Nuclear Operations Inc. The facilities are boiling water reactors with G.E. Type 3 reactor vendor/type. The facility was licensed in 1972 and renewed in 2012.

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The effects of a radiological incident may cause death and injury to persons, and damage and destruction to property and the environment. Several factors affect the severity of hazardous materials events including the quantity of the materials released, toxicity of the materials released, and the weather during a release, such as wind and rain, which may readily transport the hazardous material. Hazardous materials may have one of more of the following properties including: corrosive, oxidizing, explosive, radioactive, infectious, flammable, reactive, or poisonous (including carcinogens). Based on these properties, a hazardous material release can have significant impact on the environment; resulting in, but not limited to, water quality issues, cause of wildlife, and ground contamination.

6.6 Civil Unrest

Description

Civil unrest is defined as any public disturbance involving acts of violence by assemblages that cause an immediate danger of or results in damage or injury to the property or person of any other individual.

Civil unrest can include any variety of actions such as strikes, civil disobedience, demonstrations, riots, and rebellion. These disturbances arise from acts of civil disobedience, often spontaneous, involving an agitated group of people, generally caused by political grievances, social justice conflicts, or a decrease in the supply of essential goods and services. In addition, instances of civil unrest are often a form of protest, arising from highly emotional social and economic issues such as trade issues, and ideas of rights and liberties.

Location

Because of their often spontaneous nature, it is difficult to specifically pinpoint a location for the occurrence of civil unrest. However, monitoring social trends can often inform responders where potential demonstrations may take place. In addition, information gathered in advance may warn officials and provide locations of future civil unrest. Oftentimes, demonstrations and large crowded gatherings begin peacefully and then escalate to instances of violent civil unrest.

Instances of civil unrest may originate from a political rally, university football game celebration getting out of control, or demonstrations by protestors. Civil unrest is typically seen in large urban areas; therefore, Providence (in Providence County) is the most likely area for this hazard to occur. In addition, with Rhode Island's relative proximity to both Boston and New York City, areas of Rhode Island may be targets of civil unrest.

Extent

Civil unrest severity depends on the nature of the disturbance. Significant incidents of unrest can result in mass arrests, civilian curfews, intensive response efforts, property damage cost, injury, and death. In general, civil unrest can range from low, medium, to high impacts associated with the severity of the hazard of the instance of civil unrest.

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Police dispatched to control traffic corridors or intrusion on private property is considered a low severity civil disturbance. Disruption of businesses and potentially, property damage, are assessed as a moderate civil disturbance. In these cases, police intervention would be required to restore order without employing chemical agents or physical force. A severe civil disturbance would involve rioting, arson, looting, assault, and death, where aggressive police action (tear gas, curfews, and mass arrests) may be required.

Previous Occurrences

There have been multiple recent examples of civil unrest across the United States. The riots in Baltimore, Maryland (2016); Ferguson, Missouri (2014); and Dallas, Texas (2016), are key examples of civil unrest that included significant instances of violence, looting, and property damage. Specifically, in Rhode Island, demonstrations as part of the Occupy Wall Street and Black Lives Matter movements have impacted local response efforts. In fact, in late 2014, significant protests and demonstrations led to shutdowns on I-95 outside of Providence as protestors flooded the roadway.

An extreme example of civil unrest is the 1992 Los Angeles riots that unleashed seven days of violence, $1 billion in property damage, and left fifty people dead. Such an example indicates the possible magnitude of destruction caused by civil unrest.

Probability of Future Events

It can be reasonably assumed that civil unrest will continue to occur in the future, but these events are usually difficult to predict. However, hazard analysis indicates that there is about a 1-10% potential for a civil unrest event to occur within the next 12-60 months. Some forms of civil unrest are potentially anticipated; for example, following race riots that erupted after certain legal verdicts, ensuing civil unrest could have been predicted. It is fair to say that in many instances, there is some amount of reasonable warning available to help prepare for civil unrest.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined civil unrest to be a low priority hazard in Rhode Island. As described in the profile above, civil unrest within the state has potential to occur within the next year to three (3) years. Civil unrest events have a small range of impact, accounting for 10 percent or less of the jurisdictional boundaries. Probable hazard magnitude is considered to have negligible magnitude including minor injuries, no shutdown of critical facilities and infrastructure, and scattered incidental residential and commercial structures damaged from the events. Table 72 outlines the hazard rankings for each of the hazard priority criteria related to civil unrest.

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Table 72: Civil Unrest Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries and Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Potential** *1% to 10% probability within next 12-60 months*	**Small** *10% or less of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Negligible** *No shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Low**

Vulnerability and Impact to People and Property

Public demonstrations have the potential to lead to looting and rioting. There are many potential causes for civil unrest including: animal rights, labor disputes, civil rights, campus related issues, abortion rights, neighboring jurisdictions, political issues, events (sports, music, etc.), and spontaneous miscellaneous events. Potential consequences from acts of civil unrest include: disruptions of police and community services, closure of roads, rioting, property damage, and injuries to protesters, police officers, and uninvolved parties.

The entire population of Rhode Island is considered to be vulnerable to civil unrest. Densely populated areas may have a higher exposure to the effects of civil unrest. State-owned facilities are often target of civil disturbances and are vulnerable to the effects of these incidents. The City of Providence, given the concentration of state buildings, population density, and its role as the state capital, is particularly vulnerable to civil unrest. Facilities exposed to civil unrest may include:

- Colleges and Universities
- Correctional Facilities
- State Facilities

Civil unrest usually occurs at a special event, near a critical facility, or outside a prominent business; however, these events can escalate and spread out over streets or spark similar events in other areas. Events can be small or large depending on the population and demographics of the area.

A severe civil disturbance where emotionally-charged and highly contentious business, police, or political action engenders the outrage of a certain segment of the population could be considered high severity. A localized event that results in the damage to property, police action, and some physical harm to the people involved, such as police or protestors, may be considered moderately severe. A low severity rating may be given to a localized event that results in minimal to no property damage, no police action, and no physical harm to the participants, bystanders, or police.

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Civil disturbances are more likely to occur when large groups of people are congregated together at localized events. Special events that take place in Rhode Island could be at risk to a civil disturbance or terrorist attack due to their ability to draw large crowds, including:

- Newport St Patrick's Day Parade – 50,000 people
- Rhode Island National Guard Open House Air Show – 50,000-100,000 people
- Bristol 4th of July Parade – 100,000 people
- Autumnfest Woonsocket – 15,000 people
- Scituate Art Festival – 35,000 people
- Volvo Ocean Race Classic – 50,000-100,000 people

In addition to the special events above, activities held at the following venues may be vulnerable to civil unrest:

- Educational events at Rhode Island Convention Center, University of Rhode Island, Roger Williams University, and Brown University
- Venues and performances at The Stadium Theater, Courthouse Center for the Arts, Blackstone River Theatre, Twin River Casino, Ocean State Theatre, Spring Community Center, Dunkin Donuts Center, Providence Art Club, Jamestown Arts Center, and McCoy Stadium

This list is not exhaustive, but these events have been identified because of their attendance, area impacted, or national significance.

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7.0 Hazard Profile: Technological Hazards

7.1 Infrastructure Failure

Infrastructure failure refers to any significant disruption to critical infrastructure that could have cascading effects that negatively impact on Rhode Island's security, public health and safety, and economic vitality every day. Rhode Islanders know it as the power they use in their homes, the water they drink, the transportation that moves them, the stores they shop in, the bridges that connect them, and the communication systems they rely on to stay in touch with friends and family. More broadly, critical infrastructure refers to the assets, systems, and networks, whether physical or virtual, so vital that their incapacitation or destruction would have a debilitating effect on Rhode Island's way of life.

Critical infrastructure is increasingly at risk from a variety of hazards—including climate change and extreme weather, aging and failing infrastructure components, cybersecurity threats, pandemics, and acts of terrorism. These threats have evolved over the years, presenting ever-changing challenges. In particular, physical and cyber infrastructure have grown inextricably linked, requiring the implementation of cyber and physical measures to guard against the full array of threats. Furthermore, growing interdependencies between infrastructure sectors and the lifeline functions Rhode Island relies upon increases the possibility of cascading effects if a single sector is disrupted or compromised. Understanding and mitigating these risks is a key element of the state's security, resilience, and economic prosperity.

Though there are 16 infrastructure sectors whose resources and assets are extremely important to the safety, security, and economic well-being of Rhode Island, there are six sectors that Rhode Island designates as "Lifeline" sectors. Lifeline sectors are essentially those sectors that are key foundational elements of Rhode Island's infrastructure that provide the ability to remain resilient to the myriad of threats and hazards that could potentially impact the state each year. In line with the National Infrastructure Advisory Council's (NIAC) recommendations to the President, Rhode Island considers the Transportation, Communications, Water/Wastewater, and Energy Sectors as lifelines to resilience. In addition, Rhode Island has adopted the Information Technology Sector and the Emergency Services Sector as two additional Lifeline sectors. Ensuring the survivability of these sectors enables Rhode Island to resist or quickly recover from the impacts of catastrophic events. These Lifeline sectors impact almost every aspect of their daily lives, not to mention the interdependencies they have on all other sectors. Identifying our potential threats, clearly understanding their potential impacts and cascading effects, and working to mitigate those consequences is key prescription toward ensuring Rhode Island's wellbeing. The Lifeline sectors Rhode Island has identified as essential are outlined in detail in Table 73 below:

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Table 73: Lifeline Sectors Impacted by Infrastructure Failure

Lifeline	Description	Impacts
Communications	The communications sector includes any services that enable both routine and emergency communications, such as cell towers, phone lines, dispatch systems, radio infrastructure, and satellite communications.	The communications sector is an integral component of the underlying operations of all businesses, public safety organizations, and government. Communications (e.g., phone, cable, Internet) infrastructure can also be affected through loss of power to system components or direct physical damage to system components caused by natural disaster or intentional acts.
Emergency Services	The emergency services, which include police, fire, emergency management, public works, and emergency medical services life line sectors, provide support to the public during daily response operations. The emergency services sector represents the first line of defense in the prevention and mitigation of risk from hazards such as terrorist attacks, manmade incidents, and natural disasters. In addition, the emergency services sector has a myriad of specialized capabilities such as hazardous materials response, search and rescue, and tactical teams.	Disruption of emergency services could inhibit response, which could have cascading impacts to include serious injury or death to those who do not receive emergency services.
Energy	The energy sector provides power to the community, public and private sectors, government, and first responders. The energy sector is divided into three interrelated segments: electricity, oil, and natural gas.	This life line sector is uniquely critical because it provides and enables the functionality of all infrastructure sectors. For example, the energy sector supplies fuels to the transportation industry, electricity to households and businesses, and other sources of energy that are integral to growth and production across the nation. Power outage, the most common type of failure, can result in negative sequential patterning to the environment and lifestyle: it can cause an overabundance of carbon monoxide due to the use of generators, grills, and similar items during an outage; spoiling of food; compromised water purification

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Lifeline	Description	Impacts
		systems resulting in water that may be unsafe to drink; loss of heating/air conditioning, resulting in vulnerability to extreme heat and cold; electric shock resulting from damaged power lines and power surges when electricity is restored. Power outages can also result from other natural and man-made disasters, including earthquakes, transportation accidents, and major structural collapses. Power outages can be particularly dangerous for critical facilities, such as hospitals. Many vaccinations must be refrigerated, and a power outage could severely deplete the supply of certain vaccines in the affected area. Depending on the scale of the power outage, power may not be restored for some time. If a power outage occurs during extreme cold, water heaters, plumbing systems, and heating and cooling systems may be susceptible to damage due to freezing. If a power outage occurs during flooding such that electrical equipment and appliances are submerged, electric shock may occur.
Information Technology	The information technology sector includes all system networks, hardware, software, information technology systems and services, and the Internet.	The information technology sector is central to security, economy, and public health and safety as businesses, governments, academia, and private citizens in the State of Rhode Island are increasingly dependent upon technological functions for communications and operations.

Lifeline	Description	Impacts
Transportation Systems	Transportation incidents include a large-scale crash, collision, or incident involving the disruption of an air, land (road), rail, or marine mode of transportation. The State of Rhode Island is home to major highways, airports, railroads and marine ports.	Transportation incidents become critical when they negatively impact or affect critical infrastructure dependent on transportation systems for operations. These can include: transportation and energy systems, defense installations, banking and financial assets, water supplies, chemical plants, food and agricultural resources, police and fire departments, hospitals and public health systems, and government offices.
Water and Wastewater Systems	The water and wastewater sector ensure the provision of clean water and the treatment of all water and wastewater for the state. Safe drinking water is a prerequisite for protecting public health and all human activity and properly treated wastewater is vital for preventing disease and protecting the environment.	Water distribution can be affected in three ways: the amount of water available; the quality of the water; and the viability of the physical components of the distribution systems. Contamination of the water supply can occur naturally, as a result of human error, or intentionally. Occasionally, the release of agricultural run-off, manure or other farming byproducts can contaminate water. Accidents resulting in hazardous material spills can also adversely affect groundwater. Disruption to the distribution system can occur because of loss of power to pumping and treatment stations; it can also be caused by direct physical damage to pumping and treatment stations caused either by natural disaster or intentional acts.

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Location

Critical infrastructure in each of these sectors is located throughout the state. Rhode Island is home to communications infrastructure for multiple phone and telecommunications companies, energy facilities, major highways, airports, and water and wastewater facilities. Predicting the precise location of the next infrastructure failure is often difficult and generally dependent on the quality, upkeep, and maintenance of each piece of infrastructure as well as any protective actions that can mitigate or prevent acts of terrorism or cyber-attacks.

Extent

As a whole, the failure of any one of these infrastructure systems could have potentially devastating impacts, including significant disruption to essential life, economic and financial impacts, and physical damage to infrastructure. The reliance of virtually all industries on electric power and fuels from the energy sector is of key importance. A significant event could have cascading effects on other infrastructure sectors' ability to operate.

In addition, the information technology sector's complex and dynamic environment makes identifying threats and assessing vulnerabilities difficult and requires that these tasks be addressed in a collaborative and creative fashion. Although information technology infrastructure has a certain level of inherent resilience, its interdependent and interconnected architecture presents vulnerabilities as well as opportunities for coordinating public and private sector preparedness and protection activities.

Previous Occurrences

Oftentimes, smaller scale infrastructure failures occur as a secondary impact from a natural disaster, such as a temporary power outage due to a thunderstorm or a communications outage from downed lines following a hurricane. Rhode Island experiences these minor disruptions routinely and manages them with ease through coordination across agencies and with the private sector. Specifically, when utility and/or infrastructure failure does occur, utility providers generally respond quickly to restore service. However, depending on the cause of the utility disruption, events of prolonged outages do occur.

Probability of Future Events

In general, the state has not experienced any direct, prolonged catastrophic infrastructure failures. However, a significant failure of any of these life line sectors could result in severe disruptions to public life and overall response efforts. In addition, there are strong indications that the potential threat of a large-scale infrastructure failure is becoming more probable due to the extent of sector interdependencies. In addition, cyber-attacks against critical infrastructure sectors have increased significantly and could cause major disruptions. Overall, the State of Rhode Island is vulnerable to infrastructure failure and it has the potential (one percent to 10 percent probability) of occurring within the next 12 to 60 months.

Vulnerability and Risk Assessment

Hazard Ranking

The priority hazard ranking process for the 2016 HIRA update determined infrastructure failure to be a moderate priority hazard in Rhode Island. As described in the profile above, infrastructure failure within the state has the potential of occurring within the next year to three (3) years. Infrastructure failure has a medium range of impact, accounting for 10 to 40 percent of the jurisdictional boundaries. Probable hazard magnitude ranges from negligible to limited magnitude to include minor injuries, short shutdown of critical infrastructure and

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facilities, and scattered incidental residential and commercial structures damaged from the events. Table 74 outlines the hazard rankings for each of the hazard priority criteria related to infrastructure failure.

Table 74: Infrastructure Failure Hazard Priority

Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			Composite Hazard Index
			Injuries & Deaths	*Infrastructure*	*Structures*	
Bristol County Kent County Newport County Providence County Washington County	**Potential** *1% to 10% probability within next 12-60 months*	**Medium** *10% to 40% of the total jurisdictional boundaries*	**Negligible** *Minor injuries*	**Limited** *Short shutdown of critical infrastructure and facilities*	**Negligible** *Scattered incidental residential and commercial structures damaged*	**Moderate**

Vulnerability and Impact to People and Property

Infrastructure failures are considered to be a form of lifeline system failure. This can be the consequence of any of the other hazards identified or as a primary hazard, without an outside trigger. A failure could involve potable water system, power system, natural gas system, wastewater system, communication system, or transportation system.

Damaged or destroyed utility lines and facilities—including electricity, computer and satellite links, gas sewer, and water services—can cripple a region after a disaster. Power lines are often badly damaged or destroyed, resulting in the loss of power for days, weeks or even months. This is particularly critical considering modern societies' dependence on electricity. Without electricity, basic modern household appliances will not operate; public water supplies, water treatment and sewage facilities will not operate. Damaged or destroyed utility lines can result in a compromised water delivery system. Elevated water tanks may be damaged during a disaster event resulting in compromised safe drinking water. During disasters, citizens may be advised to boil water to eliminate waterborne pathogens introduced to the supply in breached areas.

Thunderstorms and other severe weather events are the primary causes of power outages in Rhode Island. Lightning and high winds in the summer, and ice and snow in the winter, can disrupt service to all or part of the counties. Other causes of power outages include falling tree limbs, vehicular accidents, and small animals that destroy wiring. When power outages occur, they are typically on a regional scale.

There are approximately 264.17 miles of electrical transmission lines in Rhode Island. Many energy suppliers are authorized to sell energy in Rhode Island; National Grid maintains listings of companies registered with the Division of Public Utilities and Carriers. As described in Chemical Incident, natural gas is supplied by Algonquin Gas Transmission and

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Tenneco Gas Transmission. There are a number of communications providers in Rhode Island including Verizon, Cox, Comcast, and DISH.

As the population of Rhode Island grows and traffic congestion worsens, the number of automobile accidents is likely to increase, along with automobile-related fatalities. More car accidents lead to traffic delays, resulting in economic losses to commuters and employers. Depending on the size and duration of an incident, major or minor traffic flow disruptions can cause delays for commuters. Depending on the length of an interstate shutdown, notification to neighboring states may be required. Rhode Island is also vulnerable to traffic accidents because of the frequency of severe weather incidents, which create dangerous road conditions.

Every year, bridges throughout the nation are inspected and rated based on three components: the deck (riding surface), the superstructure (main supporting element of the deck), and the substructure (supports to hold up the superstructure and deck). If any of the three elements receive a score of 4 or less out of 9, the bridge is rated "structurally deficient" by federal standards. Though a structurally deficient rating does not mean that a bridge is in danger of collapse, it does serve as an early warning sign that the bridge is in need of repairs. There are 1,162 bridges in Rhode Island, of which 22 percent are rated as structurally deficient by the Federal Highway Administration (FHWA).

Aviation accidents may be caused by problems originating from mechanical difficulties, pilot error, or acts of terrorism. Airplane accidents can result from major aircraft experiencing trouble while in flight or from mid-air collisions between aircrafts.

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8.0 Overall Hazard Results and Summary

The preceding hazard sections discussed the probability, impacts, vulnerabilities, and risk for each of the natural, human-caused and technological hazards that have been determined to have a significant impact on the population, facilities, and infrastructure in the State of Rhode Island. This final sub-section to the HIRA provides an overall assessment and summary of the individual hazard analyses.

It should be noted that while the NCDC storm events data is the most comprehensive database available to compare most natural hazards, the majority of the data gathered from damage reports and insurance records significantly underestimates actual losses.

8.1 Composite Hazard Priorities

As described in the ranking methodology, the composite hazard index characterizes vulnerability in general terms of low, medium, or high hazard propensity. To determine overall risk, the scores for each of the parameters were added together for each hazard to estimate the total county risk due to that hazard. The maximum score from deaths and injuries, infrastructure, and structures was used to assign the probability hazard magnitude factor. The overall or total hazard score for the state was determined by calculating the average hazard risk for each of the counties. Table 75, Table 76, and Table 77 summarize, by hazard, the parameters used to prioritize the identified hazards in Rhode Island.

It should be noted that the significance of the priority scores is relative in nature. A given score does not correspond to a dollar loss level or other direct measure of risk. Instead, the risk scores are intended to provide a framework for understanding the aggregate distribution of hazard and vulnerability combinations across the state. Table 75, Table 76, and Table 77 are the culmination of the hazard scores broken down by hazard. It should be noted that the results are relative to Rhode Island and should not be used to compare risk and vulnerability of the state to other geographic locations.

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Table 75: Rhode Island Natural Hazard Priorities

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
Severe Winter Weather	Bristol County	Highly Likely	Large	Limited	Negligible	Limited	High	High
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Flood	Bristol County	Highly Likely	Medium	Negligible	Limited	Limited	High	High
	Kent County			Limited				
	Newport County							
	Providence County							
	Washington County							
High Wind	Bristol County	Highly Likely	Medium	Limited	Limited	Negligible	High	High
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Extreme Temperature (Heat)	Bristol County	Likely	Large	Negligible	Negligible	Negligible	High	High
	Kent County	Highly Likely						
	Newport County	Likely						
	Providence County	Highly Likely		Limited				
	Washington County			Negligible				
Hurricane and Tropical Storm	Bristol County	Likely	Medium	Limited	Limited	Negligible	High	High
	Kent County					Limited		
	Newport County		Large					
	Providence County		Medium					
	Washington County		Large					
	Bristol County	Likely	Large	Negligible	Negligible	Negligible	High	High
	Kent County							

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
Extreme Temperature (Cold)	Newport County							
	Providence County							
	Washington County							
Thunderstorm	Bristol County	Highly Likely	Small	Limited	Negligible	Negligible	High	High
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Dam Failure	Bristol County	Potential	Small	Negligible	Negligible	Limited	Moderate	Moderate
	Kent County	Likely	Large		Limited		High	
	Newport County	Potential	Small		Negligible		Moderate	
	Providence County	Likely	Large	Limited	Limited		High	
	Washington County		Medium	Negligible				
Fire	Bristol County	Potential	Medium	Limited	Limited	Limited	Moderate	Moderate
	Kent County							
	Newport County	Likely					High	
	Providence County	Potential					Moderate	
	Washington County	Likely					HIgh	
Sea Level Rise	Bristol County	Potential	Medium	Negligible	Negligible	Negligible	Moderate	Low
	Kent County		Small				Low	
	Newport County		Medium				Moderate	
	Providence County		Small				Low	
	Washington County		Medium				Moderate	
Epidemic	Bristol County	Unlikely	Small	Limited	Negligible	Negligible	Low	Low
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Drought	Bristol County	Unlikely	Medium	Negligible	Negligible	Negligible	Low	Low

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Earthquake	Bristol County	Unlikely	Small	Negligible	Negligible	Negligible	Low	Low
	Kent County	Potential				Limited	Moderate	
	Newport County							
	Providence County	Unlikely				Negligible	Low	
	Washington County							
Tornado	Bristol County	Unlikely	Medium	Negligible	Negligible	Negligible	Low	Low
	Kent County		Small					
	Newport County							
	Providence County							
	Washington County							

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Table 76: Rhode Island Human-Caused Hazard Priorities

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
Cyber Incident	Bristol County	Likely	Small	Limited	Limited	Negligible	Moderate	Moderate
	Kent County							
	Newport County				Significant		High	
	Providence County							
	Washington County				Limited		Moderate	
Chemical Incident	Bristol County	Potential	Small	Limited	Limited	Negligible	Moderate	Moderate
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Terrorism	Bristol County	Potential	Small	Limited	Limited	Limited	Moderate	Moderate
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Biological Incident	Bristol County	Unlikely	Small	Limited	Limited	Negligible	Low	Low
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Radiological Incident	Bristol County	Unlikely	Small	Negligible	Limited	Negligible	Low	Low
	Kent County							
	Newport County							
	Providence County							
	Washington County							
Civil Unrest	Bristol County	Potential	Small	Negligible	Negligible	Negligible	Low	Low
	Kent County							

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
	Newport County							
	Providence County							
	Washington County							

Table 77: Rhode Island Technological Hazard Priorities

Hazard	Jurisdiction	Likelihood of Hazard Occurrence	Likely Range of Impact	Probable Hazard Magnitude			County Composite Hazard Index	State Average Composite Hazard Index
				Injuries and Deaths	*Infrastructure*	*Structures*		
Infrastructure Failure	Bristol County	Potential	Medium	Negligible	Limited	Negligible	Moderate	Moderate
	Kent County							
	Newport County							
	Providence County							
	Washington County							

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9.0 Emergency Management Program Elements

The following Emergency Management Accreditation Program (EMAP) Standards are met in this Hazard Identification and Risk Analysis:

- **4.1 - Overview**: An accredited Emergency Management Program has a Hazard Identification and Risk Assessment (HIRA), and Consequence Analysis (CA). The section includes responsibilities and activities associated with the identification of hazards and assessment of risks to persons, public and private property, and structures.
- **4.1.1** - The Emergency Management Program shall identify the natural and human caused hazards that potentially impact the jurisdiction using a broad range of sources. The Emergency Management Program shall assess the risk and vulnerability of people, property, the environment, and its own operations from these hazards.
- **4.1.2** - The Emergency Management Program shall conduct a consequence analysis for the hazards identified in standard 4.1.1 to consider the impact on the public; responders; continuity of operations, including continued delivery of services; property, facilities, and, infrastructure; the environment; the economic condition of the jurisdiction; and public confidence in the jurisdiction's governance.

Table 78 shows the section and page number within the HIRA in which EMAP standard is met.

Table 78: HIRA EMAP Standards

EMAP Standard	Standard Component	HIRA Section(s)	Page #
4.1	….has a Hazard Identification and Risk Assessment (HIRA) and Consequence Analysis (CA).	√	All
4.1	The section includes responsibilities and activities associated with the identification of hazards and assessment of risks to persons, public and private property, and structures.	5.0 6.0 7.0 8.0	
4.1.1	….shall identify the natural and human caused hazards that potentially impact the jurisdiction using a broad range of sources….	2.0	
4.1.1	….shall assess the risk and vulnerability of people, property, the environment, and its own operations from these hazards….	3.0 4.0	
4.1.2	….shall conduct a consequence analysis for the hazards identified in standard 4.1.1 to consider the impact on the public; responders; continuity of operations including continued delivery of services; property, facilities, and, infrastructure; the environment; the economic condition of the jurisdiction and public confidence in the jurisdiction's governance.	Appendix 1	

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I opted to populate this on the back end. I say once we gather all the SIHMC feedback and drop it in, we can populate this. If nothing else, we are the section readily identified so it should be an easy search.

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Appendix 1: Consequence Analysis (CA)

The CA investigates the impact of each identified natural and technological hazard on various elements of the community and state infrastructure of Rhode Island. The impact of each hazard is evaluated in terms of disruption of operations, recovery challenges, and overall wellbeing to all Rhode Island residents and first responder personnel. The CA supplements the hazard profile by analyzing specific impacts that the most probable hazards would have on the State of Rhode Island. The CA analyzes the impact on the following:

1. Public
2. Responders
3. Continuity of operations (including delivery of services)
4. Property, facilities, and infrastructure
5. Environment
6. Economic condition of the state
7. Public confidence in governance

Table 79 below presents a CA for the top ten ranked hazards for the State of Rhode Island. The hazards are ordered from greatest to least impact.

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Table 79: Consequence Analysis

Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
Severe Winter Weather	Freezing temperatures coupled with heavy snow accumulation cause dangerous travel conditions. These conditions may lead to collisions and injury on roadways, individuals not being able to go to work, or accessing critical community facilities. Downed powerlines can lead to a loss of electricity and heat in homes and businesses. The young and the elderly are especially susceptible to a severe reduction in home heating over an extended period of time Pets are also affected by severe winter weather, especially those that are kept outdoors. **Public Health Impacts:** Extremely cold temperatures may lead to hypothermia	Dangerous road conditions create a transportation challenge for first responders. First responders may have to manage the evacuation of people from snow impacted areas, as well as direct traffic, close down roads, operate shelters, and take care of the injured and sick. First responders must control their own exposure to the elements for prolonged periods of time and may need to continuously seek heat and shelter to stay warm. Equipment may also be damaged or destroyed due to cold temperatures, heavy wind, ice, and heavy snow fall, which may lead to a decrease in response capabilities.	Rhode Island Emergency Management Agency maintains a COOP plan. In the event of severe winter weather, the agency will utilize the plan.	The ability to deliver services can be impacted locally, regionally, or statewide depending on the severity of the severe winter weather event. Dangerous road conditions may lead to roadway and bridge closures, as well as transit service disruptions. Slick and icy conditions may lead to an increase of vehicle accidents or vehicular damage to property. Businesses and places of commerce may completely shut down, which leads to the disruption of goods and services.	Transportation, governmental operations, and communications may be heavily disrupted during severe winter weather conditions. Roads and bridges may be heavily impacted by severe winter weather which can cause detours, delays. Roads and bridges can be completely obstructed by downed trees, powerlines, and snow accumulation. Snow and ice can impact access to homes and critical entities such as hospitals, schools, and supermarkets, as well as other critical facilities. Damage to homes, vehicles, structures, and resources may adversely affect response activities. Power loss can lead to disruption of critical infrastructure and technology.	Heavy snow and ice accumulation can weigh down and damage vegetation, tree limbs, and power lines. Flooding may also occur after the rapid melting of a heavy snowfall, causing bodies of water to flood, damaging the surrounding areas. Outdoor animals are susceptible to exposure to extreme cold, which may lead to illness or death. The damage to materials and facilities may allow dangerous chemicals and agents to leak into natural environments and water reservoirs, causing further damage.	Severe winter weather poses a fiscal impact on the local and state governments, even if some of those costs can be recouped through federal grant reimbursements. Local, county, and state resources may be drained by a severe winter weather event.	The public's confidence in the state's governance is affected by immediate local and state response through direct and effective actions. Efficiency in response and recovery operations is critical in keeping public confidence high.

Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	once body temperature drops below 95 degrees Fahrenheit, which may ultimately lead to death. Cold temperatures also lead to a decrease in immune system function, causing the body to become more susceptible to illness and disease.							
Flooding	Flooding directly impacts members of the public in a low-lying area or floodplain, typically near a river, lake, or coastal area. Significant flooding events can lead to the damage and loss of homes, property, and businesses, which can impact public morale and safety. Flash flooding and excessive rainfall may lead to dangerous conditions on roadways, as well as create mudslides that may damage property. **Public Health Impacts:**	Coordinating response to flooding events can be a significant effort by first responders. Fire, police, and emergency responders are often called on to evacuate people from a flood area if flooding is imminent, as well as close roads, pump out flooded basements, attend to the injured, and direct traffic away from the flooded area and roads. First responders may face challenges with transportation and access to a location due to flooded or obstructed roadways. Flash floods and	Rhode Island Emergency Management Agency maintains a COOP plan. In the event of flooding, the agency will utilize the plan.	Flooding has the propensity to cause road and bridge closures, as well as disrupt transit service. If any of these shutdowns occur, the ability to deliver goods and services efficiently will be impacted. Exposure to water may also damage or destroy physical goods such as food, clothing, and hygiene products.	Flooding can cause significant property destruction, including water damage to houses and businesses. This in turn impacts the market value of flooded property. In addition, floods can impact schools, hospitals, and other public infrastructure which impacts the public's ability to use these services. Road infrastructure can be impaired or compromised based on the size and scale of flooding, which can also disrupt transportation infrastructure. Water sources can become contaminated with toxic chemicals,	Rising waters from flooding impact the environment by spreading pollution, inundating water and wastewater treatment plants, carrying debris, and disrupting wildlife and reserve areas. In addition, the standing water following a flooding event can facilitate the spread of vector-associated issues such as mosquitos, disease, and other public health risks.	Significant and repeated flooding can lower property value throughout the state, which can have a deleterious effect on the tax base. Furthermore, flooding drains response resources, which can be costly during a large flooding event for disaster reimbursement.	Ineffective flooding response can decrease the public's confidence in the state's ability to respond and govern. Multi-level government response requires direct actions that must be immediate and effective to maintain public confidence. Efficiency in response and recovery operations is critical in keeping public confidence high.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	Closures of primary-care physician offices is a major public health concern if flooding causes the buildings to be uninhabitable. Water sources may also become contaminated with toxic material or human waste, and water or sewer systems may be completely disrupted. Vector-associated problems can increase the risk for some mosquito-borne infectious diseases.	mudslides due to heavy rainfall can also injure first responders, as well as delay response operations.			dangerous chemicals, or fecal matter. Because water and sewer systems may be disrupted, solid-waste collection and disposal may also be impacted, causing dangerous public health risks.			
High Winds	High winds can lead to damage of private and public property, vehicles, food sources, trees, and powerlines, as well as cause bodily injury from flying debris. Power outages can lead to disruption of employment, businesses, commerce, communication, and food resources. High winds may also cause buildings and structures to collapse, which may	The ability of first responders to conduct their duties may be hindered by high winds, especially if trees, powerlines, and/or debris have impacted roadways and transit. High winds may also destroy property and resources of first responders. High winds may create power outages that can hinder critical communications, access, or usability	Rhode Island Emergency Management Agency maintains a COOP plan. In the event of high winds, the agency will utilize the plan.	The delivery of goods and services will be impacted locally, regionally, or statewide if high winds cause powerlines, debris, and woody debris to fall into roadways or other structures, obstructing passage and access. Excessive winds can also damage suspension bridges, as well as cause damage to transport vehicles, loading docks, and goods being transported.	High winds can cause minor to extreme damage to property, ranging from peeling off surfaces and roofs, to total destruction of foundations and steel-reinforced concrete structures. Excessive winds can uproot and topple trees, lift cars, break windows, and knock out powerlines, leading to power outages to critical facilities. Transportation pathways may	The impact of high winds on the environment affects foliage, trees, animals, cars, and structures, leading to the chance of hazardous and dangerous chemicals and materials being introduced into local waterways, agriculture, public and private spaces, and can affect fragile ecosystems. The power of high winds has also been harnessed for	State and local resources may be costly for recovery from high wind damage. While federal grant reimbursements help cover the costs of damage, there is still a fiscal impact on the local government.	Immediate, effective, and direct actions are necessary to build and foster public confidence in state governance. Efficiency in response and recovery operations is critical in keeping public confidence high.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	cause injury or death. **Public Health Impacts:** The damage of high winds may cause chemical and hazardous materials to spread to sources of food, water, and areas utilized by the public as well as animals.	of resources. Injuries to first responders and equipment may be caused by flying debris, further challenging response operations.			become obstructed by hazardous and non-hazardous debris, slowing down response and recovery activities. Water systems and reservoirs may become full of debris, leading to an impact on the water supply system. The ability to disrupt the power supply causes a cascading effect in other critical infrastructure, where electricity utilization is critical.	renewable energy, where wind turbines rotate with the force of the wind, creating electricity.		
Extreme Heat	The effect of extreme heat can have severe consequences on the well-being of those more vulnerable to severe conditions, such as the elderly and young children. Loss of electricity may impact air conditioning and cooling mechanisms in homes, leading to increased indoor temperatures. **Public Health Impacts:** Physical effects of heat can cause major health	Without proper mitigation efforts to heat, drinking water and proper rest, responders can become hampered in their efforts from extreme heat. Emergency responders will be susceptible to heat stroke and severe dehydration as a result of extreme heat waves. Extreme heat may also damage instruments or equipment necessary for response activities.	Rhode Island Emergency Management Agency maintains a COOP plan. In the event of extreme heat, the agency will utilize the plan.	Major urban areas of the state are much more likely locations for extreme heat. These extreme heat waves can impact efficient delivery or inability of goods or services to be delivered. This results from a cascading effect related to workers being negatively affected by the extreme heat, which in turn drives productivity down significantly. Equipment and vehicles may be damaged due to high	Major urban areas of the state, which are more likely locations for extreme heat, are vulnerable to this risk. Facility integrity is at risk with regards to power cables and stations becoming overheated. This overheating could lead to brownouts in urban areas where power lines are damaged by the heat, air conditioning systems being inoperable, increasing risk to the public. Extreme	Extreme heat can cause significant damage to the local environment by dehydrating vegetation and wildlife, which would create a cascading effect to the surrounding environment. Extreme temperatures may severely decrease the yield of Rhode Island's cash crops. Extreme heat can be associated with drought and violent weather conditions. Livestock are adversely affected	Extreme heat drains state, and local resources. Under the most severe heat conditions, some of the costs can be recouped through federal grant reimbursements, but there is a fiscal impact on the local government.	Governmental response, on all levels, requires direct actions that must be immediate and effective to maintain public confidence.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	problems, dehydration, and may lead to death. People begin to suffer heat-related illness when their bodies are unable to compensate and properly cool. Heat stroke may increase the body temperature to 106 degrees Fahrenheit or higher. Very high body temperatures may damage the brain or other vital organs.			temperatures and sun exposure. Extreme heat may also damage goods if exposed to high temperatures for longer periods of time.	heat may also lead to spontaneous fires, which can further complicate response operations, as well as soften asphalt and damage highways and roadways.	by extreme heat and may suffer medical problems or death.		
Hurricane and Tropical Storm	Rhode Island is home to several tourist and vacation destinations. The overlap between hurricane and tourist seasons could seriously impact both tourist populations and residents of coastal areas. Immediate damage to homes, businesses, infrastructure, government facilities, and roadways causes major disruptions in response operations for the entire state, which heavily impacts the public.	Coordinating an evacuation in advance of a significant hurricane or tropical storm event requires enhanced response coordination and causes a substantial strain on resources. First responders also face the hazards flooding, high winds, and storm surge bring, which may lead to personal injury, disease, or death. Critical roadways and response facilities may flood, lose power, or become damaged or	Rhode Island Emergency Management Agency maintains a COOP plan. In the event of a hurricane or tropical storm, the agency will utilize the plan. COOP plans ensure that state and local agencies are able to continue performance of essential functions in the wake of a hurricane or tropical storm. Should flooding impact a government building or agency, continuity of operations could be impacted and the	Similar to the impacts of flooding, hurricanes and tropical storms can cause road and bridge closures and transit disruptions to ensure public safety in the wake of the storm. In addition, many businesses in the hurricane evacuation zone shut down to prepare safely for the storm. As such, the ability to deliver goods and services efficiently will be impacted depending on the magnitude of the	Hurricanes and tropical storms, depending on the magnitude and impact, can cause widespread destruction to property, facilities, and infrastructure. Residential and commercial properties that are damaged or destroyed by a coastal event can face significant recovery efforts. In addition, hurricanes and tropical storms can impact roads, bridges, schools, and hospitals in the evacuation zone	Hurricanes and tropical storms can cause beach erosion and sea level rise, both of which negatively impact the environment in the long and short term. Strong winds may be generated that completely defoliate forest canopies and cause structural changes in wooded ecosystems. Changes in habitat and food availability due to flooding, winds, and storm surge can heavily impact the health of animals, as well as cause death.	Rhode Island has a significant tourist industry that furnishes the state economy. A major hurricane or tropical storm could cause damage to beaches, historical sites, and other areas that tourist frequent. In addition, the costs associated with response and recovery, although reimbursable during a federal declaration, are significant and can have cascading impacts on the state economy at large.	Ineffective response both before and after a hurricane or tropical storm can decrease the public's confidence in the state's ability to respond and govern. Governmental response across local, state, regional, and federal levels requires direct actions that must be immediate and effective to maintain public confidence.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	Longer-term impacts can include population loss and economic destruction. High winds, flooding, and flying debris may injure the public or cause death. **Public Health Impacts:** Extreme flooding, storm surge, and high winds may cause death or injury for humans and animals. Hazardous waste and material may be introduced into flooding waters, contaminating water supplies as well as standing water. Toxic materials, carcasses, and waste can lead to the spread of disease. Disease vectors such as mosquitos may increasingly spread due to standing water, and may infect humans as well as other animals.	destroyed. Response equipment and vehicles may become inoperable or inaccessible, further complicating response and recovery operations.	agency would need to relocate to their alternate facility as outlined in the COOP plan.	storm. Goods and delivery vehicles may become damaged, destroyed, or inoperable under the current conditions.	through water damage from storm surge, as well as drifting sand from storm winds. Large coastal storms can also cause power outages and disrupt transportation and communications infrastructure, such as roads, bridges, telecommunications towers, and Internet connectivity.			
Extreme Cold	Due to extreme cold, the public may have to face power failures,	First responders may face extremely icy and dangerous road conditions, as	Rhode Island Emergency Management Agency maintains a COOP	Delivery of services may be impacted by icy and dangerous transportation	The cascading effects of extreme cold can bring critical	Extreme cold can freeze crops and food sources, as well as disrupt	Local and state agencies, as well as businesses and general commerce,	Extreme cold is a very dangerous threat that can adversely affect the

Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	communication disruption, dangerous driving conditions, and even serious health problems. Extremely cold temperatures, heavy snowfall, and heavy icing of surfaces may lead to property damage, as well as power loss, heat loss, and lack of shelter from the elements. Pipes in homes may freeze and burst, causing disruption of water service, as well as flooding. The use of space heaters and fireplaces to sustain warmth increases the risk of household fires and carbon monoxide poisoning. Animals can also be heavily affected, especially if kept outdoors or without shelter. **Public Health Impacts:** Homes can quickly decrease in temperature due to a power outage, and individuals without shelter who face	well as risk personal injury due to working in an extremely cold environment. Ice on roads may lead to vehicular crashes and prolonged response times. First responders will also respond to more cold-related injuries such as hypothermia.,	plan and in the event of extreme cold, will utilize the plan appropriately to the situation.	conditions, causing food, water, and resource systems to be delayed or halted, as well as personal transportation by the public. Waterways can freeze, stopping barge and ship traffic. Extremely cold temperatures may also damage or destroy goods if exposed for longer periods of time.	infrastructure to a halt. Critical facilities may be shut down or disrupted due to unsafe travel conditions for workers, the risk of serious health problems, or the failure of processes, materials, and machinery. Energy consumption is extremely high during extremely cold conditions due to heating homes, which creates a strain on energy supply. Communities may also face ground freezing problems, which affects the water supply, sanitation, and agriculture.	ecosystems. Pipe ways and critical facility equipment may freeze and break, causing hazardous and dangerous chemicals and materials to spread into human and animal-populated areas, as well as water systems and the food supply. Extremely cold temperatures may injure or kill wildlife, as well as cause decreased or destroyed food and water resources.	may face a sharp decline in revenue as individuals stay home due to being unable to get to work. Resources from all levels will be utilized and the local government will face fiscal consequences. Energy consumption greatly increases during extremely cold weather due to the increase heating of homes, businesses, and critical facilities for prolonged periods of time. The increase in generating heat energy comes at a high cost for local and state agencies, as well as homeowners.	public, first responders, infrastructure, agriculture, economy, and overall state operations. Direct, effective, and timely response by all levels of government is required for public confidence in the state's governance.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	prolonged exposure may face cold-related health problems such as frostbite, hypothermia and death. Infants and older adults are particularly at risk.							
Thunderstorms	Thunderstorms can have high winds, rain, hail, flooding, and excessive lightning, all of which can cause heavy damage, destruction, and injury to the public. Thunderstorms can cause destruction of property, power failures, hazardous materials spills, and even injury or death. A bolt of lightning can reach temperatures near 50,000 degrees Fahrenheit. Additionally, thunderstorms present some risk to those who are exposed to the elements during such events. Those most at-risk are low-income and homeless individuals without proper shelter from	First responders may be unable to access roadways due to flooding, trees, or debris. Exposure to lightning, flooding, and high winds may cause injuries to first responders. Vehicles and resources may be damaged, leading to impaired response activities. In addition, road conditions may become hazardous as a result of the by-products of the storm. Extreme caution may need to be exercised if thunderstorms produce major rains or hail. Visibility may also decrease significantly, greatly impacting transport activities.	Rhode Island Emergency Management Agency maintains a COOP plan and in the event of thunderstorms, will enact the plan appropriately to the situation. To date, there have been few or no major incidents that have shut down state, county, or municipal governmental operations.	Delivery of services may be impaired by flooding, obstruction, and destruction of roadways and resources. The ability to deliver goods and services will be impacted locally, regionally, or statewide depending on the magnitude of the event. Goods, equipment, and vehicles may become damaged during transport due to the various elements of a thunderstorm.	Power lines and power generators are most at risk from thunderstorms and their by-products. If lightning were to strike certain power lines, it could create a cascading affect for isolated power outages or full-scale blackouts depending on the severity of the weather. Building and vehicle damage can occur from hail and other debris created by thunderstorms. In addition, properties and critical facilities may face foundational and physical damage due to flooding, lightning strike, or excessive winds, delaying response and recovery operations. Power outages and physical	Flooding and excessive winds may cause foundational and structural damage, leading to the risk of the spread of hazardous waste among populated areas, water ways, and food sources. Waste and debris from structure damage can contaminate sources of water, food, and safety. In addition, debris and by-products of thunderstorms can impact the environment by: possibly spreading debris and pollution; damaging sewer and wastewater treatment plants; and disturbing the wildlife and natural areas. Lightning strikes may also ignite wooded areas or fields, leading to	Flooding, high winds, lightning, and hail can drain state and local resources. By-products of thunderstorms can drain state and local resources. Even if some of the costs can be recouped through federal grant reimbursements (should the event warrant a federal disaster declaration), there is a fiscal impact on the local government.	Ineffective thunderstorm response can decrease the public's confidence in the state's ability to respond and govern. Governmental response across local, state, regional, and federal levels requires direct actions that must be immediate and effective to maintain public confidence.

Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	the elements during major thunderstorms. **Public Health Impacts:** Potential health concerns include lightning fatalities and long-term physical and mental effects for survivors.				damage to structures may cause energy supply and water supply systems to be disrupted or fail. Sewerage systems may be compromised and taken off grid.	destruction of agricultural crops, critical ecosystems, and natural habitats.		
Dam Failure	Dam failures impact those living within the hazard area and surrounding areas and can lead to heavy flooding, power loss, property damage, injury, and even death. Extensive flooding and damage may lead to the evacuation and displacement of those individuals in the impact zone. Roadways may be obstructed or inaccessible to the public, challenging transport and resource acquirement activities. **Public Health Impacts:** Flooding waters may reach	Heavy flooding may cause inaccessibility of roadways for first responders as well as damage of materials and resources. First responders will also have to facilitate evacuation measures to move people from the flooded area, close roads, pump out flooded homes, and direct traffic away from the flooded area and roads. The timeliness of evacuation notice is critical in getting the community to areas of safety.	Rhode Island Emergency Management Agency maintains a COOP plan and in the event of dam failures, will enact the plan appropriately to the situation.	Delivery of services may be disrupted due to flood-damaged bridges, pathways and roadways. Transit systems may face closures due to public safety concerns due to inability to operate transportation vehicles such as trains and buses. The ability to deliver food, drinking-water, and services will be impacted locally, regionally, and statewide due to problems with accessibility and transport abilities.	Flooding from dam failures impact roads and bridges, businesses, hospitals, and other critical entities directly or indirectly, making roadways inaccessible for transit. Roads and bridges are usually the main infrastructures impacted by a flood. Flooding may also interrupt communications, transportation, and governmental services operations due to power failure and accessibility challenges. Water and sewer systems may be damaged, leading to the issue of sanitation and	The impacts on the environment of dam failures include flooding and moving debris, affecting natural areas and wildlife, spreading pollution and hazardous materials, and overloading water and wastewater plants. Ecosystems and natural habitats may be completely destroyed, causing migration or death of wildlife.	There is a fiscal impact on the local government after a dam failure, even after some of the costs have been paid through federal grant reimbursements. Recourses at all levels are utilized.	Direct, immediate, and effective actions must be taken in order to maintain public confidence. Response activities must include all levels of government.

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Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	high speeds mixed with garbage, structural and natural debris such as tree limbs and building materials, which may cause injury and death to those in the vicinity of the dam failure. Standing water can also pose a public health risk due to the reproduction of disease vectors such as mosquitos.				waste collection. Property of homes and businesses may be completely destroyed if situated close to the failure point. Following a flood event, the market value of a flooded property may be significantly reduced due to the costly and long-term damage.			
Fire	The effect of fire can extend beyond the initial impact caused by fire damage. A fire of significant strength can cause major damage to buildings or farmland. People located in the immediate area of the fire are also greatly impacted by smoke inhalation and other health risks, as well as face the risk of relocation for unknown periods of time. Relocation may also be an option due to complete destruction of a certain area.	Fire, police, and emergency responders are called on to evacuate people from the fire area, close roads, create fire breaks, attend to the injured, and direct traffic away from the area. First responders may also have to deal with the psychological reactions of the public during an extreme event, such as trauma and shock. Firefighters are at a higher risk of smoke inhalation, burns, and health problems due to working in	COOP plans are a requirement of the state and local governments. COOP plans provide the framework to ensure that state and local agencies are able to continue performance of essential functions under a broad range of circumstances such as large fire events. To date, only one incident has reached the level of necessitating a potential Emergency Operations Center (EOC) activation.	Fires can cause disruption of services in the event of an urban or wildfire in the impacted area If a fire does occur, the ability to deliver goods and services efficiently will be impacted locally, regionally, or statewide depending on the magnitude of the event and level of service disruptions. Normal operations would be affected and could lead to a drop in level of services or inability to provide certain services. Goods and	Fire can damage or completely destroy property and critical facilities, as well as lead to interruption of the power supply system. Large fires may also interrupt transportation systems such as train and bus lines, creating a challenge for public transit, especially during evacuation. The 2003 nightclub Fire at The Station in West Warwick showed major weaknesses in fire prevention policies and equipment. Since then, major improvements have	Fires can cause significant impact to the environment by: spreading pollution; creating health problems; carrying ash and smoke; damaging agricultural crops; and disturbing the wildlife and natural areas. Water and soil pollution caused by fire can cause longer term threats to human and ecosystem health. Fire damage may also affect soil formation, nutrient cycling, and carbon sequestration and storage. An	Fires drain state and local resources. There is a fiscal impact on the local government even if costs can be recouped by federal grants. Rhode Island's agriculture, tourism and aquaculture are a major component of the local, county and state economy. Major fires can cause significant impact to those sectors, further draining state resources. Costs may be associated with loss of income from the land following incidents,	Governmental response, on all levels – state and local – requires direct actions that must be immediate and effective to maintain public confidence.

Hazard	Impact on Public	Impact on Responder	Continuity of Operations (COOP)	Delivery of Services	Property, Facilities, and Infrastructure	Impact on Environment	Impact on State Economy	Public Confidence in the State's Governance
	Since 2003, major changes have occurred in fire prevention and management in public venues, decreasing the risk to the public of a major fire. **Public Health Impacts:** Deaths from fires and burns are the fifth most common cause of unintentional injury deaths in the United States. Fire, whether urban or wildfire, can release toxic components which can cause adverse health effects in people as well as animals. The respiratory and cardiovascular systems are most affected by fire and smoke inhalation, and psychological and psychiatric problems may arise as well due to exposure to the traumatic event. Young children and the elderly are especially vulnerable to health and medical issues	close proximity to fires and the subsequent smoke.		facilities may also be damaged or destroyed by fire, smoke, or extremely high temperatures. There may also be an increased demand on health services due to the challenge of access to healthcare facilities by patients with chronic healthcare conditions.	increased safety standard of buildings and facilities as a whole.	important component of recovery also includes restoring sensitive habitats and environments that were damaged.	the cost of damage to property, firefighting, and restoring sensitive habitats and environments.	

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	stemming from fire and smoke exposure.							

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Cybersecurity Incident	The public is heavily reliant on technology for daily life, including cell phones, handheld devices such as tablets, and computers. Any disruption to this technology caused by a cyber incident could impair the ability for the public to conduct basic activities, such as communications and mobile banking. **Public Health Impacts:** Although mostly indirect, public health impacts of cybersecurity incidents may include loss of access of important medical information and services, personal information, and unwanted sharing or dissemination of that information to other parties. Disruption in attaining medical help or resources may delay receiving proper medical attention or care.	Cyber incidents can interfere with emergency response communication and activities. Given that many first responders rely on technology both at operations center and in the field, a cyber incident could impair the ability to communicate. For example, many agencies rely on technology to notify and route responders to the scene of the emergency. More specifically, 911 dispatch centers rely on technology which makes them vulnerable to cyber exploits. In addition, the nebulous nature of a cyber incident makes coordinated response convoluted and complicated.	A cyber incident could cause significant communications or energy-based disruptions. Specifically, agencies that rely on electronic backup of critical files are vulnerable to cyber incident. In these instances, activating COOP plans that account for such disruptions is key. The COOP plan should ensure that agencies are able to continue performance of essential functions even in the wake of a cyber incident that disrupts access to technology.	In today's world, the delivery of goods and services is heavily reliant of technology for the facilitation of transactions. A cyber incident could significantly disrupt the delivery of goods and services to the extent upon which businesses and entities rely on technology for the delivery of their materials.	Property and facilities may become either uninhabitable or unusable as a result of a cyber incident, particularly if their infrastructure if reliant on technology for sustainability. In addition, a significant majority of critical infrastructure systems are in some way tied to technology, oftentimes through virtual operations and supervisory control and data acquisition (SCADA) systems. Therefore, a cyber incident could disable the vast majority of systems which control these pieces of critical infrastructure, as well as traffic control, dispatch, utility, and response systems.	Targeted cyber incidents can impact water or wastewater treatment facilities. The disruption of the virtual systems tied to this infrastructure could cause water pollution or contamination and subsequent environmental issues. In addition, a cyber incident could impact the environment if a release of a hazardous material was triggered as a cascading effect of the incident.	A significant cyber incident could have glaring ramifications on the state economy. Society is heavily reliant on electronic-based commerce through mobile banking, automated teller machines, and electronic trading. Any disruption to daily activities by a cyber incident can have disastrous impacts to the economy, effectively halting the ability to conduct transactions electronically.	In the case of a cyber incident in which significant amounts of data is stolen, the government's inability to protect confidential personal data would impact confidence in the state. Such an incident would also subsequently cause pause regarding the security of using electronic systems for government services.

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