SECTION 5
HAZARD PROFILES

This section includes detailed hazard profiles for each of the hazards identified in the previous section (*Hazard Identification*) as significant enough for further evaluation in the Wake County Multi-Jurisdictional Hazard Mitigation Plan. It contains the following subsections:

- 5.1 Overview
- 5.2 Study Area
- 5.3 Drought
- 5.4 Extreme Heat
- 5.5 Hailstorm
- 5.6 Hurricane and Tropical Storm
- 5.7 Lightning
- 5.8 Severe Thunderstorm/High Wind
- 5.9 Tornado
- 5.10 Winter Storm and Freeze
- 5.11 Earthquake
- 5.12 Landslide
- 5.13 Dam and Levee Failure
- 5.14 Erosion
- 5.15 Flood
- 5.16 Hazardous Materials Incident
- 5.17 Wildfire
- 5.18 Nuclear Accident
- 5.19 Terror Threat
- 5.20 Conclusions on Hazard Risk
- 5.21 Final Determinations

44 CFR Requirement
44 CFR Part 201.6(c)(2)(i): The risk assessment shall include a description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events

5.1 OVERVIEW

This section includes detailed hazard profiles for each of the hazards identified in the previous section (*Hazard Identification*) as significant enough for further evaluation in the Wake County hazard risk assessment by creating a hazard profile. Each hazard profile includes a general description of the hazard, its location and extent, notable historical occurrences, the probability of future occurrences, and a brief consequence analysis that outlines potential impacts on people, the built environment, the economy, and the natural environment. Each profile also includes specific items noted by members of the Wake County Regional Work Groups as it relates to unique historical or anecdotal hazard information for the county and its municipalities.

The following hazards were identified:

- **Atmospheric**
  - Drought
  - Extreme Heat
  - Hailstorm
  - Hurricane and Tropical Storm

- Lightning
- Severe Thunderstorm (including straight-line winds)
- Tornado
- Winter Storm and Freeze

- **Geologic**
  - Earthquake
  - Landslide
- **Hydrologic**
  - Dam and Levee Failure
  - Erosion
  - Flood
- **Other**
  - Hazardous Materials Incident
  - Wildfire
  - Nuclear Accident
  - Terror Threat

5.2 STUDY AREA

Wake County includes twelve municipalities. **Table 5.1** provides a summary table of the participating jurisdictions within the county. In addition, **Figure 5.1** provides a base map, for reference, of Wake County and its incorporated municipalities.

TABLE 5.1: PARTICIPATING JURISDICTIONS IN THE WAKE COUNTY MULTI-JURISDICTIONAL HAZARD MITIGATION PLAN

Wake County	
Apex	Morrisville
Cary	Raleigh
Fuquay-Varina	Rolesville
Garner	Wake Forest
Holly Springs	Wendell
Knightdale	Zebulon

FIGURE 5.1: WAKE COUNTY BASE MAP

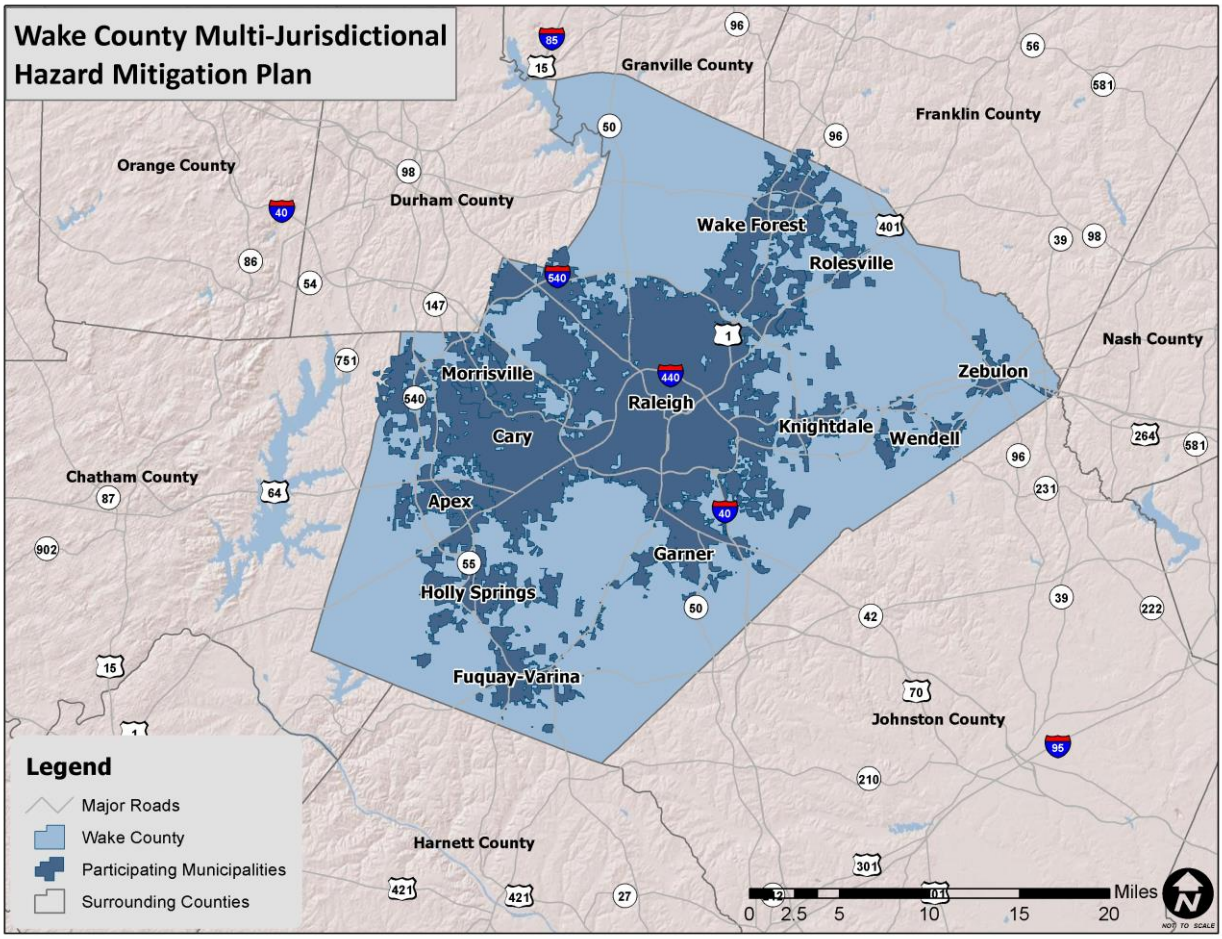


Table 5.2 lists each significant hazard for Wake County and identifies whether or not it has been determined to be a specific hazard of concern for the county and twelve municipal jurisdictions. This is based on the best available data and information from the Regional Work Groups. (● = hazard of concern)

TABLE 5.2 SUMMARY OF IDENTIFIED HAZARD EVENTS IN WAKE COUNTY

Jurisdiction	Atmospheric								Geologic		Hydrologic			Other			
	Drought	Extreme Heat	Hailstorm	Hurricane and Tropical Storm	Lightning	Thunderstorm	Tornado	Winter Storm	Earthquake	Landslide	Dam and Levee Failure	Erosion	Flood	HAZMAT	Wildfire	Nuclear Accident	Terror Threat
Wake County																	
Apex	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Cary	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Fuquay-Varina	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Garner	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Jurisdiction	Atmospheric								Geologic		Hydrologic			Other			
	Drought	Extreme Heat	Hailstorm	Hurricane and Tropical Storm	Lightning	Thunderstorm	Tornado	Winter Storm	Earthquake	Landslide	Dam and Levee Failure	Erosion	Flood	HAZMAT	Wildfire	Nuclear Accident	Terror Threat
Holly Springs	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Knightdale	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Morrisville	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Raleigh	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Rolesville	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Wake Forest	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Wendell	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Zebulon	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Unincorporated Area	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Atmospheric Hazards

5.3 DROUGHT

5.3.1 Background

Drought is a normal part of virtually all climatic regions, including areas with high and low average rainfall. Drought is the consequence of a natural reduction in the amount of precipitation expected over an extended period of time, usually a season or more in length. High temperatures, high winds, and low humidity can exacerbate drought conditions. In addition, human actions and demands for water resources can hasten drought-related impacts.

Droughts are typically classified into one of four types: 1) meteorological, 2) hydrologic, 3) agricultural, or 4) socioeconomic. **Table 5.3** presents definitions for these types of drought.

TABLE 5.3 DROUGHT CLASSIFICATION DEFINITIONS

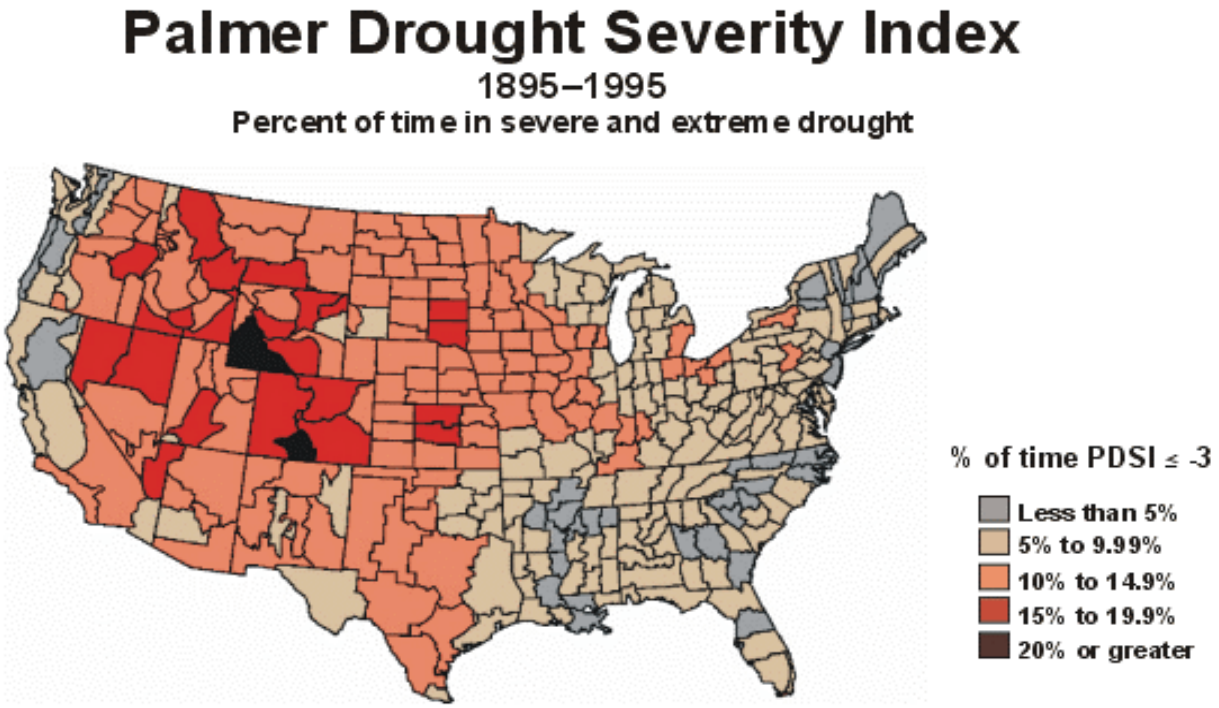
Meteorological Drought	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales.
Hydrologic Drought	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels.
Agricultural Drought	Soil moisture deficiencies relative to water demands of plant life, usually crops.
Socioeconomic Drought	The effect of demands for water exceeding the supply as a result of a weather-related supply shortfall.

Source: Multi-Hazard Identification and Risk Assessment: A Cornerstone of the National Mitigation Strategy, FEMA

Droughts are slow-onset hazards, but, over time, can have very damaging affects to crops, municipal water supplies, recreational uses, and wildlife. If drought conditions extend over a number of years, the direct and indirect economic impact can be significant.

The Palmer Drought Severity Index (PDSI) is based on observed drought conditions and range from -0.5 (incipient dry spell) to -4.0 (extreme drought). Evident in **Figure 5.2**, the Palmer Drought Severity Index Summary Map for the United Stated, drought affects most areas of the United States, but is less severe in the Eastern United States.

FIGURE 5.2: PALMER DROUGHT SEVERITY INDEX SUMMARY MAP FOR THE UNITED STATES



Source: National Drought Mitigation Center

5.3.2 Location and Spatial Extent

Drought typically covers a large area and cannot be confined to any geographic or political boundaries. According to the Palmer Drought Severity Index (**Figure 5.2**), Central North Carolina has a relatively low risk for drought hazard. However, local areas may experience much more severe and/or frequent drought events than what is represented on the Palmer Drought Severity Index map. Furthermore, it is assumed that Wake County would be uniformly exposed to drought, making the spatial extent potentially widespread. It is also notable that drought conditions typically do not cause significant damage to the built environment.

5.3.3 Historical Occurrences

Data from the North Carolina Drought Management Advisory Council and National Climatic Data Center (NCDC) were used to ascertain historical drought events in Wake County. The North Carolina Drought Management Advisory Council reports data on North Carolina drought conditions from 2000 to 2013 through the North Carolina Drought Monitor. It classifies drought conditions by county on a scale of D0 to D4:

- D0: Abnormally Dry
- D1: Moderate Drought
- D2: Severe Drought
- D3: Extreme Drought
- D4: Exceptional Drought

According to the North Carolina Drought Monitor, Wake County has had drought occurrences in all of the last fourteen years (2000-2013) (**Table 5.4**). In addition, **Table 5.5** shows the most severe drought classification for each year, according to North Carolina Drought Monitor classifications.

TABLE 5.4: SUMMARY OF DROUGHT OCCURRENCES IN WAKE COUNTY

Location	Number Years with Drought Occurrences	Number Years with Exceptional Drought Occurrences
Wake County	**14**	**3**

Source: North Carolina Drought Monitor

TABLE 5.5: HISTORICAL DROUGHT OCCURRENCES IN WAKE COUNTY

Abnormally Dry **Moderate Drought** **Severe Drought** **Extreme Drought** **Exceptional Drought**

	Wake County
2000	MODERATE
2001	SEVERE
2002	**EXCEPTIONAL**
2003	ABNORMAL
2004	ABNORMAL
2005	SEVERE
2006	SEVERE
2007	**EXCEPTIONAL**
2008	**EXCEPTIONAL**
2009	MODERATE
2010	SEVERE
2011	SEVERE
2012	MODERATE
2013	MODERATE

Source: North Carolina Drought Monitor

5.3.4 Probability of Future Occurrences

Based on historical occurrence information, it is assumed that all of Wake County has a probability level of likely (10-100 percent annual probability) for future drought events. This hazard may vary slightly by location but all areas have an equal probability of experiencing a drought. However, historical information also indicates that there is a much lower probability for extreme, long-lasting drought conditions.

5.3.5 Consequence Analysis

People (The Public and Public Confidence)

Drought can have a detrimental effect on the livelihood of farmers and agricultural producers in Wake County. Efforts to mitigate against drought, such as using irrigation equipment, have a high initial cost, including the need for an increase in management requirements, cost of operation and maintenance, and the lack of good quality water resources—which during times of drought would be severely affected. Public confidence would likely not be impacted severely.

Responders

Although drought would have many of the same impacts on responders as it would on the public, the overall effects would be relatively limited when compared to other hazards.

Continuity of Operations

Drought would have minimal impacts on continuity of operations due to the relatively long warning time that would allow for plans to be made to maintain continuity of operations.

Built Environment (Property, Facilities, and Infrastructure)

Water Use

Drought has the potential to affect Wake County's water supply for residential, commercial, institutional, industrial, and government-owned areas. Drought can reduce water supply in wells and reservoirs. When drought conditions persist with no relief, local or State governments often institute water restrictions.

Irrigation

Drought would affect irrigation and outdoor landscaping efforts around residential, commercial, institutional, industrial, and government-owned land. Water conservation strategies can limit the amount of water used to maintain the aesthetic environment around buildings, businesses, and areas such as golf courses. This would include automatic and non-automatic spray irrigation systems, hose-end sprinklers, handheld hoses, bucket watering, drip irrigation, athletic field irrigation, swimming pools, car washing, pressure washing, and reuse water.

Economy

Drought can have a detrimental effect on agricultural and agribusiness industry sectors. In 2000, all agricultural and agribusiness industries in the United States encompassed $2,330,828,659, which is 8.19 percent share of the county income.[1] In addition, in 2000, employment in agriculture and agribusiness was 64,367, or 13 percent of the county's total employment.

Extreme drought has the potential to depress local businesses and industries such as landscaping, recreation and tourism, and public utilities. Nursery and landscape businesses can also face significant losses from a drought. Losses include reduction of output and sales of nursery crops, reduction in plant sales, and an increase in watering costs. This can lead to the closing of many business locations, lay-off of employees, and increases in bankruptcy filing.

[1] North Carolina State University College of Agriculture and Life Sciences. (2003). *Agriculture and agribusiness in Wake County*. Retrieved May 7, 2012, from http://www.cals.ncsu.edu/cfprod/apps/calswebsite/documents/County/wake.pdf

Environment

Agriculture

The agriculture sector of Wake County is particularly susceptible to drought damage. **Table 5.6** shows there are 827 farms in Wake County, with 84,956 acres of 532,415 acres total being farmland.[2] Agricultural drought has the potential to directly affect almost 16.0 percent of the land in Wake County. Agricultural areas at particular risk are cropland (54.05 percent of farmland in Wake County) and pastures (10.67 percent of farmland in Wake County).

TABLE 5.6: WAKE COUNTY FARMLAND OVERVIEW

Census of Agriculture (2007)	
Total Acres in County	532,415
Number of Farms	827
Total Land in Farms, Acres	84,956
Average Farm Size, Acres	103
Median Farm Size, Acres	38

Crops

Prolonged periods of dry weather are the most difficult and damaging problem faced by crop growers and agricultural suppliers. Wake County has 35,610 acres (6.69 percent) of harvested cropland (see **Table 5.7**).

TABLE 5.7: WAKE COUNTY AGRICULTURE INFORMATION

Census of Agriculture (2007)	
Harvested Cropland, Acres	35,610
Irrigated land, Acres	3,764

Short- or long-term moisture deficits—even with the use of irrigation methods—during critical stages of crop development can severely reduce yields, with the amount of yield lost depending on when the drought occurs (see **Table 5.8**for a list of Wake County crop specific information), the growth stage of the crop, the severity of dry conditions, and the amount of available water that the soil can hold.

TABLE 5.8: WAKE COUNTY CROP INFORMATION

Crops	Farms	Acres	Bushels
Corn for Grain	53	2,224	152,018
Wheat for grain, all	44	3,238	126,880
Winter wheat for grain	44	3,238	126,880
Oats for grain	20	493	25,930

Livestock[3]

Table 5.9shows the type of livestock in Wake County, including the number of farms and the quantity of livestock that are at risk for being affected by drought conditions in the county, based on the 2007 Agriculture Census.

[2] *Wake County: Census of agriculture—2007*. Retrieved May 7, 2012, from http://www.ncagr.gov/stats/codata/wake.pdf

[3] North Carolina Division of Water Resources. (2009). *The water connection: Water resources, drought and the hydrologic cycle in North Carolina*. Retrieved May 7, 2012, from http://www.ncwater.org/Reports_and_Publications/primer/The_Water_Connection_Booklet_9x12_150dpi.pdf

Livestock losses from drought will most likely be confined to forage-based production systems. Losses in beef and dairy systems will potentially be of a single-season or multiyear variety. Single-season losses will include lost forage production (on both hay and grazing land), reduced weaning weights, reduced milk production, and increased mortality.

Multiyear losses could include the cost of reestablishing pastures and reduced meat or milk production in subsequent years due to forced sales in the drought year. In addition, drought conditions could result in poor pasture conditions, reduced drinking water supplies, and a critical hay shortage that directly affects livestock and poultry health.

TABLE 5.9: WAKE COUNTY LIVESTOCK (2010)

Livestock	Farms	Number
Cattle and calves inventory	159	4,392
Beef cows	121	-
Milk cows	5	-
Cattle and calves sold	134	1812
Hogs and pigs inventory	8	-
Hogs and pigs sold	-	30
Sheep and lambs inventory	581	71
Layers inventory	71	24,534
Broilers and other meat-type chickens sold	10	-

Environmental Degradation

Drought may also lead to pollution of water sources as a result of lack of rain water to dilute industrial and agricultural chemical runoff. This poses a risk to plants and animals and makes it difficult to maintain a clean drinking water supply.

Lack of water reaching the soil may also cause the ground to become dry and unstable. Erosion can increase and loss of topsoil can be severe if a high-intensity rain falls on ground lacking a ground cover of plants. As a result of these environmental impacts, habitats may be degraded through a loss of wetlands, lake capacity, and vegetation.

5.4 EXTREME HEAT

5.4.1 Background

Extreme heat, like drought, poses little risk to property. However, extreme heat can have devastating effects on health. Extreme heat is often referred to as a "heat wave." According to the National Weather Service, there is no universal definition for a heat wave, but the standard U.S. definition is any event lasting at least three days where temperatures reach ninety degrees Fahrenheit or higher. However, it may also be defined as an event at least three days long where temperatures are ten degrees greater than the normal temperature for the affected area. Heat waves are typically accompanied by humidity but may also be very dry. These conditions can pose serious health threats causing an average of 1,500 deaths each summer in the United States[4].

[4] http://www.noaawatch.gov/themes/heat.php

According to the National Oceanic and Atmospheric Administration, heat is the number one weather-related killer among natural hazards, followed by frigid winter temperatures[1]. The National Weather Service devised the Heat Index as a mechanism to better inform the public of heat dangers. The Heat Index Chart, shown in **Figure 5.3**, uses air temperature and humidity to determine the heat index or apparent temperature. **Table 5.10** shows the dangers associated with different heat index temperatures. Some populations, such as the elderly and young, are more susceptible to heat danger than other segments of the population.

FIGURE 5.3: HEAT INDEX CHART

Air Temp (in F)	Relative Humidity (in percent)																				
	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125																				
135	120	128																			
130	117	122	131																		
125	111	116	123	131	141																
120	107	111	116	123	130	139	148														
115	103	107	111	115	120	127	135	143	151												
110	99	102	105	108	112	117	123	130	137	143	150										
105	95	97	100	102	105	109	113	118	123	129	135	142	149								
100	91	93	95	97	99	101	104	107	110	115	120	126	132	138	144						
95	87	88	90	91	93	94	96	98	101	104	107	110	114	119	124	130	136				
90	83	84	85	86	87	88	90	91	93	95	96	98	100	102	106	109	113	117	122		
85	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	95	97	99	102	105	108
80	73	74	75	76	77	77	78	79	79	80	81	81	82	83	85	86	86	87	88	89	91
75	69	69	70	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	79	80
70	64	64	65	65	66	66	67	67	68	68	69	69	70	70	70	70	71	71	71	71	72

Source: NOAA

TABLE 5.10: HEAT DISORDERS ASSOCIATED WITH HEAT INDEX TEMPERATURE

Heat Index Temperature (Fahrenheit)	Description of Risks
80°- 90°	Fatigue possible with prolonged exposure and/or physical activity
90°- 105°	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity
105°- 130°	Sunstroke, heat cramps, and heat exhaustion likely, and heatstroke possible with prolonged exposure and/or physical activity
130° or higher	Heatstroke or sunstroke is highly likely with continued exposure

Source: National Weather Service, NOAA

In addition, NOAA has seventeen metropolitan areas participating in the Heat HealthWatch/Warning System in order to better inform and warn the public of heat dangers. A Heat HealthWatch is issued when conditions are favorable for an excessive heat event in the next 12 to 48 hours. A Heat Warning is issued when an excessive heat event is expected in the next 36 hours. Furthermore, a warning is issued when the conditions are occurring, imminent, or have a high likelihood of occurrence. Urban areas

participate in the Heat Health Watch/Warning System because urban areas are at greater risk to heat affects. Stagnant atmospheric conditions trap pollutants, thus adding unhealthy air to excessively hot temperatures. In addition, the "urban heat island effect" can produce significantly higher nighttime temperatures because asphalt and concrete (which store heat longer) gradually release heat at night.

5.4.2 Location and Spatial Extent

Excessive heat typically impacts a large area and cannot be confined to any geographic or political boundaries. All of Wake County is susceptible to extreme heat conditions.

5.4.3 Historical Occurrences

Data from the National Climatic Data Center was used to determine historical extreme heat and heat wave events in Wake County. There were two events reported:

July 22, 1998 – *Excessive Heat* - Excessive heat plagued central North Carolina during July 22 through July 23. Maximum temperatures reached the 98 to 103 degree range combined with dew points in the 78 to 80 degree range with little wind to give heat index values of around 110 degrees.

August 22, 2007 – *Heat* - An athlete from Enloe High School running track collapsed from heat exhaustion and was sent to the hospital in critical condition. The student remained in the hospital in critical condition for several days.

In addition, information from the State Climate Office of North Carolina was reviewed to obtain historical temperature records in the county. Temperature information has been reported since 1898. The recorded maximum for Wake County was 107 degrees Fahrenheit in Raleigh at North Carolina State University in 2011.

The State Climate Office also reports average maximum temperatures in various locations in the region. The most centralized location is in Raleigh at North Carolina State University. **Table 5.11** shows the average maximum temperatures from 1971 to 2000 at the North Carolina State University observation station which can be used as a general comparison for the region.

Table 5.11: Average Maximum Temperature in Raleigh, Wake County

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Avg. Max (°F)	48.8	53.0	61.2	70.6	77.5	84.4	87.9	85.9	80.0	69.8	61.3	52.1

Source: State Climate Office of North Carolina

5.4.4 Probability of Future Occurrences

Based on historical occurrence information, it is assumed that all of Wake County has a probability level of likely (10 to 100 percent annual probability) for future extreme heat events to impact the region.

5.4.5 Consequence Analysis

People (The Public and Public Confidence)

Extreme heat can affect many people and to varying degrees. Often the elderly and very young are susceptible to the most detrimental impacts, but heat stroke and exhaustion can plague anyone. A heat wave would have minimal effects on public confidence.

Responders

Extreme heat can also affect responders who are often more susceptible to heat stroke and exhaustion due to the nature of their work which often forces police and emergency medical providers to be exposed to the elements. In these cases, responders could be negatively impacted by extreme heat.

Continuity of Operations

Extreme heat would likely have few impacts on continuity of operations as the warning time for these events is usually long and direct impacts to large numbers of personnel or other resources necessary to maintain operations are unlikely.

Built Environment (Property, Facilities, and Infrastructure)

Extreme heat would likely have a minor effect on the built environment, although high temperatures could potentially put a strain on infrastructure such as power generation and water systems due to higher demand.

Economy

An extreme heat event could potentially have a negative impact on the economy in the short term as the public may be advised to stay inside, causing them to reduce overall spending and negatively impact businesses in the community. Extended periods of extreme heat may also disrupt the local economy if agricultural, dairy, and livestock production declines, resulting in income loss for famers and others affected.

Environment

The environment would be impacted by extreme heat as many plants and animals that are not able to withstand the heat may die off and crops and livestock may be impacted by unusually high temperatures, resulting in death or illness.

5.5 HAILSTORM

5.5.1 Background

Hailstorms are a potentially damaging outgrowth of severe thunderstorms (thunderstorms are discussed separately in Section 5.8). Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until they develop to a sufficient weight and fall as precipitation. Hail typically takes the form of spheres or irregularly-shaped masses greater than 0.75 inches in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in

thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size.

5.5.2 Location and Spatial Extent

Hailstorms frequently accompany thunderstorms, so their locations and spatial extents coincide. It is assumed that Wake County is uniformly exposed to severe thunderstorms; therefore, all areas of the region are equally exposed to hail which may be produced by such storms.

5.5.3 Historical Occurrences

According to the National Climatic Data Center, 261 recorded hailstorm events have affected Wake County since 1966.[5] **Table 5.12** is a summary of the hail events in Wake County. **Table 5.13** provides detailed information about each event that occurred in the region. In all, hail occurrences resulted in around $9,000 (2013 dollars) in property damages. Hail ranged in diameter from 0.75 inches to 4.0 inches. It should be noted that hail is notorious for causing substantial damage to cars, roofs, and other areas of the built environment that may not be reported to the National Climatic Data Center. Therefore, it is likely that damages are greater than the reported value. Additionally, a single storm event may have affected multiple jurisdictions.

TABLE 5.12: SUMMARY OF HAIL OCCURRENCES IN WAKE COUNTY

Location	Number of Occurrences	Property Damage (2013)
Apex	12	$0
Cary	22	$9,008
Fuquay-Varina	10	0
Garner	13	$0
Holly Springs	7	$0
Knightdale	8	$0
Morrisville	7	$0
Raleigh	55	$0
Rolesville	5	$0
Wake Forest	8	$0
Wendell	6	$0
Zebulon	6	$0
Unincorporated Area	102	$0
WAKE COUNTY TOTAL	**261**	**$9,008**

Source: National Climatic Data Center

TABLE 5.13: HISTORICAL HAIL OCCURRENCES IN WAKE COUNTY

	Date	Magnitude	Deaths/Injuries	Property Damage*
Wake County				
Wake County	8/15/1958	1 in.	0/0	$0

[5] These hail events are only inclusive of those reported by the National Climatic Data Center (NCDC). It is likely that additional hail events have affected Wake County. In addition to NCDC, the North Carolina Department of Insurance office was contacted for information. As additional local data becomes available, this hazard profile will be amended.

	Date	Magnitude	Deaths/Injuries	Property Damage*
Wake County	3/19/1966	1 in.	0/0	$0
Wake County	3/19/1966	1 in.	0/0	$0
Wake County	2/9/1970	0.75 in.	0/0	$0
Wake County	5/23/1973	0.75 in.	0/0	$0
Wake County	5/28/1973	1.75 in.	0/0	$0
Wake County	4/8/1976	1.5 in.	0/0	$0
Wake County	4/19/1978	1.25 in.	0/0	$0
Wake County	4/19/1978	1 in.	0/0	$0
Wake County	6/22/1978	1 in.	0/0	$0
Wake County	4/27/1980	1.75 in.	0/0	$0
Wake County	4/27/1980	0.75 in.	0/0	$0
Wake County	4/27/1980	0.75 in.	0/0	$0
Wake County	4/30/1981	0.75 in.	0/0	$0
Wake County	6/3/1982	1 in.	0/0	$0
Wake County	6/3/1982	1.75 in.	0/0	$0
Wake County	6/3/1982	2 in.	0/0	$0
Wake County	6/16/1982	2 in.	0/0	$0
Wake County	5/26/1983	0.75 in.	0/0	$0
Wake County	4/16/1985	0.75 in.	0/0	$0
Wake County	6/24/1986	1.75 in.	0/0	$0
Wake County	6/24/1986	1.75 in.	0/0	$0
Wake County	8/2/1986	0.75 in.	0/0	$0
Wake County	7/13/1987	1.5 in.	0/0	$0
Wake County	8/21/1987	1.75 in.	0/0	$0
Wake County	10/6/1987	1 in.	0/0	$0
Wake County	5/17/1988	1.75 in.	0/0	$0
Wake County	5/19/1988	1 in.	0/0	$0
Wake County	5/19/1988	1 in.	0/0	$0
Wake County	6/2/1988	2 in.	0/0	$0
Wake County	6/2/1988	0.75 in.	0/0	$0
Wake County	6/17/1988	1 in.	0/0	$0
Wake County	7/19/1988	0.75 in.	0/0	$0
Wake County	7/31/1988	1 in.	0/0	$0
Wake County	9/24/1988	2.5 in.	0/0	$0
Wake County	4/25/1989	1.75 in.	0/0	$0
Wake County	6/15/1989	0.88 in.	0/0	$0
Wake County	6/16/1989	3 in.	0/0	$0
Wake County	4/2/1990	1 in.	0/0	$0
Wake County	5/4/1990	1.5 in.	0/0	$0
Wake County	6/3/1990	1 in.	0/0	$0
Wake County	7/1/1990	2.5 in.	0/0	$0
Wake County	8/29/1990	1.75 in.	0/0	$0
Wake County	8/29/1990	0.75 in.	0/0	$0
Wake County	6/26/1992	0.75 in.	0/0	$0
Wake County	6/26/1992	1 in.	0/0	$0
Wake County	7/26/1992	1 in.	0/0	$0
Wake County	9/4/1992	1.5 in.	0/0	$0

	Date	Magnitude	Deaths/Injuries	Property Damage*
New Hill	3/27/1993	0.75 in.	0/0	$0
New Hill	5/19/1993	1.75 in.	0/0	$0
Wake County	5/1/1994	0.75 in.	0/0	$0
Wake County	5/26/1995	1.75 in.	0/0	$0
FALLS LAKE	5/11/1996	0.75 in.	0/0	$0
CARPENTER	3/21/1999	1 in.	0/0	$0
SHOTWELL	8/13/2000	0.88 in.	0/0	$0
NEW HILL	5/14/2006	0.75 in.	0/0	$0
FALLS	5/20/2006	0.75 in.	0/0	$0
BAYLEAF	5/9/2008	0.75 in.	0/0	$0
WAKE XRDS	5/9/2008	0.75 in.	0/0	$0
WILLOW SPGS	5/9/2008	0.88 in.	0/0	$0
NEWHILL	5/20/2008	1.75 in.	0/0	$0
WILLOW	5/20/2008	0.88 in.	0/0	$0
MACEDONIA	5/20/2008	0.75 in.	0/0	$0
WILLOW SPGS	5/20/2008	1 in.	0/0	$0
MACEDONIA	7/6/2008	0.75 in.	0/0	$0
MILLBROOK	7/22/2008	0.75 in.	0/0	$0
FAWLERS XRDS	5/5/2009	0.88 in.	0/0	$0
WILLOW SPGS	7/1/2009	0.75 in.	0/0	$0
FALLS	7/27/2009	1 in.	0/0	$0
LEESVILLE	7/28/2009	0.88 in.	0/0	$0
WILLIAMS XRDS	8/5/2009	0.88 in.	0/0	$0
ROYAL MILLS	2/28/2011	1 in.	0/0	$0
SIX FORKS	8/29/2011	1.25 in.	0/0	$0
ECHO HGTS	3/31/2012	0.75 in.	0/0	$0
AUBURN	3/31/2012	1.25 in.	0/0	$0
PET XRDS	5/4/2012	1 in.	0/0	$0
AUBURN	5/17/2012	1.25 in.	0/0	$0
AUBURN	5/23/2012	1.25 in.	0/0	$0
FORESTVILLE	5/23/2012	1 in.	0/0	$0
STARMOUNT	5/23/2012	1 in.	0/0	$0
STARMOUNT	5/23/2012	1 in.	0/0	$0
STARMOUNT	5/23/2012	1 in.	0/0	$0
BAYLEAF	7/1/2012	1 in.	0/0	$0
BAYLEAF	7/1/2012	1.75 in.	0/0	$0
UPCHURCH	7/1/2012	1 in.	0/0	$0
FAWLERS XRDS	7/1/2012	1 in.	0/0	$0
FAWLERS XRDS	7/1/2012	1.5 in.	0/0	$0
BAYLEAF	7/1/2012	1.75 in.	0/0	$0
FALLS	7/1/2012	1 in.	0/0	$0
UPCHURCH	7/1/2012	1.75 in.	0/0	$0
SIX FORKS	7/1/2012	1 in.	0/0	$0
AUBURN	7/1/2012	1 in.	0/0	$0
FALLS	7/6/2012	1 in.	0/0	$0
STARMOUNT	7/6/2012	1.75 in.	0/0	$0
Apex				

	Date	Magnitude	Deaths/Injuries	Property Damage*
Apex	5/19/1993	1.75 in.	0/0	$0
Apex	5/19/1993	1 in.	0/0	$0
Apex	5/19/1993	1.75 in.	0/0	$0
Apex	3/23/1995	1.75 in.	0/0	$0
APEX	3/21/1999	0.75 in.	0/0	$0
APEX	4/22/2006	1 in.	0/0	$0
APEX	5/14/2006	1.75 in.	0/0	$0
APEX	6/13/2007	0.75 in.	0/0	$0
APEX	6/1/2008	0.75 in.	0/0	$0
APEX	6/21/2008	0.88 in.	0/0	$0
APEX	3/23/2011	0.75 in.	0/0	$0
APEX	6/21/2011	1 in.	0/0	$0
Cary				
Cary	5/19/1993	2.25 in.	0/0	$9,008
Cary	5/19/1993	1.75 in.	0/0	$0
CARY	7/2/1996	0.75 in.	0/0	$0
CARY	6/2/1997	1 in.	0/0	$0
CARY	6/2/1997	0.88 in.	0/0	$0
CARY	3/20/1998	0.75 in.	0/0	$0
CARY	5/7/1998	0.75 in.	0/0	$0
CARY	4/29/2000	0.75 in.	0/0	$0
CARY	4/1/2001	0.75 in.	0/0	$0
CARY	5/12/2001	0.75 in.	0/0	$0
CARY	5/12/2001	0.75 in.	0/0	$0
CARY	5/14/2006	0.75 in.	0/0	$0
CARY	5/14/2006	0.75 in.	0/0	$0
CARY	4/21/2008	0.88 in.	0/0	$0
CARY	5/20/2008	0.75 in.	0/0	$0
CARY	5/20/2008	0.75 in.	0/0	$0
CARY	8/30/2008	1 in.	0/0	$0
CARY	8/29/2011	1 in.	0/0	$0
CARY	3/31/2012	1.75 in.	0/0	$0
CARY	5/23/2012	2 in.	0/0	$0
CARY	7/27/2012	1.75 in.	0/0	$0
Fuquay Varina				
FUQUAY SPGS	3/20/1998	0.75 in.	0/0	$0
FUQUAY SPGS	7/10/2003	1.75 in.	0/0	$0
FUQUAY SPGS	3/31/2004	0.75 in.	0/0	$0
VARINA	5/14/2006	1 in.	0/0	$0
FUQUAY SPGS	5/14/2006	1 in.	0/0	$0
FUQUAY SPGS	5/14/2006	1 in.	0/0	$0
FUQUAY SPGS	5/14/2006	1 in.	0/0	$0
FUQUAY SPGS	5/14/2006	1.25 in.	0/0	$0
FUQUAY SPGS	5/14/2006	1 in.	0/0	$0
FUQUAY SPGS	4/15/2007	1 in.	0/0	$0
FUQUAY SPGS	7/17/2007	0.75 in.	0/0	$0

	Date	Magnitude	Deaths/Injuries	Property Damage*
Garner				
Nr Garner	7/10/1995	0.75 in.	0/0	$0
GARNER	3/20/1998	0.75 in.	0/0	$0
GARNER	5/26/1998	0.75 in.	0/0	$0
GARNER	6/3/2000	1.75 in.	0/0	$0
GARNER	6/14/2000	1 in.	0/0	$0
GARNER	5/19/2004	1 in.	0/0	$0
GARNER	6/7/2005	1 in.	0/0	$0
GARNER	4/3/2006	1.75 in.	0/0	$0
GARNER	5/14/2006	0.75 in.	0/0	$0
GARNER	5/14/2006	1 in.	0/0	$0
GARNER	5/14/2006	1.75 in.	0/0	$0
GARNER	5/14/2006	0.88 in.	0/0	$0
GARNER	5/14/2006	1.75 in.	0/0	$0
GARNER	5/20/2006	0.75 in.	0/0	$0
Holly Springs				
HOLLY SPGS	6/3/2000	0.75 in.	0/0	$0
HOLLY SPGS	6/1/2001	0.75 in.	0/0	$0
HOLLY SPGS	5/29/2007	1 in.	0/0	$0
HOLLY SPGS	4/27/2008	0.75 in.	0/0	$0
HOLLY SPGS	5/9/2008	0.75 in.	0/0	$0
HOLLY SPGS	5/20/2008	1.75 in.	0/0	$0
HOLLY SPGS	5/23/2012	0.88 in.	0/0	$0
Knightdale				
KNIGHTDALE	5/29/1996	0.75 in.	0/0	$0
KNIGHTDALE	5/7/1998	0.75 in.	0/0	$0
KNIGHTDALE	4/1/2001	1 in.	0/0	$0
KNIGHTDALE	8/5/2004	0.75 in.	0/0	$0
KNIGHTDALE	3/28/2005	0.75 in.	0/0	$0
KNIGHTDALE	5/25/2006	1.75 in.	0/0	$0
KNIGHTDALE	5/20/2008	0.75 in.	0/0	$0
KNIGHTDALE	5/5/2009	1 in.	0/0	$0
Morrisville				
Morrisville	7/10/1994	0.75 in.	0/0	$0
MORRISVILLE	7/14/2004	0.88 in.	0/0	$0
MORRISVILLE	5/9/2008	0.75 in.	0/0	$0
MORRISVILLE	5/20/2008	1.5 in.	0/0	$0
MORRISVILLE	5/20/2008	0.88 in.	0/0	$0
MORRISVILLE	6/14/2008	0.75 in.	0/0	$0
MORRISVILLE	5/5/2009	0.75 in.	0/0	$0
Raleigh				
Raleigh	3/27/1993	0.75 in.	0/0	$0
Raleigh	3/27/1993	0.75 in.	0/0	$0
Raleigh	5/19/1993	1 in.	0/0	$0
Raleigh	5/19/1993	0.75 in.	0/0	$0
RALEIGH, WAKE	5/29/1996	0.75 in.	0/0	$0

	Date	Magnitude	Deaths/Injuries	Property Damage*
FOREST				
RALEIGH	7/31/1996	0.75 in.	0/0	$0
RALEIGH DURHAM ARPT	3/5/1997	1 in.	0/0	$0
NW RALEIGH	5/1/1997	0.75 in.	0/0	$0
2S RDU AIRPORT	5/1/1997	0.88 in.	0/0	$0
RALEIGH	5/1/1997	0.75 in.	0/0	$0
RALEIGH	5/1/1997	0.75 in.	0/0	$0
RALEIGH, CARY, APEX	6/2/1997	1.75 in.	0/0	$0
RALEIGH	6/2/1997	0.75 in.	0/0	$0
NW RALEIGH	7/4/1997	1 in.	0/0	$0
N RALEIGH	7/16/1997	0.75 in.	0/0	$0
RALEIGH	5/8/1998	1 in.	0/0	$0
RALEIGH	5/27/1998	0.75 in.	0/0	$0
RALEIGH	6/15/1998	1.75 in.	0/0	$0
RALEIGH	6/23/1998	1 in.	0/0	$0
RALEIGH	7/4/1998	0.75 in.	0/0	$0
RALEIGH	7/6/1999	0.75 in.	0/0	$0
RALEIGH	5/28/2000	0.75 in.	0/0	$0
RALEIGH	6/3/2000	1 in.	0/0	$0
RALEIGH	6/14/2000	1.75 in.	0/0	$0
RALEIGH	7/17/2000	1.75 in.	0/0	$0
RALEIGH DURHAM ARPT	4/1/2001	0.75 in.	0/0	$0
RALEIGH	3/26/2002	0.88 in.	0/0	$0
RALEIGH	3/31/2002	0.88 in.	0/0	$0
RALEIGH	7/4/2002	0.75 in.	0/0	$0
RALEIGH	3/31/2004	0.88 in.	0/0	$0
RALEIGH	7/14/2004	0.88 in.	0/0	$0
RALEIGH	5/12/2005	1 in.	0/0	$0
RALEIGH	7/13/2005	2 in.	0/0	$0
RALEIGH	10/21/2005	4 in.	0/0	$0
RALEIGH	10/21/2005	0.75 in.	0/0	$0
RALEIGH	4/3/2006	0.88 in.	0/0	$0
RALEIGH	4/22/2006	1.75 in.	0/0	$0
RALEIGH	5/14/2006	1 in.	0/0	$0
RALEIGH	5/14/2006	1 in.	0/0	$0
RALEIGH	5/14/2006	1.75 in.	0/0	$0
RALEIGH	5/20/2006	0.75 in.	0/0	$0
RALEIGH	5/20/2006	1.75 in.	0/0	$0
RALEIGH	5/20/2006	1 in.	0/0	$0
RALEIGH	5/25/2006	1 in.	0/0	$0
RALEIGH	6/6/2006	0.75 in.	0/0	$0
RALEIGH	6/11/2006	1 in.	0/0	$0
RALEIGH	7/27/2006	0.75 in.	0/0	$0
RALEIGH	4/11/2007	0.75 in.	0/0	$0
PURNELL	4/15/2007	0.75 in.	0/0	$0

	Date	Magnitude	Deaths/Injuries	Property Damage*
RALEIGH	4/15/2007	0.88 in.	0/0	$0
RALEIGH	6/29/2007	0.75 in.	0/0	$0
RALEIGH	6/29/2007	0.88 in.	0/0	$0
RALEIGH	7/17/2007	0.75 in.	0/0	$0
RALEIGH	7/17/2007	1 in.	0/0	$0
RALEIGH	7/17/2007	1 in.	0/0	$0
RALEIGH	7/17/2007	0.75 in.	0/0	$0
RALEIGH	7/27/2007	1 in.	0/0	$0
Rolesville				
Rolesville	6/12/1995	1.5 in.	0/0	$0
ROLESVILLE	4/3/2006	1 in.	0/0	$0
ROLESVILLE	5/18/2006	1.75 in.	0/0	$0
ROLESVILLE	5/20/2006	0.88 in.	0/0	$0
ROLESVILLE	5/20/2008	1 in.	0/0	$0
Wake Forest				
WAKE FOREST	5/27/1996	0.75 in.	0/0	$0
WAKE FOREST	4/21/1997	0.75 in.	0/0	$0
WAKE FOREST	6/3/1998	1.25 in.	0/0	$0
WAKE FOREST	6/1/2002	0.75 in.	0/0	$0
WAKE FOREST	4/22/2006	1.75 in.	0/0	$0
WAKE FOREST	4/22/2006	1.75 in.	0/0	$0
WAKE FOREST	4/15/2007	0.88 in.	0/0	$0
WAKE FOREST	6/9/2007	0.88 in.	0/0	$0
Wendell				
Wendell	6/8/1995	0.75 in.	0/0	$0
WENDELL	6/4/1996	1 in.	0/0	$0
WENDELL	5/14/2006	0.75 in.	0/0	$0
WENDELL	5/26/2006	0.75 in.	0/0	$0
WENDELL	6/6/2006	0.75 in.	0/0	$0
WENDELL	5/9/2008	0.75 in.	0/0	$0
Zebulon				
Zebulon	5/26/1995	0.75 in.	0/0	$0
ZEBULON	5/24/1996	1 in.	0/0	$0
ZEBULON	6/3/1998	0.75 in.	0/0	$0
ZEBULON	6/1/2002	1.75 in.	0/0	$0
ZEBULON	3/28/2005	0.75 in.	0/0	$0
ZEBULON	5/25/2006	0.88 in.	0/0	$0

*Property damage is reported in 2013 dollars; All damage may not have been reported.
Source: National Climatic Data Center

5.5.4 Probability of Future Occurrences

Based on historical occurrence information, it is assumed that the probability of future hail occurrences is likely (10 – 100 percent annual probability). Since hail is an atmospheric hazard (coinciding with thunderstorms), it is assumed that all of Wake County has equal exposure to this

hazard. It can be expected that future hail events will continue to cause minor damage to property and vehicles throughout the region.

5.5.5 Consequence Analysis

People (The Public and Public Confidence)

Hail can have a negative impact on the public as it can often cause injury if people are struck by hail stones. Often the impoverished are detrimentally impacted if they cannot find shelter, but hail can impact anyone. There would be little negative impact on public confidence.

Responders

Hail can also affect responders who are often more susceptible to hail events due to the nature of their work which often forces police and emergency medical providers to be exposed to the elements. In these cases, responders could be negatively impacted by hail.

Continuity of Operations

Hail would likely have some impacts on continuity of operations as the warning time for these events is usually shorter and hail stones could potentially knock out power supplies or other critical resources which would affect operations.

Built Environment (Property, Facilities, and Infrastructure)

Hail can often have a significant effect on the built environment, depending on the size of the hail stones. Often these can damage roofs or other parts of homes and businesses as they are essentially rocks that are being propelled at high speeds. Hail can affect most any type of facility or infrastructure as well, causing damage to the structure.

Economy

A hailstorm could negatively impact the economy to some degree if the damage from the storm is large enough. Often hail causes a great deal of damage to personal property such as cars and homes, and these impacts would hurt the overall economy due to recovery efforts.

Environment

Hail often has a serious effect on crops and has been known to cause millions of dollars' worth of damage to farmers. It can also negatively impact livestock, as well as any flora or fauna that is not properly sheltered.

5.6 HURRICANE AND TROPICAL STORM

5.6.1 Background

Hurricanes and tropical storms are classified as cyclones and defined as any closed circulation developing around a low-pressure center in which the winds rotate counter-clockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and whose diameter averages 10 to 30 miles across. A tropical cyclone refers to any such circulation that develops over tropical waters. Tropical cyclones act as a "safety-valve," limiting the continued build-up of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole-ward

latitudes. The primary damaging forces associated with these storms are high-level sustained winds, heavy precipitation, and tornadoes.

The key energy source for a tropical cyclone is the release of latent heat from the condensation of warm water. Their formation requires a low-pressure disturbance, warm sea surface temperature, rotational force from the spinning of the earth, and the absence of wind shear in the lowest 50,000 feet of the atmosphere. The majority of hurricanes and tropical storms form in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico during the official Atlantic hurricane season, which encompasses the months of June through November. The peak of the Atlantic hurricane season is in early to mid-September and the average number of storms that reach hurricane intensity per year in the Atlantic basin is about six.

As an incipient hurricane develops, barometric pressure (measured in millibars or inches) at its center falls and winds increase. If the atmospheric and oceanic conditions are favorable, it can intensify into a tropical depression. When maximum sustained winds reach or exceed 39 miles per hour, the system is designated a tropical storm, given a name, and is closely monitored by the National Hurricane Center in Miami, Florida. When sustained winds reach or exceed 74 miles per hour the storm is deemed a hurricane. Hurricane intensity is further classified by the Saffir-Simpson Scale (**Table 5.14**), which rates hurricane intensity on a scale of 1 to 5, with 5 being the most intense.

TABLE 5.14: SAFFIR-SIMPSON SCALE

Category	Maximum Sustained Wind Speed (MPH)	Minimum Surface Pressure (Millibars)
1	74–95	Greater than 980
2	96–110	979–965
3	111–129	964–945
4	130–156	944–920
5	157 +	Less than 920

Source: National Hurricane Center (2012)

The Saffir-Simpson Scale categorizes hurricane intensity linearly based upon maximum sustained winds and barometric pressure, which are combined to estimate potential damage. Categories 3, 4, and 5 are classified as "major" hurricanes and, while hurricanes within this range comprise only 20 percent of total tropical cyclone landfalls, they account for over 70 percent of the damage in the United States. **Table 5.15** describes the damage that could be expected for each category of hurricane. Damage during hurricanes may also result from spawned tornadoes, storm surge, and inland flooding associated with heavy rainfall that usually accompanies these storms.

TABLE 5.15: HURRICANE DAMAGE CLASSIFICATIONS

Storm Category	Damage Level	Description of Damages	Photo Example
1	MINIMAL	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage.	
2	MODERATE	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings may break their moorings.	
3	EXTENSIVE	Some structural damage to small residences and utility buildings, with a minor amount of curtainwall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Terrain may be flooded well inland.	
4	EXTREME	More extensive curtainwall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland.	
5	CATASTROPHIC	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required.	

Source: National Hurricane Center; Federal Emergency Management Agency

5.6.2 Location and Spatial Extent

Hurricanes and tropical storms threaten the entire Atlantic and Gulf seaboard of the United States. While coastal areas are most directly exposed to the brunt of landfalling storms, their impact is often felt hundreds of miles inland and they can affect Wake County and its municipalities. All areas in Wake County are equally susceptible to hurricane and tropical storms.

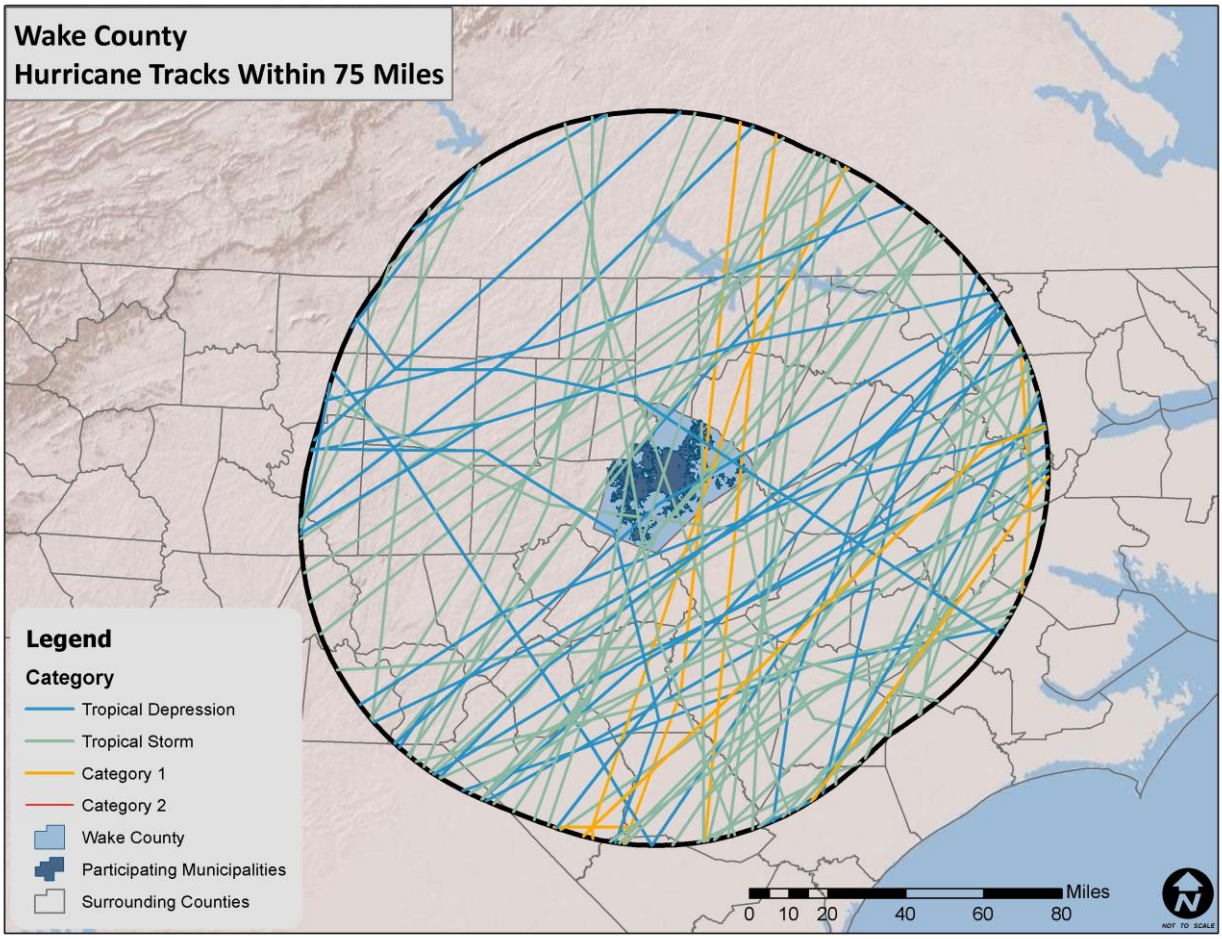
5.6.3 Historical Occurrences

According to the National Hurricane Center's historical storm track records, 87 hurricane or tropical storm tracks have passed within 75 miles of Wake County since 1850.[6] This includes eight hurricanes, fifty-five tropical storms, and twenty-four tropical depressions.

Of the recorded storm events, twenty-one storms traversed directly through Wake County as shown in **Figure 5.4**. **Table 5.16** provides for each event the date of occurrence, name (if applicable), maximum wind speed (as recorded within 75 miles of Wake County) and Category of the storm based on the Saffir-Simpson Scale.

[6] These storm track statistics do not include extra-tropical storms. Though these related hazard events are less severe in intensity, they may cause significant local impact in terms of rainfall and high winds.

FIGURE 5.4: HISTORICAL HURRICANE STORM TRACKS WITHIN 75 MILES OF WAKE COUNTY



Source: National Oceanic and Atmospheric Administration; National Hurricane Center

TABLE 5.16: HISTORICAL STORM TRACKS WITHIN 75 MILES OF WAKE COUNTY (1850–2013)

Date of Occurrence	Storm Name	Maximum Wind Speed (knots)	Storm Category
1851	NOT NAMED	35	Tropical Storm
1853	NOT NAMED	62	Tropical Storm
1854	NOT NAMED	57	Tropical Storm
1859	NOT NAMED	53	Tropical Storm
1859	NOT NAMED	35	Tropical Storm
1867	NOT NAMED	35	Tropical Storm
1873	XXXX873144	44	Tropical Storm
1873	NOT NAMED	44	Tropical Storm
1876	NOT NAMED	62	Tropical Storm
1877	NOT NAMED	48	Tropical Storm
1878	NOT NAMED	44	Tropical Storm
1878	NOT NAMED	79	Category 1
1882	NOT NAMED	53	Tropical Storm

Date of Occurrence	Storm Name	Maximum Wind Speed (knots)	Storm Category
1883	NOT NAMED	44	Tropical Storm
1885	NOT NAMED	35	Tropical Storm
1886	NOT NAMED	31	Tropical Depression
1886	NOT NAMED	35	Tropical Storm
1886	NOT NAMED	53	Tropical Storm
1887	NOT NAMED	31	Tropical Depression
1888	NOT NAMED	31	Tropical Depression
1889	NOT NAMED	35	Tropical Storm
1891	NOT NAMED	35	Tropical Storm
1893	NOT NAMED	44	Tropical Storm
1893	NOT NAMED	70	Category 1
1893	NOT NAMED	31	Tropical Depression
1896	NOT NAMED	62	Tropical Storm
1899	NOT NAMED	66	Category 1
1902	NOT NAMED	35	Tropical Storm
1902	NOT NAMED	31	Tropical Depression
1904	NOT NAMED	48	Tropical Storm
1907	NOT NAMED	53	Tropical Storm
1911	NOT NAMED	22	Tropical Depression
1912	NOT NAMED	53	Tropical Storm
1913	NOT NAMED	57	Tropical Storm
1913	NOT NAMED	66	Category 1
1915	NOT NAMED	35	Tropical Storm
1916	NOT NAMED	31	Tropical Depression
1916	NOT NAMED	31	Tropical Depression
1920	NOT NAMED	31	Tropical Depression
1924	NOT NAMED	53	Tropical Storm
1927	NOT NAMED	44	Tropical Storm
1928	NOT NAMED	35	Tropical Storm
1928	NOT NAMED	40	Tropical Storm
1929	NOT NAMED	35	Tropical Storm
1935	NOT NAMED	53	Tropical Storm
1940	NOT NAMED	62	Tropical Storm
1944	NOT NAMED	48	Tropical Storm
1944	NOT NAMED	31	Tropical Depression
1945	NOT NAMED	35	Tropical Storm
1946	NOT NAMED	22	Tropical Depression
1947	NOT NAMED	22	Tropical Depression
1954	HAZEL	70	Category 1
1955	DIANE	53	Tropical Storm
1956	IVY	35	Tropical Storm
1959	CINDY	26	Tropical Depression

Date of Occurrence	Storm Name	Maximum Wind Speed (knots)	Storm Category
1960	BRENDA	44	Tropical Storm
1961	UNNAMED	44	Tropical Storm
1964	CLEO	26	Tropical Depression
1965	UNNAMED	26	Tropical Depression
1968	CELESTE	31	Tropical Depression
1970	ALMA	22	Tropical Depression
1971	UNNAMED	40	Tropical Storm
1971	HEIDI	40	Tropical Storm
1972	AGNES	35	Tropical Storm
1976	SUBTROP:SUBTROP 3	35	Tropical Storm
1979	DAVID	35	Tropical Storm
1984	DIANA	40	Tropical Storm
1985	ONE-C	31	Tropical Depression
1985	BOB	26	Tropical Depression
1987	UNNAMED	53	Tropical Storm
1996	JOSEPHINE	44	Tropical Storm
1996	BERTHA	57	Tropical Storm
1996	FRAN	57	Tropical Storm
1997	DANNY	31	Tropical Depression
1998	EARL	66	Category 1
1999	DENNIS	31	Tropical Depression
1999	FLOYD*	66	Category 1
2000	GORDON	35	Tropical Storm
2000	HELENE	35	Tropical Storm
2003	NOT NAMED	57	Tropical Storm
2004	CHARLEY	79	Category 1
2004	GASTON	35	Tropical Storm
2004	JEANNE	31	Tropical Depression
2006	ALBERTO	35	Tropical Storm
2008	OMAR	26	Tropical Depression
2008	SIXTEEN	26	Tropical Depression
2008	HANNA	40	Tropical Storm

**Although Hurricane Floyd's track traversed just outside of the 75 mile buffer area, it was included in the hazard history since a federal disaster area was declared for Wake County as a result of the storm's impact.*
Source: National Hurricane Center

The National Climatic Data Center reported seven events associated with a hurricane or tropical storm in Wake County between 1950 and 2013. These storms are listed in **Table 5.17** and are generally representative of storms with the greatest impact on the county over the time period.

TABLE 5.17: HISTORICAL HURRICANE/TROPICAL STORM OCCURRENCES IN WAKE COUNTY

Date of Occurrence	Storm Name	Deaths/Injuries	Property Damage*
7/12/1996	Hurricane Bertha	0/0	$0

Date of Occurrence	Storm Name	Deaths/Injuries	Property Damage*
9/5/1996	Hurricane Fran	7/2	$0
8/27/1998	Hurricane Bonnie	0/0	$0
9/4/1999	Hurricane Dennis	0/0	$0
9/15/1999	Hurricane Floyd	0/0	$179,765,471
9/18/2003	Hurricane Isabel	1/0	$776,235
9/1/2006	Tropical Storm Ernesto	0/0	$0

*Property damage is reported in 2013 dollars; All damage may not have been reported.

Federal records also indicate that three disaster declarations were made in 1996 (Hurricane Fran), 1999 (Hurricane Floyd), and 2003 (Hurricane Isabel) for the county.[7]

Flooding and high winds are both hazards of concern with hurricane and tropical storm events in Wake County as evidenced by the difference in impacts caused by Hurricanes Fran and Floyd. Whereas Floyd's effects were primarily due to flooding, Fran's high winds caused damage throughout the county in conjunction with flooding impacts. Some anecdotal information is available for the major storms that have impacted the area as found below:

Hurricane Fran – September 5-6, 1996
After being saturated with rain just a few weeks earlier by Hurricane Bertha, Wake County was impacted by the one of the most devastating storms to ever make landfall along the Atlantic Coast. Fran dropped more than 10 inches of rain in many areas and had sustained winds of around 115 miles per hour as it hit the coast and began its path along the I-40 corridor towards Wake County. In the end, over 900 million dollars in damages to residential and commercial property and at least 1 death were reported in Wake County alone. Damages to infrastructure and agriculture added to the overall toll and more than 1.7 million people in the state were left without power.

Hurricane Floyd – September 16-17, 1999
Much like Hurricane Fran, Hurricane Floyd hit the North Carolina coast just 10 days after Tropical Storm Dennis dropped more than 10 inches of rain in many areas of the state. As a result, the ground was heavily saturated when Floyd dumped an additional 15 to 20 inches in some areas. Although much of the heavy damage from the storm was found further east, Wake County suffered significant damage from the storm. Across the state more than 6 billion dollars in property damage was recorded and agricultural impacts were extremely high.

5.6.4 Probability of Future Occurrences

Given the inland location of the county, Wake County is less likely to be affected by a hurricane or tropical storm system than counties closer to the coast. However, given its location in the eastern part of the state, hurricanes and tropical storms still remain a real threat to Wake County. Based on historical evidence, the probability level of future occurrence is likely (annual probability between 10 and 100 percent). Given the regional nature of the hazard, all areas are equally exposed to this hazard. When the county is impacted, the damage could be catastrophic, threatening lives and property throughout the planning area.

[7] A complete listing of historical disaster declarations can be found in Section 4: *Hazard Identification*.

5.6.5 Consequence Analysis

People (The Public and Public Confidence)

HAZUS-MH estimates the number of households that are expected to be displaced from their homes and the number of displaced people that will require accommodations in temporary public shelters due to a hurricane scenario that was modeled similar to Hurricane Fran in 1996. The model estimates 637 households to be displaced due to the hurricane. Of these, 156 people (out of a total population of 627,846) will seek temporary shelter in public shelters. The total economic loss estimated for the hurricane is $751 million, which represents 1.53 percent of the total replacement value of the county's buildings. This hazard could potentially have a negative effect on public confidence due to the possibility of a high magnitude event and the difficulties that might arise for governments in terms of response and recovery.

Responders

The impacts on responders from this type of storm could potentially be very high as responders may be physically injured or killed during a storm event by flooding or high winds. In addition, their homes and personal effects could also be impacted which would limit their response capability.

In terms of their actual response capacity, downed trees in the wake of a hurricane often block roads and make ingress and egress difficult, thereby causing issues with response time. This is also often true of the resulting floodwaters. Moreover, due to the large scale spatial impact of hurricanes and the number of citizens affected by the storm, response time will be reduced because of the number of incidents that require emergency responders.

Continuity of Operations

Continuity of operations in a hurricane event can be severely affected if power is lost or if critical facilities or infrastructure are damaged during an event. Although Wake County has a plan in place to maintain continuity of operations in the event of a storm, a hurricane with a high magnitude would likely disrupt operations to some degree due to the impacts it would have on personnel.

Built Environment (Property, Facilities, and Infrastructure)

HAZUS-MH estimates that about 8,186 buildings will be at least moderately damaged due to the Category 3 storm. This is over 3 percent of the total number of buildings in the county. There are an estimated 163 buildings that will be completely destroyed. **Table 5.18** summarizes the expected damage by general occupancy for buildings in Wake County, and **Table 5.19** summarizes the expected damage by general building type.

TABLE 5.18 DAMAGE BY GENERAL BUILDING OCCUPANCY IN WAKE COUNTY

Occupancy	None	Minor	Moderate	Severe	Destruction
Agriculture	861 (82.12%)	131 (12.50%)	38 (3.61%)	17 (1.61%)	2 (.16%)
Commercial	12,784 (82.31%)	1,908 (12.28%)	769 (4.95%)	70 (.45%)	1 (.01%)
Education	460 (84.49%)	65 (12.00%)	18 (3.23%)	2 (.28%)	0 (0%)
Government	392 (80.26%)	69 (14.24%)	24 (4.99%)	2 (.51%)	0 (0%)
Industrial	3,797 (85.66%)	479 (10.81%)	132 (2.98%)	22 (.55%)	1 (.03%)
Religion	1,127 (84.26%)	171 (12.78%)	36 (2.73%)	3 (.23%)	0 (0%)

Occupancy	None	Minor	Moderate	Severe	Destruction
Residential	173,128 (79.19%)	38,447 (17.59%)	6,693 (3.06%)	195 (.09%)	159 (.07%)
Total	192,549	41,271	7,711	312	163

TABLE 5.19 DAMAGE BY GENERAL BUILDING TYPE IN WAKE COUNTY

Building Type	None	Minor	Moderate	Severe	Destruction
Concrete	2,677 (79.81%)	477 (14.21%)	194 (5.79%)	6 (.19%)	0 (0%)
Masonry	23,733 (79.53%)	4,180 (14.01%)	1,846 (6.19%)	76 (.25%)	7 (.02%)
MH	13,453 (96.56%)	314 (2.25%)	130 (.93%)	2 (.001%)	34 (.24%)
Steel	9,223 (82.45%)	1,260 (11.26%)	635 (5.68%)	68 (.61%)	1 (.01%)
Wood	145,517 (79.22%)	33,708 (18.35%)	4,157 (2.26%)	176 (.10%)	128 (.07%)
Total	194,603	39,939	6,962	328	170

Economy

Debris Generation

HAZUS-MH estimates the amount of debris that will be generated by the hurricane scenario. The model breaks the debris into three general categories: brick/wood, reinforced concrete/steel, and trees. This distinction is made because of the different types of material-handling equipment required to handle the debris. The model estimates that a total of 623,927 tons of debris will be generated. Of the total amount, brick/wood comprises 20 percent of the total, reinforced concrete/steel comprises 0 percent of the total, and tree debris comprises 80 percent of the total. The total economic loss estimated for the hurricane is $751 million, which represents 1.53 percent of the total replacement value of the county's buildings.

Building-Related Losses

The building-related losses include direct property damage losses and business interruption losses. Direct property damage losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the hurricane. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the hurricane.

TABLE 5.20 BUILDING DAMAGE LOSSES (IN THOUSANDS OF DOLLARS)

Category Area	Residential	Commercial	Industrial	Others	Total
Building	$482,932.2	$57,563.02	$7,848.39	$9,540.64	$557,884.47
Content	$46,139.39	$17,695.36	$4,083.74	$2,969.34	$79,887.82
Inventory	$0	$501.80	$1,009.18	$121.81	$1,632.79
Subtotal	$529,071.59	$75.760.18	$12,941.31	$12,631.79	$639,405.08

Property Damage and Business Interruption

Total property damage losses are $751 million. Four percent of the estimated losses were related to the business interruption of the county. By far, the largest loss was sustained by the residential occupancies which made up over 78 percent of the total loss. **Table 5.20** provides a summary of the losses associated with the building damage, and **Table 5.21** provides a summary of the losses associated with property damage.

TABLE 5.21 PROPERTY DAMAGE LOSSES (IN THOUSANDS OF DOLLARS)

Category Area	Residential	Commercial	Industrial	Others	Total
Income	$.11	$11,463.75	$144.66	$1,546.19	$13,154.72
Relocation	$41,120.72	$15,923.89	$867.87	$2,717.07	$60,629.55
Rental	$19,385.88	$8,314.43	$113.84	$354.26	28,168.41
Wage	$.26	$9,056.99	$243.10	$9,457.60	$18,757.94
Subtotal	$60,506.97	$44,759.06	$1,369.47	$14,075.12	$120,710.62

Environment

Flooding and wind damage are the main impacts that would be felt by a hurricane in Wake County. Please refer to the Flood Hazard Profile for a discussion on flood-related impacts and the Tornado Hazard Profile for a discussion on relevant wind-related impacts.

5.7 LIGHTNING

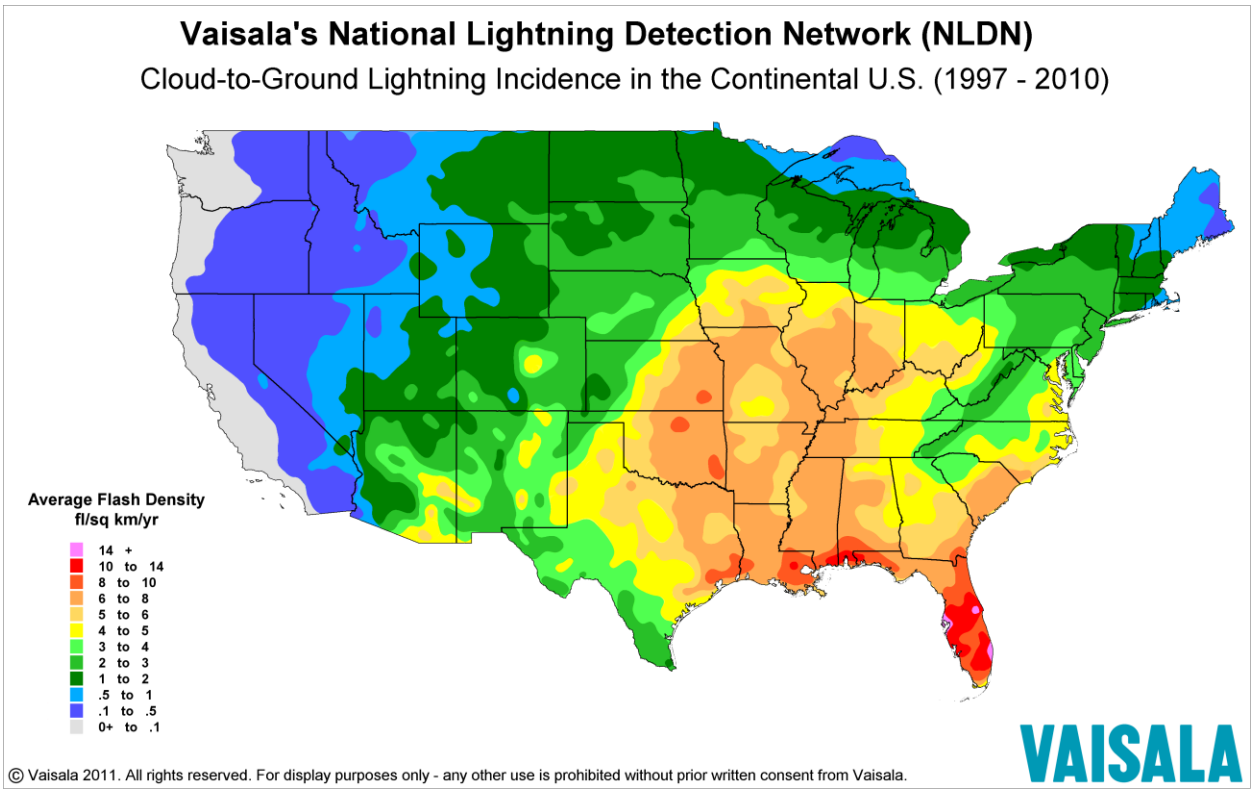
5.7.1 Background

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes the thunder which often accompanies lightning strikes. While most often affiliated with severe thunderstorms, lightning may also strike outside of heavy rain and might occur as far as 10 miles away from any rainfall.

Lightning strikes occur in very small, localized areas. For example, they may strike a building, electrical transformer, or even a person. According to FEMA, lightning injures an average of 300 people and kills 80 people each year in the United States. Direct lightning strikes also have the ability to cause significant damage to buildings, critical facilities, and infrastructure largely by igniting a fire. Lightning is also responsible for igniting wildfires that can result in widespread damages to property.

Figure 5.5 shows a lightning flash density map for the years 1997-2010 based upon data provided by Vaisala's U.S. National Lightning Detection Network (NLDN®).

FIGURE 5.5: LIGHTNING FLASH DENSITY IN THE UNITED STATES



Source: Vaisala U.S. National Lightning Detection Network

5.7.2 Location and Spatial Extent

Lightning occurs randomly, therefore it is impossible to predict where and with what frequency it will strike. It is assumed that all of Wake County is uniformly exposed to lightning.

5.7.3 Historical Occurrences

According to the National Climatic Data Center, there have been a total of 34 recorded lightning events in Wake County since 1950.[8] These events resulted in nearly $3.4 million (2013 dollars) in damages, as listed in summary **Table 5.22**. Furthermore, lightning caused two fatalities throughout Wake County. Detailed information on historical lightning events can be found in **Table 5.23.**

It is certain that more than 34 events have impacted the county. Many of the reported events are those that caused significant damage. Therefore, it should be expected that damages are likely much higher for this hazard than what is reported.

[8] These lightning events are only inclusive of those reported by the National Climatic Data Center (NCDC). It is certain that additional lightning events have occurred in Wake County. The State Fire Marshall's office was also contacted for additional information but none could be provided. As additional local data becomes available, this hazard profile will be amended.

TABLE 5.22: SUMMARY OF LIGHTNING OCCURRENCES IN WAKE COUNTY

Location	Number of Occurrences	Deaths/Injuries	Property Damage (2013)
Apex	2	0/0	$95,703
Cary	6	0/0	$133,182
Fuquay-Varina	1	0/0	$0
Garner	0	0/0	$0
Holly Springs	2	0/0	$1,463,162
Knightdale	2	1/0	$11,255
Morrisville	1	0/0	$5,305
Raleigh	6	0/0	$670,412
Rolesville	0	0/0	$0
Wake Forest	1	0/0	$55,838
Wendell	1	0/0	$622,905
Zebulon	0	0/0	$0
Unincorporated Area	12	1/0	$294,407
WAKE COUNTY TOTAL	**34**	**2/0**	**$3,352,169**

Source: National Climatic Data Center

TABLE 5.23: HISTORICAL LIGHTNING OCCURRENCES IN WAKE COUNTY

	Date	Deaths/ Injuries	Property Damage*	Details
Wake County				
FALLS	7/24/1999	1/0	$0	A man was stepping from his boat onto the dock when he was hit by lightning. He never regained consciousness and died the next day.
MACEDONIA	7/16/2010	0/0	$11,255	A broken line of showers and thunderstorms developed across western North Carolina during the afternoon and then moved east across central and eastern North Carolina during the evening hours
FALLS	7/20/2010	0/0	$11,255	An upper level disturbance combined with strong afternoon heating to produce scattered strong to severe storms. Additional storms then developed along the numerous outflow boundaries.
WILDERS GROVE	7/17/2010	0/0	$11,255	Thunderstorms developed across Virginia and central North Carolina as a small long lived MCS crossed the central and southern Appalachians. Widespread wind damage was reported across northern and central portions of central North Carolina.

	Date	Deaths/ Injuries	Property Damage*	Details
SIX FORKS	7/29/2010	0/0	$2,251	A line of strong to severe storms formed as a cold front moved into a very moist and moderately unstable air mass..
LEESVILLE	7/20/2010	0/0	$16,883	An upper level disturbance combined with strong afternoon heating to produce scattered strong to severe storms. Additional storms then developed along the numerous outflow boundaries.
FORESTVILLE	7/1/2009	0/0	$5,796	A strong upper level disturbance and attendant surface cold front combined to produce scattered showers and thunderstorms across the eastern half of central North Carolina. The unseasonably dry low levels of the atmosphere across central North Carolina created a favorable environment for any thunderstorms that developed to produce damaging winds. Many of the thunderstorms that developed became severe and produced damaging winds across the eastern half of central North Carolina
UPCHURCH	6/15/2010	0/0	$56,275	A broken line of thunderstorms, some which were severe, tracked east across the Northwest and Eastern Piedmont. The storms were associated with a weak upper level disturbance which combined with afternoon heating.
UPCHURCH	6/22/2010	0/0	$140,689	Strong insolation underneath an oppressive upper level heat ridge resulted in isolated pulse severe convection.
WILLOW	6/2/2010	0/0	$28,138	Strong to severe slow moving storms and merging storms resulted in severe damaging winds and flash flooding across portions of Central North Carolina. Frequent to excessive lightning resulted in property damage across the area to homes and businesses.
WYATT	5/9/2012	0/0	$5,305	A cold front moved into central North Carolina and interacted with an unstable air mass to

	Date	Deaths/ Injuries	Property Damage*	Details
				produce scattered showers and thunderstorms. Some of these storms became strong to severe across portions of the Piedmont and Coastal Plain of central North Carolina.
UPCHURCH	7/6/2012	0/0	$5,305	An upper level disturbance moved across central North Carolina and interacted with moderate to strong instability to trigger scattered showers and thunderstorms. Several of these storms became severe and produced damaging winds and a few isolated severe hail reports.
Apex				
Apex	5/19/1993	0/0	$90,075	Lightning caused $5,000 of structural damage to a house.
APEX	7/27/2010	0/0	$5,628	A very moist and moderately unstable air mass combined with a weak upper level disturbance to cause minor flash flooding and an isolated severe storm..
Cary				
CARY	5/3/1998	0/0	$79,768	A large house was struck by lightning on Gold Meadow Drive in Cary. The strike caused an electrical fire that damaged most of the house. Smoke from the fire produced the most damage.
CARY	9/3/2000	0/0	$0	Lightning struck a house.
CARY	3/7/2005	0/0	$26,095	Lighting struck a tree outside a Cary residence. Lightning then entered the natural gas line rupturing the line under the house resulting in a severely damaging fire.
CARY	2/28/2011	0/0	$5,464	A bowing line segment developed ahead of a strong cold front approaching from the west. Despite very strong deep layer shear, marginal instability resulted in only sporadic |reports of wind damage across central North Carolina.
CARY	2/28/2011	0/0	$5,464	A bowing line segment developed ahead of a strong cold front approaching from the west. Despite very strong deep layer shear, marginal instability

	Date	Deaths/ Injuries	Property Damage*	Details
				resulted in only sporadic |reports of wind damage across central North Carolina.
CARY	7/24/2011	0/0	$16,391	A cluster of shower and thunderstorms moved off the Appalachians and into central North Carolina during the afternoon. The severe storms produced thunderstorm wind damage across the Central Piedmont with minor structural damage to a couple of outdoor buildings.
Fuquay-Varina				
FUQUAY SPGS	6/22/2001	0/0	$0	Lightning set fire to a house on Bennet Road. Damage amount unknown.
Garner				
None reported				
Holly Springs				
HOLLY SPGS	7/29/2010	0/0	$337,653	A line of strong to severe storms formed as a cold front moved into a very moist and moderately unstable air mass.
HOLLY SPGS	6/2/2010	0/0	$1,125,509	Strong to severe slow moving storms and merging storms resulted in severe damaging winds and flash flooding across portions of Central North Carolina. Frequent to excessive lightning resulted in property damage across the area to homes and businesses.
Knightdale				
KNIGHTDALE	7/13/2005	1/0	$0	A smoldering tree which had been struck by lightning a few hours earlier fell, killing a firefighter.
KNIGHTDALE	7/17/2010	0/0	$11,255	Thunderstorms developed across Virginia and central North Carolina as a small long lived MCS crossed the central and southern Appalachians. Widespread wind damage was reported across northern and central portions of central North Carolina.
Morrisville				
MORRISVILLE	7/6/2012	0/0	$5,305	An upper level disturbance moved across central North Carolina and interacted with moderate to strong instability

	Date	Deaths/ Injuries	Property Damage*	Details
				to trigger scattered showers and thunderstorms. Several of these storms became severe and produced damaging winds and a few isolated severe hail reports.
Raleigh				
Raleigh	7/10/1994	0/0	$87,785	A lightning strike entered a home on New Hope Road and shorted out the television set, causing the house to go up in flames.
Raleigh	7/17/1994	0/0	$87,785	Three house fires were caused by lightning.
N Raleigh	7/17/1995	0/0	$256,032	Lightning started a fire that destroyed a home.
RALEIGH	4/22/2006	0/0	$0	Numerous house fires reported throughout the county. At least four homes totally destroyed and 24 apartments in brier creek community destroyed.
RALEIGH	4/3/2006	0/0	$0	Lightning destroyed 3 apartment units.
RALEIGH	8/15/2008	0/0	$238,810	Two homes struck by lightning in the Raleigh caught fire resulting in extensive damage to each home.
Rolesville				
None reported				
Wake Forest				
WAKE FOREST	1/16/1998	0/0	$55,838	Lightning struck a brick house on Seawell Drive in Wake Forest about 20 miles northeast of Raleigh during the early afternoon. The lightning bolt hit the chimney of the new two story house, and the current ran throughout the house's wiring and into one of the bedrooms. Most of the damage was to the roof and in the bedroom. Flying debris and brick knocked holes in the walls, and bricks from the chimney were found 105 feet away in a neighbor's yard.
Wendell				
WENDELL	8/22/2003	0/0	$622,905	Lightning set fire to a home, destroying it.
Zebulon				
None reported				

	Date	Deaths/ Injuries	Property Damage*	Details

*Property damage is reported in 2013 dollars; All damages have not likely been reported.
Source: National Climatic Data Center

5.7.4 Probability of Future Occurrences

Although there were not a high number of historical lightning events reported throughout Wake County via NCDC data, it is a regular occurrence accompanied by thunderstorms. In fact, lightning events will assuredly happen on an annual basis, though not all events will cause damage. According to Vaisala's U.S. National Lightning Detection Network (NLDN®), Wake County is located in an area of the country that experienced an average of 4 to 5 lightning flashes per square kilometer per year between 1997 and 2010. Therefore, the probability of future events is highly likely (100 percent annual probability). It can be expected that future lightning events will continue to threaten life and cause minor property damages throughout the region.

5.7.5 Consequence Analysis

People (The Public and Public Confidence)
Although relatively rare when compared to other hazards, the impacts of lightning on people can be severe, resulting in death or severe injury if a person is struck. Fatalities and injuries from lightning events most often occur when a person is exposed and in outdoor conditions during a thunderstorm. Exposure to water and open areas also increases the likelihood that a person will be struck. Lightning generally has a low probability of impacting public confidence.

Responders
Although responders are generally aware of the effects of lightning and take precautions to avoid being impacted by a lightning strike, it is possible that they could be struck. Moreover, taking the necessary precautions to avoid a lightning strike can often reduce response times as staying inside and away from lightning is the best way to avoid injury from the hazard.

Continuity of Operations
Most critical facilities and infrastructure are protected against lightning via surge protectors and lightning rods. However, if lightning were to shut down large parts of the power grid due to blowing a transformer, operations would be detrimentally impacted. In general, however, continuity of operations during a lightning event would not be affected.

Built Environment (Property, Facilities, and Infrastructure)
Lightning generally does not have a major impact on property, facilities, or infrastructure. However, it has been known to affect power and energy sources through strikes which can shut down power for hours and sometimes days. Lightning is also responsible for igniting fires that can result in widespread damage to property.

Economy
Since lightning events generally pass through the area quickly and cause relatively little property damage when compared to other hazards, effects on the economy will likely be minimal. Nevertheless,

if power-related infrastructure is damaged, this could cause some economic strain to replace and get the system back to full capacity.

Environment

The environmental effects of lightning are relatively minimal, although lightning has been known to cause wildfires which can lead to widespread damage. For more details on these impacts, please see this section of the wildfire hazard.

5.8 SEVERE THUNDERSTORM/HIGH WIND

5.8.1 Background

Thunderstorms can produce a variety of accompanying hazards including wind (discussed here), hail, and lightning.[9] Although thunderstorms generally affect a small area, they are very dangerous and may cause substantial property damage.

Three conditions need to occur for a thunderstorm to form. First, it needs moisture to form clouds and rain. Second, it needs unstable air, such as warm air that can rise rapidly (this often referred to as the "engine" of the storm). Third, thunderstorms need lift, which comes in the form of cold or warm fronts, sea breezes, mountains, or the sun's heat. When these conditions occur simultaneously, air masses of varying temperatures meet, and a thunderstorm is formed. These storm events can occur singularly, in lines, or in clusters. Furthermore, they can move through an area very quickly or linger for several hours.

According to the National Weather Service, more than 100,000 thunderstorms occur each year, though only about 10 percent of these storms are classified as "severe." A severe thunderstorm occurs when the storm produces at least one of these three elements: 1) hail of three-quarters of an inch, 2) a tornado, or 3) winds of at least 58 miles per hour.

Thunderstorm events have the capability of producing straight-line winds that can cause severe destruction to communities and threaten the safety of a population. Such wind events, sometimes separate from a thunderstorm event, are common in Wake County. Therefore, high winds are also reported in this section.

High winds can form due to pressure of the Northeast coast that combines with strong pressure moving through the Ohio Valley. This creates a tight pressure gradient across the region, resulting in high winds which increase with elevation. It is common for gusts of 30 to 60 miles per hour during the winter months.

Downbursts are also possible with thunderstorm events. Such events are a burst of wind in excess of 125 miles per hour. They are often confused with tornadoes. Downbursts are caused by down drafts from the base of a convective thunderstorm cloud. It occurs when rain-cooled air within the cloud becomes heavier than its surroundings. Thus, air rushes towards the ground in a destructive yet isolated manner. There are two types of downbursts. Downbursts less than 2.5 miles wide, duration less than 5 minutes, and winds up to 168 miles per hour are called "microbursts." Larger events greater than 2.5

[9]Lightning and hail hazards are discussed as separate hazards in this section.

miles at the surface and longer than 5 minutes with winds up to 130 miles per hour are referred to as "macrobursts."

5.8.2 Location and Spatial Extent

A wind event is an atmospheric hazard, and thus has no geographic boundaries. It is typically a widespread event that can occur in all regions of the United States. However, thunderstorms are most common in the central and southern states because atmospheric conditions in those regions are favorable for generating these powerful storms. Also, Wake County typically experiences several straight-line wind events each year. These wind events can and have caused significant damage. It is assumed that Wake County has uniform exposure to a thunderstorm/wind event and the spatial extent of an impact could be large.

5.8.3 Historical Occurrences

Severe storms were at least partially responsible for three disaster declarations in Wake County in 1988, 1998, and 2011. According to NCDC, there have been 351 reported historic thunderstorm/high wind events in Wake County.[10] This includes data collected since 1994 for high wind and since 1950 for thunderstorms. These events caused over $1.2 million (2013 dollars) in damages. There were reports of six injuries and one fatality. **Table 5.24** summarize this information. **Table 5.25** present detailed high wind and thunderstorm wind event reports including date, magnitude, and associated damages for each event.[11]

TABLE 5.24: SUMMARY OF HIGH WIND/THUNDERSTORM OCCURRENCES IN WAKE COUNTY

Location	Number of Occurrences	Deaths/Injuries	Property Damage (2013 dollars)
Apex	9	0/0	$51,338
Cary	18	0/0	$51,206
Fuquay-Varina	21	0/4	$467,105
Garner	11	0/0	$0
Holly Springs	13	0/0	$119,110
Knightdale	2	0/0	$1,126
Morrisville	5	0/0	$0
Raleigh	67	0/0	$164,787
Rolesville	9	0/0	$0
Wake Forest	5	0/0	$0
Wendell	1	0/0	$24,303
Zebulon	4	0/0	$40,283
Unincorporated Area	186	1/2	$323,146
WAKE COUNTY TOTAL	**351**	**1/6**	**$1,242,404**

Source: National Climatic Data Center

[10] These thunderstorm events are only inclusive of those reported by the National Climatic Data Center (NCDC). It is likely that additional thunderstorm events have occurred in Wake County. As additional local data becomes available, this hazard profile will be amended.

[11] The dollar amount of damages provided by NCDC is divided by the number of affected counties to reflect a damage estimate for the county.

TABLE 5.25: HISTORICAL HIGH WIND/THUNDERSTORM OCCURRENCES IN WAKE COUNTY

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Wake County					
Wake County	6/15/1958	TSTM WIND	0 kts.	0/0	$0
Wake County	6/15/1958	TSTM WIND	0 kts.	0/0	$0
Wake County	6/21/1964	TSTM WIND	50 kts.	0/0	$0
Wake County	10/7/1965	TSTM WIND	0 kts.	0/0	$0
Wake County	7/14/1966	TSTM WIND	0 kts.	0/0	$0
Wake County	7/20/1970	TSTM WIND	0 kts.	0/0	$0
Wake County	8/3/1970	TSTM WIND	0 kts.	0/0	$0
Wake County	5/17/1973	TSTM WIND	0 kts.	0/0	$0
Wake County	5/28/1973	TSTM WIND	0 kts.	0/0	$0
Wake County	8/12/1973	TSTM WIND	0 kts.	0/0	$0
Wake County	8/12/1973	TSTM WIND	0 kts.	0/0	$0
Wake County	6/23/1974	TSTM WIND	0 kts.	0/0	$0
Wake County	3/24/1975	TSTM WIND	0 kts.	0/0	$0
Wake County	3/24/1975	TSTM WIND	0 kts.	0/0	$0
Wake County	3/24/1975	TSTM WIND	0 kts.	0/0	$0
Wake County	10/9/1976	TSTM WIND	0 kts.	0/0	$0
Wake County	7/13/1977	TSTM WIND	0 kts.	0/0	$0
Wake County	2/11/1981	TSTM WIND	0 kts.	0/0	$0
Wake County	6/16/1982	TSTM WIND	0 kts.	0/0	$0
Wake County	7/3/1982	TSTM WIND	0 kts.	0/0	$0
Wake County	7/4/1982	TSTM WIND	0 kts.	0/0	$0
Wake County	8/23/1983	TSTM WIND	0 kts.	0/0	$0
Wake County	3/20/1984	TSTM WIND	52 kts.	0/0	$0
Wake County	3/20/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	3/21/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	3/21/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	4/4/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	5/8/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	5/8/1984	TSTM WIND	52 kts.	0/0	$0
Wake County	5/8/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	5/8/1984	TSTM WIND	0 kts.	0/0	$0
Wake County	4/16/1985	TSTM WIND	0 kts.	0/0	$0
Wake County	5/22/1985	TSTM WIND	0 kts.	0/0	$0
Wake County	6/5/1985	TSTM WIND	0 kts.	0/0	$0
Wake County	6/5/1985	TSTM WIND	0 kts.	0/0	$0
Wake County	2/6/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	2/6/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	3/13/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	7/22/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	7/26/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	7/26/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	7/29/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	8/2/1986	TSTM WIND	53 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Wake County	8/2/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	8/10/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	8/11/1986	TSTM WIND	0 kts.	0/0	$0
Wake County	4/12/1987	TSTM WIND	50 kts.	0/0	$0
Wake County	4/12/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	4/12/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	6/1/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	6/3/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	6/23/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	7/3/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	7/12/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	7/26/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	8/4/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	8/21/1987	TSTM WIND	0 kts.	0/0	$0
Wake County	5/23/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	6/17/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	6/20/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	6/20/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	6/20/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	7/31/1988	TSTM WIND	0 kts.	0/0	$0
Wake County	2/21/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	2/21/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	3/18/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	4/25/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	4/27/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	5/5/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	5/6/1989	TSTM WIND	0 kts.	0/0	$0
Wake County	5/1/1990	TSTM WIND	0 kts.	0/0	$0
Wake County	6/22/1990	TSTM WIND	0 kts.	0/0	$0
Wake County	6/22/1990	TSTM WIND	0 kts.	0/0	$0
Wake County	6/22/1990	TSTM WIND	0 kts.	0/0	$0
Wake County	8/16/1990	TSTM WIND	0 kts.	0/0	$0
Wake County	4/8/1991	TSTM WIND	0 kts.	0/0	$0
Wake County	3/10/1992	TSTM WIND	0 kts.	0/0	$0
Wake County	3/10/1992	TSTM WIND	0 kts.	0/0	$0
Wake County	4/24/1992	TSTM WIND	0 kts.	0/0	$0
Wake County	8/12/1992	TSTM WIND	0 kts.	0/0	$0
Wake County	8/5/1994	THUNDERSTORM WINDS	0 kts.	0/0	$0
Wake County	5/19/1995	THUNDERSTORM WINDS	0 kts.	0/0	$68,275
Wake County	6/11/1995	THUNDERSTORM WINDS	60 kts.	0/0	$0
COUNTYWIDE	1/19/1996	TSTM WIND	0 kts.	0/0	$0
NEW HILL	4/15/1996	TSTM WIND	0 kts.	0/0	$16,574
SRN HALF	7/2/1996	TSTM WIND	0 kts.	0/0	$0
Wake County	4/1/1997	HIGH WIND	50 kts.	1/1	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Wake County	7/24/1997	HIGH WIND	50 kts.	0/0	$0
Wake County	2/3/1998	HIGH WIND	35 kts.	0/0	$0
Wake County	2/16/1998	HIGH WIND	52 kts.	0/0	$0
PURNELL	5/20/2000	TSTM WIND	50 kts.	0/0	$0
FALLS	8/10/2000	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	7/5/2002	TSTM WIND	50 kts.	0/0	$0
Wake County	3/7/2004	TSTM WIND	65 kts.	0/0	$7,030
Wake County	11/22/2006	HIGH WIND	38 kts.	0/0	$12,668
Wake County	4/16/2007	TSTM WIND	42 kts.	0/0	$0
Wake County	2/10/2008	TSTM WIND	43 kts.	0/0	$229
WILLIAMS XRDS	3/4/2008	TSTM WIND	61 kts.	0/0	$0
BAYLEAF	6/1/2008	TSTM WIND	50 kts.	0/0	$0
BAYLEAF	6/1/2008	TSTM WIND	50 kts.	0/0	$0
MILLBROOK	6/27/2008	TSTM WIND	50 kts.	0/0	$0
PURNELL	6/29/2008	TSTM WIND	50 kts.	0/0	$0
PURNELL	6/29/2008	TSTM WIND	50 kts.	0/0	$0
CARPENTER	7/4/2008	TSTM WIND	50 kts.	0/0	$0
PET XRDS	7/22/2008	STRONG WIND	50 kts.	0/0	$0
BAYLEAF	8/15/2008	THUNDERSTORM WIND	50 kts.	0/0	$17,911
BRENTWOOD	8/20/2008	STRONG WIND	50 kts.	0/0	$0
Wake County	9/6/2008	THUNDERSTORM WIND	50 kts.	0/0	$14,926
Wake County	9/6/2008	STRONG WIND	39 kts.	0/0	$7,463
Wake County	1/7/2009	THUNDERSTORM WIND	55 kts.	0/0	$115,927
UPCHURCH	5/5/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
BROOKHAVEN	5/9/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
COLLEGE VIEW	5/9/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
LEESVILLE	5/9/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
ROYAL MILLS	5/9/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
SIX FORKS	5/9/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
PURNELL	6/17/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
WILDERS GROVE	7/1/2009	THUNDERSTORM WIND	50 kts.	0/0	$2,319
WILLOW SPGS	7/27/2009	THUNDERSTORM WIND	60 kts.	0/0	$0
WILLOW SPGS	7/27/2009	HIGH WIND	50 kts.	0/0	$0
BAYLEAF	8/11/2009	STRONG WIND	50 kts.	0/0	$0
WESTOVER	8/17/2009	HIGH WIND	50 kts.	0/0	$0
PURNELL	9/28/2009	THUNDERSTORM	50 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
		WIND			
ROCKTON	6/13/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
LEESVILLE	7/20/2010	THUNDERSTORM WIND	57 kts.	0/0	$0
SIX FORKS	7/20/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
MILLBROOK	7/29/2010	THUNDERSTORM WIND	50 kts.	0/0	$1,126
CARALEIGH	8/5/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
WILDERS GROVE	8/5/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
PURNELL	8/23/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
FRIENDSHIP	11/16/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
AUBURN	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
BARHAM	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
COLLEGE VIEW	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
KENNEBEC	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
ROCKTON	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
WAKE XRDS	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
WILDERS GROVE	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
WILDERS GROVE	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$0
ROYAL MILLS	3/23/2011	THUNDERSTORM WIND	50 kts.	0/0	$21,855
BAYLEAF	6/10/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
ASBURY	6/20/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
BURT	6/21/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
MC CULLERS	6/27/2011	THUNDERSTORM WIND	54 kts.	0/0	$0
BONSAL	6/28/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
GREEN LEVEL	7/24/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
WILLIAMS XRDS	7/25/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
BROOKHAVEN	8/29/2011	THUNDERSTORM	50 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
		WIND			
WESTOVER	2/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
ASBURY	5/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
ASBURY	5/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
MC CULLERS	5/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
ROYAL MILLS	5/23/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
WYATT	5/23/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
WAKE XRDS	6/1/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
PURNELL	6/29/2012	THUNDERSTORM WIND	50 kts.	0/0	$5,305
BARHAM	7/1/2012	THUNDERSTORM WIND	50 kts.	0/0	$1,061
BANKS	7/3/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
CAMP POLK	7/3/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
MILLBROOK	7/3/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
WILDERS GROVE	7/3/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
COLLEGE VIEW	7/4/2012	THUNDERSTORM WIND	50 kts.	0/0	$5,305
MILLBROOK	7/4/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
SIX FORKS	7/4/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
EAGLE ROCK	7/5/2012	THUNDERSTORM WIND	50 kts.	0/0	$3,183
MACEDONIA	7/5/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
MILLBROOK	7/5/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
WILDERS GROVE	7/5/2012	THUNDERSTORM WIND	50 kts.	0/0	$3,183
MILLBROOK	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
ROCKTON	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
STARMOUNT	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
UPCHURCH	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
AUBURN	7/24/2012	THUNDERSTORM	50 kts.	0/0	$2,122

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
		WIND			
CAMP POLK	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
CAMP POLK	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
ECHO HGTS	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
LEESVILLE	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
METHOD	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$5,305
WILBON	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
CAMP POLK	7/28/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
FAWLERS XRDS	7/28/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
LEESVILLE	7/28/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
BAYLEAF	8/1/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
LASSITER	8/1/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
BAYLEAF	8/8/2012	THUNDERSTORM WIND	50 kts.	0/0	$769
ROCKTON	9/18/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
Apex					
Apex	8/3/1993	THUNDERSTORM WINDS	0 kts.	0/0	$9,008
APEX	7/14/2004	TSTM WIND	50 kts.	0/0	$0
APEX	7/19/2006	TSTM WIND	50 kts.	0/0	$0
APEX	4/5/2011	THUNDERSTORM WIND	50 kts.	0/0	$32,782
APEX	8/14/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
APEX	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
APEX	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$2,122
APEX	7/6/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
APEX	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$7,426
Cary					
Cary	8/3/1993	THUNDERSTORM WINDS	0 kts.	0/0	$0
Cary	8/3/1993	THUNDERSTORM WINDS	52 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Cary	3/21/1995	THUNDERSTORM WINDS	0 kts.	0/0	$51,206
CARY	6/4/1996	TSTM WIND	0 kts.	0/0	$0
CARY	6/30/1998	TSTM WIND	50 kts.	0/0	$0
CARY	8/18/2000	TSTM WIND	50 kts.	0/0	$0
CARY	8/19/2002	TSTM WIND	50 kts.	0/0	$0
CARY	8/19/2002	TSTM WIND	50 kts.	0/0	$0
CARY	1/14/2005	TSTM WIND	50 kts.	0/0	$0
CARY	3/8/2005	TSTM WIND	60 kts.	0/0	$0
CARY	4/17/2006	TSTM WIND	50 kts.	0/0	$0
CARY	4/22/2006	TSTM WIND	50 kts.	0/0	$0
CARY	8/9/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	3/4/2008	THUNDERSTORM WIND	51 kts.	0/0	$0
CARY	7/28/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	7/30/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	7/24/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
Cary	8/3/1993	THUNDERSTORM WINDS	0 kts.	0/0	$0
Cary	8/3/1993	THUNDERSTORM WINDS	52 kts.	0/0	$0
Cary	3/21/1995	THUNDERSTORM WINDS	0 kts.	0/0	$51,206
CARY	6/4/1996	TSTM WIND	0 kts.	0/0	$0
CARY	6/30/1998	TSTM WIND	50 kts.	0/0	$0
CARY	8/18/2000	TSTM WIND	50 kts.	0/0	$0
CARY	8/19/2002	TSTM WIND	50 kts.	0/0	$0
CARY	8/19/2002	TSTM WIND	50 kts.	0/0	$0
CARY	1/14/2005	TSTM WIND	50 kts.	0/0	$0
CARY	3/8/2005	TSTM WIND	60 kts.	0/0	$0
CARY	4/17/2006	TSTM WIND	50 kts.	0/0	$0
CARY	4/22/2006	TSTM WIND	50 kts.	0/0	$0
CARY	8/9/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	3/4/2008	THUNDERSTORM WIND	51 kts.	0/0	$0
CARY	7/28/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	7/30/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
CARY	7/24/2011	THUNDERSTORM	50 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
		WIND			
Fuquay-Varina					
Fuquay-Varina	1/7/1995	THUNDERSTORM WINDS	0 kts.	0/4	$426,721
FUQUAY SPGS	4/19/1998	TSTM WIND	50 kts.	0/0	$39,884
FUQUAY SPGS	7/7/2005	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	4/17/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	4/22/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	4/22/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	4/22/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	5/14/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	5/14/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	5/14/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	6/11/2006	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	3/2/2007	TSTM WIND	50 kts.	0/0	$0
FUQUAY SPGS	6/29/2007	THUNDERSTORM WIND	54 kts.	0/0	$0
VARINA	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	9/14/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	9/14/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	9/14/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	9/14/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	7/23/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
VARINA	7/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$530
Garner					
GARNER	3/3/1999	TSTM WIND	50 kts.	0/0	$0
GARNER	7/12/2004	TSTM WIND	50 kts.	0/0	$0
GARNER	7/28/2005	TSTM WIND	52 kts.	0/0	$0
GARNER	4/17/2006	TSTM WIND	50 kts.	0/0	$0
GARNER	4/25/2006	TSTM WIND	54 kts.	0/0	$0
GARNER	6/11/2006	TSTM WIND	56 kts.	0/0	$0
GARNER	7/29/2006	TSTM WIND	50 kts.	0/0	$0
GARNER	4/15/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
GARNER	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
GARNER	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
GARNER	5/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
Holly Springs					

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Holly Springs	8/17/1994	THUNDERSTORM WINDS	56 kts.	0/0	$0
HOLLY SPGS	6/3/1998	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	3/3/1999	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	5/13/2002	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	4/25/2006	TSTM WIND	51 kts.	0/0	$0
HOLLY SPGS	4/25/2006	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	4/25/2006	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	4/25/2006	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	6/11/2006	TSTM WIND	50 kts.	0/0	$0
HOLLY SPGS	7/11/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
HOLLY SPGS	7/31/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
HOLLY SPGS	7/31/2009	THUNDERSTORM WIND	50 kts.	0/0	$115,927
HOLLY SPGS	7/9/2012	THUNDERSTORM WIND	50 kts.	0/0	$3,183
Knightdale					
KNIGHTDALE	6/13/2010	THUNDERSTORM WIND	50 kts.	0/0	$1,126
KNIGHTDALE	4/5/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
Morrisville					
MORRISVILLE	5/6/1996	TSTM WIND	0 kts.	0/0	$0
MORRISVILLE	4/17/2000	TSTM WIND	50 kts.	0/0	$0
MORRISVILLE	6/7/2005	TSTM WIND	50 kts.	0/0	$0
MORRISVILLE	8/30/2008	THUNDERSTORM WIND	50 kts.	0/0	$0
MORRISVILLE	7/23/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
Raleigh					
Raleigh	8/17/1993	THUNDERSTORM WINDS	0 kts.	0/0	$0
Raleigh	7/17/1994	THUNDERSTORM WINDS	0 kts.	0/0	$0
NW Raleigh	7/18/1994	THUNDERSTORM WINDS	61 kts.	0/0	$0
RDU Airport	8/5/1994	THUNDERSTORM WIND	0 kts.	0/0	$0
N Raleigh	11/11/1995	THUNDERSTORM WINDS	0 kts.	0/0	$20,483
W Raleigh	11/11/1995	THUNDERSTORM WINDS	0 kts.	0/0	$0
RALEIGH	4/23/1996	TSTM WIND	0 kts.	0/0	$0
RALEIGH-DURHAM ARPT	5/11/1996	TSTM WIND	55 kts.	0/0	$82,869
RALEIGH	8/22/1996	TSTM WIND	50 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
RALEIGH	11/8/1996	TSTM WIND	50 kts.	0/0	$0
RDU AIRPORT	2/21/1997	TSTM WIND	56 kts.	0/0	$0
RALEIGH	5/1/1997	TSTM WIND	50 kts.	0/0	$48,606
RALEIGH	6/15/1998	TSTM WIND	50 kts.	0/0	$0
RALEIGH	8/16/1998	TSTM WIND	50 kts.	0/0	$0
RALEIGH	8/14/1999	TSTM WIND	0 kts.	0/0	$0
RALEIGH	4/8/2000	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2000	TSTM WIND	60 kts.	0/0	$0
RALEIGH	8/18/2000	TSTM WIND	50 kts.	0/0	$0
RALEIGH	3/26/2002	TSTM WIND	50 kts.	0/0	$0
RALEIGH	8/24/2002	TSTM WIND	50 kts.	0/0	$0
RALEIGH	7/10/2003	TSTM WIND	50 kts.	0/0	$0
RALEIGH	3/7/2004	TSTM WIND	60 kts.	0/0	$0
RALEIGH	6/11/2004	TSTM WIND	50 kts.	0/0	$0
RALEIGH	7/29/2004	TSTM WIND	60 kts.	0/0	$0
RALEIGH	8/13/2004	TSTM WIND	50 kts.	0/0	$0
RALEIGH	9/17/2004	TSTM WIND	50 kts.	0/0	$0
RALEIGH DURHAM ARPT	9/17/2004	TSTM WIND	69 kts.	0/0	$0
RALEIGH	6/7/2005	TSTM WIND	50 kts.	0/0	$0
RALEIGH	7/28/2005	TSTM WIND	50 kts.	0/0	$0
RALEIGH	4/3/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	4/22/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	4/22/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/25/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/26/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	5/26/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	6/23/2006	TSTM WIND	50 kts.	0/0	$0
RALEIGH	7/27/2006	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	11/16/2006	THUNDERSTORM WIND	52 kts.	0/0	$0
RALEIGH DURHAM ARPT	3/2/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	6/9/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/17/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/17/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/17/2007	THUNDERSTORM	51 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
		WIND			
RALEIGH	7/17/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	8/10/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	8/21/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	3/4/2008	THUNDERSTORM WIND	61 kts.	0/0	$0
RALEIGH	7/6/2008	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/1/2009	THUNDERSTORM WIND	50 kts.	0/0	$1,159
RALEIGH	7/17/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/17/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/17/2009	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	9/28/2011	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/3/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/4/2012	THUNDERSTORM WIND	50 kts.	0/0	$1,061
RALEIGH	7/23/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
RALEIGH	7/24/2012	THUNDERSTORM WIND	50 kts.	0/0	$10,609
(RDU)RALEIGH-DURHAM	7/28/2012	THUNDERSTORM WIND	57 kts.	0/0	$0
Rolesville					
ROLESVILLE	5/1/1997	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	8/18/2000	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	11/11/2002	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	4/3/2006	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	5/14/2006	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	6/23/2006	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	7/27/2006	TSTM WIND	50 kts.	0/0	$0
ROLESVILLE	7/11/2007	THUNDERSTORM WIND	50 kts.	0/0	$0
ROLESVILLE	8/21/2011	THUNDERSTORM WIND	50 kts.	0/0	$0

Location	Date	Type	Magnitude	Deaths/ Injuries	Property Damage*
Wake Forest					
WAKE FOREST	1/19/1996	TSTM WIND	0 kts.	0/0	$0
WAKE FOREST/ZEBULON	3/5/1997	TSTM WIND	50 kts.	0/0	$0
WAKE FOREST	8/14/1999	TSTM WIND	0 kts.	0/0	$0
WAKE FOREST	6/11/2004	TSTM WIND	50 kts.	0/0	$0
WAKE FOREST	7/1/2012	THUNDERSTORM WIND	50 kts.	0/0	$0
Wendell					
WENDELL	5/1/1997	TSTM WIND	50 kts.	0/0	$24,303
Zebulon					
ZEBULON	5/1/1997	TSTM WIND	50 kts.	0/0	$32,404
ZEBULON	6/2/1997	TSTM WIND	50 kts.	0/0	$0
ZEBULON	3/8/2005	TSTM WIND	50 kts.	0/0	$0
ZEBULON	11/17/2010	THUNDERSTORM WIND	50 kts.	0/0	$7,879

5.8.4 Probability of Future Occurrences

Given the high number of previous events, it is certain that wind events, including straight-line wind and thunderstorm wind, will occur in the future. This results in a probability level of highly likely (100 percent annual probability) for future wind events for the entire planning area.

5.8.5 Consequence Analysis

People (The Public and Public Confidence)

Thunderstorms are generally associated with several other hazards such as high wind and flooding, the latter of which is caused by torrential rain. As such, the public could be impacted in a number of ways by a thunderstorm event. High wind can cause trees to fall and potentially result in injuries or death and rising floodwaters can lead to drowning or other serious injury. Although often not as severe as hurricanes or tornadoes, the impacts on the public from thunderstorms can be significant. However, the public confidence is usually not affected to a large degree as a result of thunderstorms.

Responders

Responders are not generally affected to any great degree by thunderstorm events, although it should be noted that they could be impacted in many of the same ways as the public. Otherwise, responders could be affected by road blockages caused by downed trees or floodwaters, which would ultimately reduce their response time.

Continuity of Operations

In general, continuity of operations during a thunderstorm event can be maintained. Thunderstorm events often affect power in much the same way as tornadoes and hurricanes, which ultimately may

impact operations. However, thunderstorm events are typically not large enough and their impacts are not wide enough to disrupt continuity of operations in Wake County.

Built Environment (Property, Facilities, and Infrastructure)

Thunderstorms often have their greatest impact on the built environment as they can cause damage to homes via strong winds or flooding and will often impact facilities and infrastructure in the same way. Power losses often occur due to damage to power lines and roads can flood and cause damage as well. In fact, thunderstorms are often considered one of the greater hazards of concern even though any given event will cause relatively little damage, because damaging events occur so frequently.

Economy

Economic impacts from thunderstorm events can often be far reaching as the damage from these events are often widespread, affecting both homes and businesses. This damage can result in business and economic disruption through the recovery process.

Environment

Thunderstorms can impact crops via high wind and flooding and can also impact the natural environment through these elements. Flooding can kill plants and animals as well as contaminate drinking water supplies for human populations. High wind can harm forests by bringing down trees and cause fires from downed power lines that impact the environment.

5.9 TORNADO

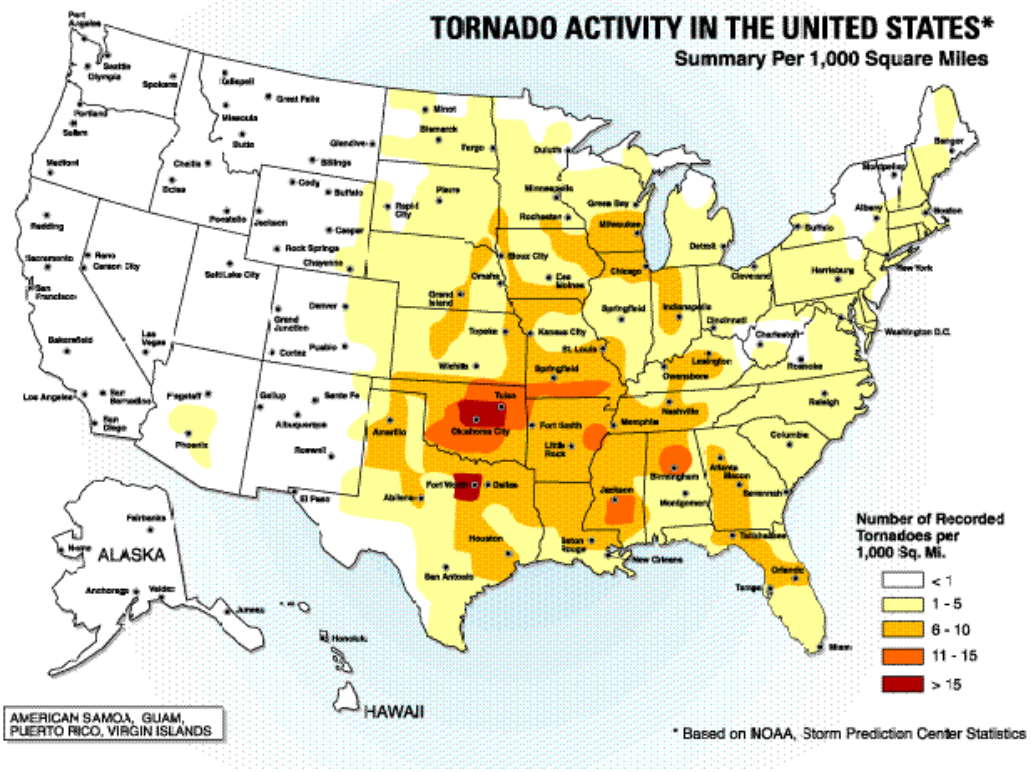
5.9.1 Background

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the National Weather Service, tornado wind speeds normally range from 40 miles per hour to more than 300 miles per hour. The most violent tornadoes have rotating winds of 250 miles per hour or more and are capable of causing extreme destruction and turning normally harmless objects into deadly missiles.

Each year, an average of over 800 tornadoes is reported nationwide, resulting in an average of 80 deaths and 1,500 injuries.[12] According to the NOAA Storm Prediction Center (SPC), the highest concentration of tornadoes in the United States has been in Oklahoma, Texas, Kansas, and Florida respectively. Although the Great Plains region of the Central United States does favor the development of the largest and most dangerous tornadoes (earning the designation of "tornado alley"), Florida experiences the greatest number of tornadoes per square mile of all U.S. states (SPC, 2002). **Figure 5.6** shows tornado activity in the United States based on the number of recorded tornadoes per 1,000 square miles.

[12] NOAA, 2009.

FIGURE 5.6: TORNADO ACTIVITY IN THE UNITED STATES



Source: Federal Emergency Management Agency

Tornadoes are more likely to occur during the months of March through May and are most likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touch down briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, including residential dwellings (particularly mobile homes). Tornadic magnitude is reported according to the Fujita and Enhanced Fujita Scales. Tornado magnitudes prior to 2005 were determined using the traditional version of the Fujita Scale (**Table 5.26**). Tornado magnitudes that were determined in 2005 and later were determined using the Enhanced Fujita Scale (**Table 5.27**).

TABLE 5.26: THE FUJITA SCALE (EFFECTIVE PRIOR TO 2005)

F-SCALE NUMBER	INTENSITY	WIND SPEED	TYPE OF DAMAGE DONE
F0	GALE TORNADO	40–72 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
F1	MODERATE TORNADO	73–112 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	SIGNIFICANT TORNADO	113–157 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	SEVERE TORNADO	158–206 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F4	DEVASTATING TORNADO	207–260 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	INCREDIBLE TORNADO	261–318 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.
F6	INCONCEIVABLE TORNADO	319–379 MPH	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

Source: National Weather Service

TABLE 5.27 THE ENHANCED FUJITA SCALE (EFFECTIVE 2005 AND LATER)

EF-SCALE NUMBER	INTENSITY PHRASE	3 SECOND GUST (MPH)	TYPE OF DAMAGE DONE
F0	GALE	65–85	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
F1	MODERATE	86–110	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	SIGNIFICANT	111–135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	SEVERE	136–165	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F4	DEVASTATING	166–200	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	INCREDIBLE	Over 200	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.

Source: National Weather Service

5.9.2 Location and Spatial Extent

Tornadoes occur throughout the state of North Carolina, and thus in Wake County. Tornadoes typically impact a relatively small area, but damage may be extensive. Event locations are completely random and it is difficult to predict specific areas that are more susceptible to tornado strikes over time. Therefore, it is assumed that all of Wake County is uniformly exposed to this hazard.

5.9.3 Historical Occurrences

Tornadoes are becoming a more and more common occurrence in central and eastern North Carolina as demonstrated by a recent outbreak of tornadoes in the spring of 2011. According to the National Climatic Data Center, there have been a total of thirty-three recorded tornado events in Wake County since 1956 (**Table 5.28**), resulting in over $700 million (2013 dollars) in property damages.[13] In addition, 7 deaths and 213 injuries were reported (**Table 5.29**). The magnitude of these tornadoes ranges from F0 to F4 in intensity, although an F5 event is possible. It is important to note that only tornadoes that have been reported are factored into this risk assessment. It is likely that a high number of occurrences have gone unreported over the past 63 years.

[13] These tornado events are only inclusive of those reported by the National Climatic Data Center (NCDC). It is likely that additional tornadoes have occurred in Wake County. As additional local data becomes available, this hazard profile will be amended.

TABLE 5.28: SUMMARY OF TORNADO OCCURRENCES IN WAKE COUNTY

Location	Number of Occurrences	Deaths/Injuries	Property Damage (2013)
Apex	1	0/0	$0
Cary	2	0/0	$82,869
Fuquay-Varina	0	0/0	$0
Garner	2	0/2	$1,036,983
Holly Springs	1	0/0	$0
Knightdale	0	0/0	$0
Morrisville	0	0/0	$0
Raleigh	2	0/0	$23,930
Rolesville	1	0/1	$109,273
Wake Forest	0	0/0	$0
Wendell	2	0/26	$4,988,724
Zebulon	1	0/0	$0
Unincorporated Area	21	7/184	$700,021,569
WAKE COUNTY TOTAL	**33**	**7/213**	**$706,263,348**

Source: National Climatic Data Center

TABLE 5.29: HISTORICAL TORNADO IMPACTS IN WAKE COUNTY

	Date	Magnitude	Deaths/ Injuries	Property Damage*	Details
Wake County					
Wake County	5/12/1950	F0	0/0	$0	
Wake County	5/12/1950	F1	0/0	$0	
Wake County	4/5/1952	F2	0/0	$245,175	
Wake County	3/18/1956	F1	0/1	$239,506	
Wake County	3/18/1956	F2	0/0	$23,951	
Wake County	11/2/1966	F2	0/9	$2,011,388	
Wake County	5/14/1967	F0	0/0	$0	
Wake County	7/11/1967	F1	0/0	$194,529	
Wake County	5/28/1973	F1	0/0	$146,412	
Wake County	5/29/1973	F0	0/0	$146,412	
Wake County	12/31/1975	F1	0/0	$12,080	
Wake County	5/7/1977	F0	0/0	$10,734	
Wake County	2/11/1981	F2	0/2	$715,623	
Wake County	6/13/1982	F1	1/0	$67,373	
Wake County	6/16/1982	F2	0/0	$673,733	
Wake County	3/14/1986	F1	0/0	$59,362	
Wake County	3/26/1988	F0	2/105		
Wake County	11/28/1988	F4	0/0	$569,530,309	
Wake County	10/23/1990	F1	0/0	$0	
ROCKTON	4/25/2010	F0	0/0	$281,377	EPISODE NARRATIVE: An isolated cell formed over Moore County in advance of a strong surface cold front in a high shear and moderate CAPE environment. The lone storm strengthened into a super cell over

	Date	Magnitude	Deaths/ Injuries	Property Damage*	Details
					central Wake County before it produced a weak EF0 tornado near Zebulon in eastern Wake County.
BURT	4/16/2011	F3	4/67	$125,663,605	EPISODE NARRATIVE: A strong storm system that had a history of producing deadly tornadoes across Oklahoma and the deep south on the 14th and 15th weakened as it crossed the southern Appalachians during the early morning hours of the 16th. A squall line descended the Blue Ridge by the late morning hours, and rapidly intensified |as it moved east into the central Piedmont of North Carolina, with four long live tornadic supercells evolving from the linear convective segment. These tornadic supercells went on to produce 9 tornadoes in the Raleigh CWA, including 2 EF3s, and 4 EF2s. The tornadoes left 6 dead with approximately 275 injuries
Apex					
Apex	9/27/2004	F0	0/0	$0	A tornado touched down near the intersection of Holly Springs Road and Kildaire Farm Road. Minor property damage occurred to a few mobile homes, and a few trees and power lines were blown down. The tornado lifted briefly, and then touched down again on the north side of Apex were several large trees were blown down, especially near the intersection of Schiefflin Road and James road, and along Culvert Street.
Cary					
Cary	7/12/1996	F0	0/0	$82,869	A small tornado formed along an outer band of Hurricane Bertha. The hurricane was centered approximately 140 miles to the southeast. The tornado was on the ground about 6 minutes and moved east to west at 50 mph. Numerous trees were snapped or uprooted. About 10 homes received minor damage due to falling trees.
Cary	6/1/2001	F0	0/0	$0	Siding was blown off of apartment buildings near Highway 54 and Cary Parkway. Trees were also blown down in the area, and a funnel cloud was reported.

	Date	Magnitude	Deaths/ Injuries	Property Damage*	Details
Fuquay-Varina					
None reported					
Garner					
Garner	3/20/1998	F2	0/2	$1,036,983	The tornado remained a funnel as it roared over the Greenbrier Estates just east of US401. Trees were sporadically uprooted and snapped off. Several trees fell on homes and outbuildings. The tornado touched down on Highway 70 at a church. The roof of one section was taken off and the steeple was blown off the chapel. The debris from the church took out windows at a car lot across the street. A block way, the wind removed several large siding sheets from a business
Garner	9/14/2007	F0	0/0	$0	EVENT NARRATIVE: Public reported a brief touch down of a tornado with debris just south of Garner near Lake Benson.
Holly Springs					
Holly Springs	3/20/1998	F0	0/0	$0	A home video of this storm showed a wall cloud with several small vortices. One of these touched down very briefly and damaged the roof of one home. The adjacent homes, and there were many, were untouched. The insulation from the home was then spread into adjacent trees
Knightdale					
None reported					
Morrisville					
None reported					
Raleigh					
Raleigh	3/27/1993	F0	0/0	$0	A small tornado touched down briefly south of Lake Wheeler and moved northward blowing down trees in its path.
Raleigh	3/20/1998	F0	0/0	$23,930	The storm that hit Garner produced another tornado 6 miles to the northeast on the east side of Raleigh. Damage began just off US64 at Wake Medical Center and the Tower Shopping Center. Cars were overturned, trees were damaged, and a steel-beamed billboard was twisted. The tornado then crossed the highway where it lifted the roof off the business office of a tree nursey, damaged two sheds, and

	Date	Magnitude	Deaths/ Injuries	Property Damage*	Details
					destroyed 5 greenhouses. Insulation and debris was strewn up in the trees well away from the path.
Rolesville					
ROLESVILLE	3/6/2011	F0	0/1	$109,273	EPISODE NARRATIVE: Convection developed along and ahead of a cold front that moved across the state during the late afternoon and early evening hours. Two weak EF0 tornadoes developed across central North Carolina when discrete cells along a couple of mesolows merged with the main convective band.
Wake Forest					
None reported					
Wendell					
Wendell	4/15/1996	F1	0/26	$4,972,150	The second is a series of three tornadoes began about 100 yards to the SE of where the first tornado began (off Hwy 64 in Wendell). The storm was initially less than 25 yards wide asit moved NNE and twisted trees and blew shingles off several houses. About one half mile from the initial touchdown, the storm widened to 50 yards as it approached the town of Zebulon. Trees were downed and the roof was blown off a brick home near the railroad tracks. Another home and a manufactured home were damaged as the storm crossed a street and moved up a hill. The storm then preceded over and down the hill into a mobile home park. Damage was extensive to all the trailers in the park that were directly in the path. The storm continued moving NNE into downtown Zebulon where it downed numerous large trees. Houses in the direct path of the storm were all brick and sustained only roof damage. The Zebulon Middle School sustained major roof damage to the main building. The tornado was last noted at Karial and Old Bunn Roads where minor damage occurred to a frame house and severel trees were twisted
Wendell	4/15/1996	F0	0/0	$16,574	An F0 tornado initially touched down off Hwy 64 in Wendell. The tornado width was initially only 50 feet where several trees were taken down. The tornado increased in width to 200

	Date	Magnitude	Deaths/ Injuries	Property Damage*	Details
					yards as it paralleled Hwy 64 and moved into the west side of the town of Zebulon. The storm damaged the Courtesy Car Dealership and tossed a showroom car across the highway. Numerous trees were twisted and felled. The tornado then crossed the highway and narrowed significantly as it reached Hwy 96 and Greenspeace Road about 0.3 miles west of the Wakefield community where it lifted.
Zebulon					
ZEBULON	9/18/2012	F0	0/0	$0	EPISODE NARRATIVE: Multiple line segments of strong to severe storms developed over North Carolina as a compact but potent shortwave emanating from the gulf coast region and along the eastern flanks of a full latitude trough moved through the Carolinas. The accompanying 50 to 60 knot mid level jet within a moist and unstable air mass produced scattered thunderstorm wind damage and an isolated EF-0 tornado near Zebulon.

*Property Damage is reported in 2013 dollars.
Source: NCDC

5.9.4 Probability of Future Occurrences

According to historical information, tornado events are not an annual occurrence for the county. However, tornadoes are a somewhat common occurrence in the county as it is located in an area of relatively flat topography in the southeastern United States. While the majority of the reported tornado events are small in terms of size, intensity, and duration, they do pose a significant threat should Wake County experience a direct tornado strike. The probability of future tornado occurrences affecting Wake County is likely (10-100 percent annual probability).

5.9.5 Consequence Analysis

People (The Public and Public Confidence)

The entire Wake County population is vulnerable to the impacts of a tornado regardless of the measured magnitude. Because it cannot be predicted where a tornado will touch down, it cannot be said which areas of the population within the county are most vulnerable. However, injuries as well as deaths resulting from tornadoes are the most significant impacts. Tornadoes often have a high likelihood of affecting public confidence due to their destructive and highly visible impacts.

Responders

Responders could be critically affected by tornado events as the onset is often very rapid and unpredictable, thereby putting response personnel potentially in harm's way. Due to the unpredictability of such events, response may also be hindered as responders may be unable to access those that have been affected if storm conditions persist and they are unable to safely enter affected areas.

Continuity of Operations

Continuity of operations could be greatly impacted by a tornado as personnel may be harmed and critical resources damaged or destroyed during a tornado. In many ways, since the impacts of a tornado are unpredictable, it is also difficult to predict and plan for the appropriate ways to ensure a continuity of operations. Although Wake County is well prepared for such an event, disruption of operations will likely take place to some degree.

Built Environment (Property, Facilities, and Infrastructure)

Building Inventory

Wake County has been impacted by tornadoes ranging in intensity from F0 through F4 based on the Fujita and Enhanced-Fujita scales. Because it cannot be predicted where a tornado may touch down, all buildings and facilities within the county are considered exposed to the hazard and at risk for being impacted. **Table 5.30** lists the number of buildings by type of structure in Wake County—according to the 2010 U.S. Census—at risk for being impacted by a tornado.

TABLE 5.30 WAKE COUNTY BUILDINGS BY TYPE (2010)

Building Type	Total Number of Buildings	Percentage of Total
Residential	218,598	90.34%
Commercial	15,526	6.42%
Industrial	4,432	1.83%
Agriculture	1,048	.43%
Religion	1,336	.55%
Government	488	.20%
Education	545	.23%
Total	241,973	

Wind

Building materials play a role in how well a structure can withstand tornado force winds. **Table 5.31** shows the percentage of buildings by type within Wake County. Buildings that use structural steel, reinforced concrete, or load-bearing masonry have the best chance of withstanding a tornado event in the county. Homes constructed of wood or manufactured material are most at risk. Non-engineered structures in the county are far more vulnerable than engineered buildings to damage from tornado winds.

TABLE 5.31 WAKE COUNTY BUILDINGS BY MATERIAL TYPE

Building Material	Total Number of Buildings	Percentage of Total
Manufactured Concrete	29,853	12.33%
Manufactured	13,934	5.76%

Building Material	Total Number of Buildings	Percentage of Total
Masonry	10,997	4.54%
Steel	2,491	1.03%
Wood	183,668	75.9%
Other	1,030	.427%
Total	241,973	

Critical Facilities and Key Resources
All critical facilities and key resources are equally vulnerable to the impacts of a tornado. The magnitude of the tornado will determine the extent of damage and impacts that are felt throughout the county. These impacts can include structural failure, debris damage, and loss of facility functionality.

Critical Infrastructure
The county's infrastructure system is equally vulnerable to the impacts of a tornado. This includes critical infrastructure such as roads, railroads, bridges, utilities (power and gas), and pipelines. Any number of these infrastructure systems could be damaged in the event of a tornado. Impacts could include structural damage, impassable or blocked roadways, failed utility lines, railway failure, and impassable bridges.

Key Resources
The county's key resources are equally vulnerable to the impacts of a tornado. Any number of key resources could be damaged or lost in the event of a tornado. Impacts could include structural damage, and loss of power and utilities.

Economy

A tornado can impact any area of Wake County at any time and brings with it significant property and crop damage costs. **Table 5.32** shows a breakdown of the costs incurred from tornadoes that have impacted Wake County between 1950 and 2010.

TABLE 5.32 WAKE COUNTY PROPERTY AND CROP DAMAGE COSTS

Time Period	Property Damage	Crop Damage
1950–1960	$53,000	$0
1961–1970	$275,000	$0
1971–1980	$56,000	$0
1981–1990	$250,000,000	$0
1991–2000	$6,715,000	$0
2001–2010	$350,000	$25,000

Environment

Downed trees, power lines, and other forms of vegetation and building material can block roadways, cover residential areas, and cause property and building damage. Coordinated countywide cleanup efforts after a tornado can include removal of debris. Multi-material facilities may be available for debris drop-off for residents. Debris cleanup may be part of individual insurance policies.

5.10 WINTER STORM AND FREEZE

5.10.1 Background

A winter storm can range from a moderate snow over a period of a few hours to blizzard conditions with blinding wind-driven snow that lasts for several days. Events may include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Some winter storms might be large enough to affect several states, while others might affect only localized areas. Occasionally, heavy snow might also cause significant property damages, such as roof collapses on older buildings.

All winter storm events have the potential to present dangerous conditions to the affected area. Larger snowfalls pose a greater risk, reducing visibility due to blowing snow and making driving conditions treacherous. A heavy snow event is defined by the National Weather Service as an accumulation of 4 of more inches in 12 hours or less. A blizzard is the most severe form of winter storm. It combines low temperatures, heavy snow, and winds of 35 miles per hour or more, which reduces visibility to a quarter mile or less for at least 3 hours. Winter storms are often accompanied by sleet, freezing rain, or an ice storm. Such freeze events are particularly hazardous as they create treacherous surfaces.

Ice storms are defined as storms with significant amounts of freezing rain and are a result of cold air damming (CAD). CAD is a shallow, surface-based layer of relatively cold, stably-stratified air entrenched against the eastern slopes of the Appalachian Mountains. With warmer air above, falling precipitation in the form of snow melts, then becomes either super-cooled (liquid below the melting point of water) or re-freezes. In the former case, super-cooled droplets can freeze on impact (freezing rain), while in the latter case, the re-frozen water particles are ice pellets (or sleet). Sleet is defined as partially frozen raindrops or refrozen snowflakes that form into small ice pellets before reaching the ground. They typically bounce when they hit the ground and do not stick to the surface. However, it does accumulate like snow, posing similar problems and has the potential to accumulate into a layer of ice on surfaces. Freezing rain, conversely, usually sticks to the ground, creating a sheet of ice on the roadways and other surfaces. All of the winter storm elements – snow, low temperatures, sleet, ice, etcetera – have the potential to cause significant hazard to a community. Even small accumulations can down power lines and trees limbs and create hazardous driving conditions. Furthermore, communication and power may be disrupted for days.

5.10.2 Location and Spatial Extent

Nearly the entire continental United States is susceptible to winter storm and freeze events. Some ice and winter storms may be large enough to affect several states, while others might affect limited, localized areas. The degree of exposure typically depends on the normal expected severity of local winter weather. Wake County is accustomed to smaller scale severe winter weather conditions and often receives winter weather during the winter months. Given the atmospheric nature of the hazard, the entire region has uniform exposure to a winter storm.

5.10.3 Historical Occurrences

Winter weather has resulted in six disaster declarations in Wake County. This includes ice storms in 1968 and 2002, snow storms in 1977, 1993, and 1996, and a severe winter storm in 2000. According to the National Climatic Data Center, there have been a total of 30 recorded winter storm events in Wake County since 1993 (**Table 5.33**).[14] These events resulted in over $900,000 (2013 dollars) in damages. Those events with reported damages and fatalities are presented in **Table 5.34**.[15]

TABLE 5.33: SUMMARY OF WINTER STORM EVENTS IN WAKE COUNTY

Location	Number of Occurrences	Deaths/Injuries	Property Damage (2013)
Apex	0	0/0	$0
Cary	0	0/0	$0
Fuquay-Varina	0	0/0	$0
Garner	0	0/0	$0
Holly Springs	0	0/0	$0
Knightdale	0	0/0	$0
Morrisville	0	0/0	$0
Raleigh	0	0/0	$0
Rolesville	0	0/0	$0
Wake Forest	0	0/0	$0
Wendell	0	0/0	$0
Zebulon	0	0/0	$0
Unincorporated Area	30	2/10*	$900,752
WAKE COUNTY TOTAL	**30**	**2/10***	**$900,752**

*These fatalities/injuries were the result of a statewide event and NCDC did not indicate in which county they occurred. Therefore, these may not have occurred in Wake County, but were caused by an event that impacted the county.

Source: National Climatic Data Center

TABLE 5.34: HISTORICAL WINTER STORM IMPACTS IN WAKE COUNTY

	Date	Type of Storm	Deaths/Injuries	Property Damage*
Wake County				
Statewide	3/12/1993	WINTER STORM	2/10	$900,752
Northern and Central	1/3/1994	HEAVY SNOW	0/0	$0
Northern Interior	2/10/1994	ICE STORM	0/0	$0
Wake County	1/6/1996	WINTER STORM	0/0	$0
Wake County	1/11/1996	ICE STORM	0/0	$0
Wake County	2/2/1996	ICE STORM	0/0	$0
Wake County	2/16/1996	HEAVY SNOW	0/0	$0
Wake County	1/19/1998	HEAVY SNOW	0/0	$0
Wake County	12/23/1998	ICE STORM	0/0	$0
Wake County	1/18/2000	WINTER STORM	0/0	$0

[14] These ice and winter storm events are only inclusive of those reported by the National Climatic Data Center (NCDC). It is likely that additional winter storm conditions have affected Wake County.

[15] The dollar amount of damages provided by NCDC is divided by the number of affected counties to reflect a damage estimate for the county.

	Date	Type of Storm	Deaths/Injuries	Property Damage*
Wake County	1/20/2000	WINTER STORM	0/0	$0
Wake County	1/22/2000	WINTER STORM	0/0	$0
Wake County	1/24/2000	WINTER STORM	0/0	$0
Wake County	1/28/2000	WINTER STORM	0/0	$0
Wake County	11/19/2000	HEAVY SNOW	0/0	$0
Wake County	1/3/2002	WINTER STORM	0/0	$0
Wake County	12/4/2002	WINTER STORM	0/0	$0
Wake County	2/16/2003	WINTER STORM	0/0	$0
Wake County	2/27/2003	WINTER STORM	0/0	$0
Wake County	1/26/2004	WINTER STORM	0/0	$0
Wake County	2/15/2004	WINTER STORM	0/0	$0
Wake County	2/26/2004	WINTER STORM	0/0	$0
Wake County	12/26/2004	WINTER STORM	0/0	$0
Wake County	1/18/2007	WINTER WEATHER	0/0	$0
Wake County	2/1/2007	WINTER WEATHER	0/0	$0
Wake County	2/1/2007	WINTER STORM	0/0	$0
Wake County	1/17/2008	WINTER WEATHER	0/0	$0
Wake County	12/25/2010	WINTER STORM	0/0	$0
Wake County	1/28/2014	WINTER STORM	0/0	$0
Wake County	2/12/2014	WINTER STORM	0/0	$0

There have been several severe winter weather events in the Wake County. The text below describes one of the major events and associated impacts on the county. Similar impacts can be expected with severe winter weather.

1996 Winter Storm
This storm left two feet of snow and several thousand citizens without power for up to nine days. Although shelters were opened, some roads were impassible for up to four days. This event caused considerable disruption to business, industry, schools, and government services.

Winter storms throughout the planning area have several negative externalities including hypothermia, cost of snow and debris cleanup, business and government service interruption, traffic accidents, and power outages. Furthermore, citizens may resort to using inappropriate heating devices that could to fire or an accumulation of toxic fumes.

5.10.4 Probability of Future Occurrences

Winter storm events will remain a somewhat regular occurrence in Wake County due to its location and latitude. According to historical information, Wake County experiences an average of 1-2 winter storm events each year. Therefore, the annual probability is likely (10-100 percent).

5.10.5 Consequence Analysis

People (The Public and Public Confidence)
Winter storms most often impact people indirectly. Winter storms can create dangerous driving conditions by limiting visibility for drivers or creating slick conditions that make maneuverability difficult.

Loss of power can create very cold conditions for residents, making it difficult to stay warm. Residents may try to heat their home using alternative means, which runs the risk of carbon monoxide poisoning caused by improperly ventilated heating sources. In addition, dangerously cold temperatures increase the risk of wind chill, frostbite, and hypothermia. Winter storms generally do not have a large impact on public confidence, but it could be impacted if road clearing or response operations are slow.

Responders

Responders in winter storm and freeze events face a variety of hazards themselves including slick or icy roads that could cause harm to responders if they are attempting to quickly respond to an emergency as is often the case. Crashed emergency vehicles and injuries to responders are always a possibility, but their chances increase during a winter storm event. Winter storms can also make it difficult to access more rural areas if roads are snowed over and vehicles cannot pass through.

Continuity of Operations

Generally, continuity of operations can be maintained during a winter storm event in Wake County. However, winter storms do have the potential to affect power transmission and can make it difficult for emergency management employees to arrive to work. As a result, there will likely be some disruption of operations during a winter storm event.

Built Environment (Property, Facilities, and Infrastructure)

Schools

Winter storms have the potential to impact public and private school schedules through closings and delays. Poor driving conditions, lack of power and heat, and mechanical problems with school buses and equipment due to cold weather conditions are potential concerns.

School closures and delays can lead to logistical problems for teachers and school administrators, especially in the event of end-of-term exams and standardized testing schedules. It can also result in logistical problems for making up school days; however, Wake County has “built in” a number of snow days in the academic calendar to account for possible cancellations due to winter weather.[16]

Critical Infrastructure and Key Resources

Winter storms have the potential to create hazardous driving conditions leading to accidents on roadways. The North Carolina Climate Office reports that 70 percent of winter-weather–related injuries are a result of accidents on the road.[17] The North Carolina Highway Patrol call volume can double during a winter storm compared to a typical 24-hour period. This creates significant problems for emergency workers. Accidents can cause highways to become as “large parking lots” as well as cause motorists to strand their vehicles, making it difficult for emergency workers to reach those who need assistance. In general, major and local roadways become severely impacted when temperatures drop, making pre-treatment solutions ineffective. Transportation impacts can be minimized during early- and late-season events when paved surfaces are able to warm sufficiently to prevent winter precipitation accumulation.

Winter storms can also result in delays and cancellations of flights at airports in Wake County due to slick conditions on runways. There is also the potential of a loss of power that can close the airport. The

[16] Fuhrmann, C. M., Connolly, R. P., & Konrad, C. E. (2009). *Winter storms: An overlooked source of death, destruction, and inconvenience in the Carolina Piedmont Region.* 66th Eastern Snow Conference, Niagara-on-the-Lake, Ontario, Canada. Retrieved May 7, 2012, from http://www.sercc.com/projects/WinterImpactsSERCC.pdf

[17] State Climate Office of North Carolina. *Winter weather—impacts*. Retrieved May 7, 2012, from http://www.nc-climate.ncsu.edu/climate/winter_wx/Impacts.php

most notable example of this was after the January 2000 snowstorm in which RDU airport lost power on two occasions and had to close for a week.

Utilities
One of the primary identified impacts of winter storms on Wake County is the disruption of utilities. In 2009, 50 percent of winter storms that impacted the RDU general area resulted in power outages to at least 10,000 customers in the Raleigh-Durham area.[18]

Additional utilities that are at risk of being affected include telephone, internet, cable, and water. Newspaper reports typically cite trees falling on electrical wires—as well as trees that have already been damaged from previous incidents that fall during a winter storm—or the stress caused by ice accumulation as main causes for power outages.

Economy
In the event of a winter storm, there is a high potential of business and office closures, modified business and office hours, and cancellation or postponement of sporting and other planned events in the county. This can be contributed to poor road conditions (including icy and slick conditions) that result in fewer people using the roads to get to their destination or a loss of power and heat that result in a loss of operations at specific facilities. Businesses that seek the most benefit from a winter storm event are those associated with cleanup, recovery operations, or rebuilding.

Environment
Winter storms have an impact on the environment through the clearing of roadways. Snow on the roads can pick up contaminants from chemicals and oil products in traffic as well as the salt mixture that is used to de-ice the roads. These contaminants can be carried to nearby waterways, which, contaminates water sources and is absorbed by groundwater.

In addition, vegetation can be damaged by these storm types. Vegetation destruction reduces available habitats, and threatens wildlife.

Geologic Hazards

5.11 EARTHQUAKE

5.11.1 Background

An earthquake is movement or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, landslides, or the collapse of caverns. Earthquakes can affect hundreds of thousands of square miles, cause damage to property measured in the tens of billions of dollars, result in loss of life and injury to hundreds of thousands of persons, and disrupt the social and economic functioning of the affected area.

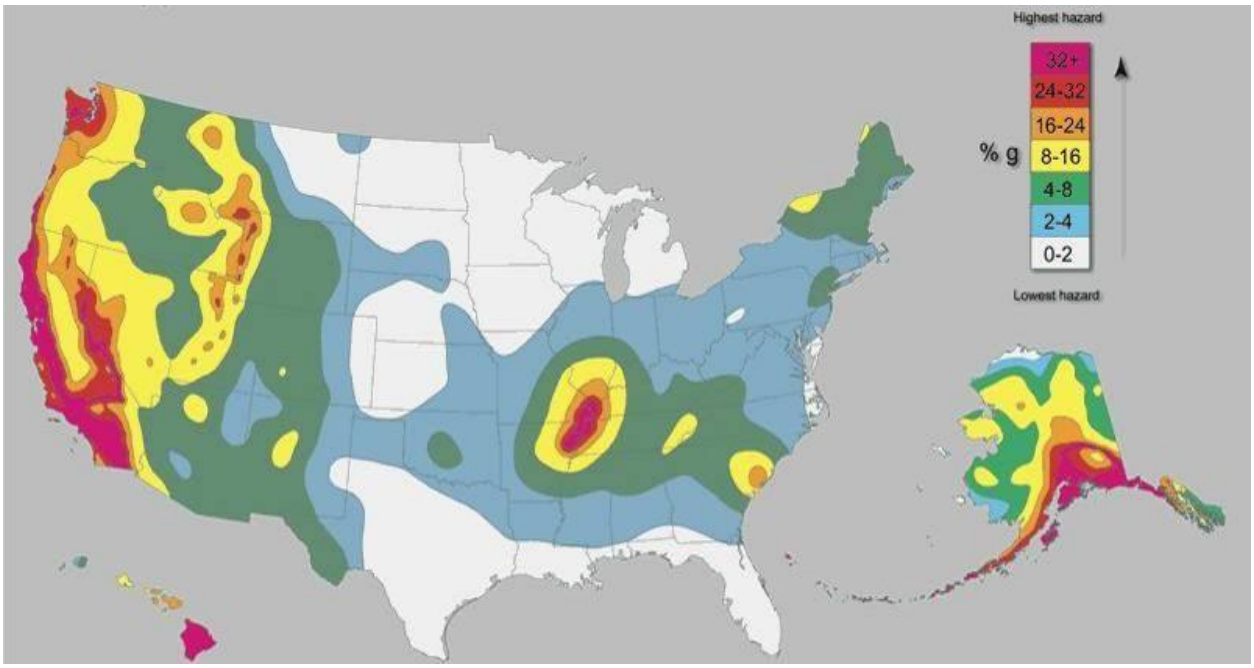
[18] Fuhrmann, C. M., Connolly, R. P., & Konrad, C. E. (2009). *Winter storms: An overlooked source of death, destruction, and inconvenience in the Carolina Piedmont Region.* 66th Eastern Snow Conference, Niagara-on-the-Lake, Ontario, Canada. Retrieved May 7, 2012, from http://www.sercc.com/projects/WinterImpactsSERCC.pdf

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault, site, and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quick sand. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

Most earthquakes are caused by the release of stresses accumulated as a result of the rupture of rocks along opposing fault planes in the Earth's outer crust. These fault planes are typically found along borders of the Earth's 10 tectonic plates. The areas of greatest tectonic instability occur at the perimeters of the slowly moving plates, as these locations are subjected to the greatest strains from plates traveling in opposite directions and at different speeds. Deformation along plate boundaries causes strain in the rock and the consequent buildup of stored energy. When the built-up stress exceeds the rocks' strength a rupture occurs. The rock on both sides of the fracture is snapped, releasing the stored energy and producing seismic waves, generating an earthquake.

The greatest earthquake threat in the United States is along tectonic plate boundaries and seismic fault lines located in the central and western states; however, the Eastern United State does face moderate risk to less frequent, less intense earthquake events. **Figure 5.7** shows relative seismic risk for the United States.

FIGURE 5.7: UNITED STATES EARTHQUAKE HAZARD MAP



Source: United States Geological Survey

Earthquakes are measured in terms of their magnitude and intensity. Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude (**Table 5.35**). Each unit increase in magnitude on the Richter Scale corresponds to a 10-fold increase in wave amplitude, or a 32-fold increase in energy.

Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, ranging from "I" corresponding to imperceptible (instrumental) events to "XII" for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in **Table 5.36**.

TABLE 5.35: RICHTER SCALE

RICHTER MAGNITUDES	EARTHQUAKE EFFECTS
< 3.5	Generally not felt, but recorded.
3.5 - 5.4	Often felt, but rarely causes damage.
5.4 - 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1 - 6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0 - 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or >	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Source: Federal Emergency Management Agency

TABLE 5.36: MODIFIED MERCALLI INTENSITY SCALE FOR EARTHQUAKES

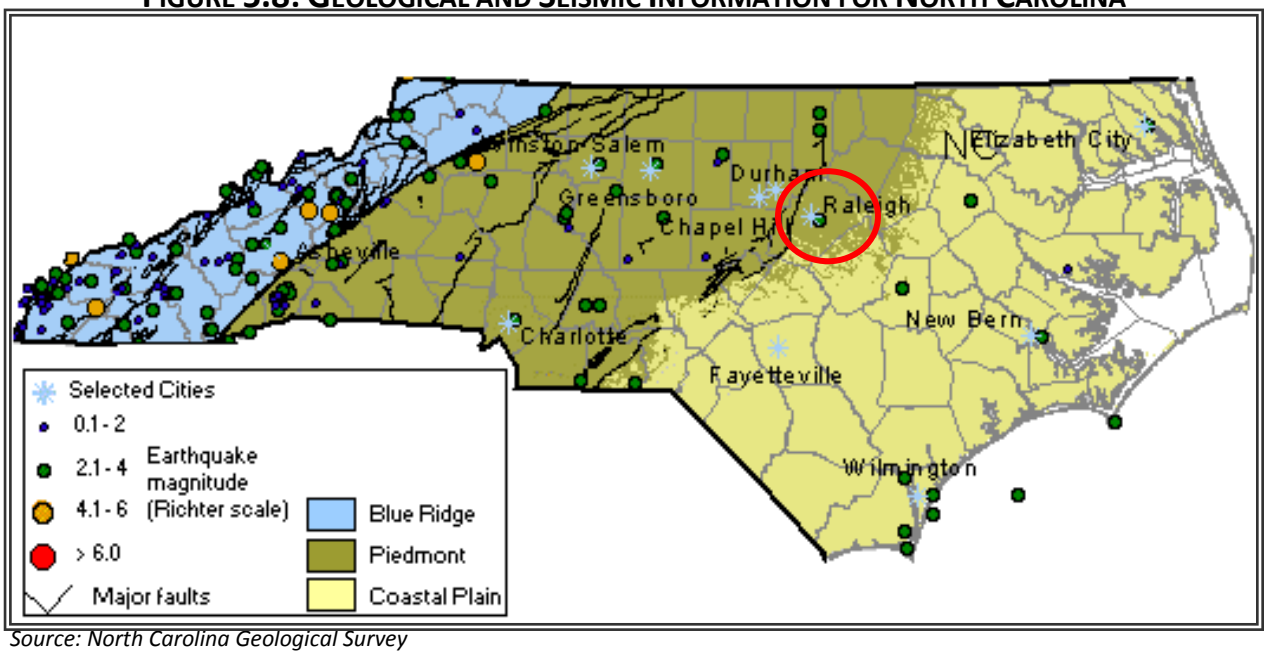
SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER SCALE MAGNITUDE
I	INSTRUMENTAL	Detected only on seismographs.	
II	FEEBLE	Some people feel it.	< 4.2
III	SLIGHT	Felt by people resting; like a truck rumbling by.	
IV	MODERATE	Felt by people walking.	
V	SLIGHTLY STRONG	Sleepers awake; church bells ring.	< 4.8
VI	STRONG	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	VERY STRONG	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	DESTRUCTIVE	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	
IX	RUINOUS	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	DISASTROUS	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	VERY DISASTROUS	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards.	< 8.1
XII	CATASTROPHIC	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

Source: Federal Emergency Management Agency

5.11.2 Location and Spatial Extent

Approximately two-thirds of North Carolina is subject to earthquakes, with the western and southeast region most vulnerable to a very damaging earthquake. The state is affected by both the Charleston Fault in South Carolina and New Madrid Fault in Tennessee. Both of these faults have generated earthquakes measuring greater than 8 on the Richter Scale during the last 200 years. In addition, there are several smaller fault lines throughout North Carolina. **Figure 5.8** is a map showing geological and seismic information for North Carolina.

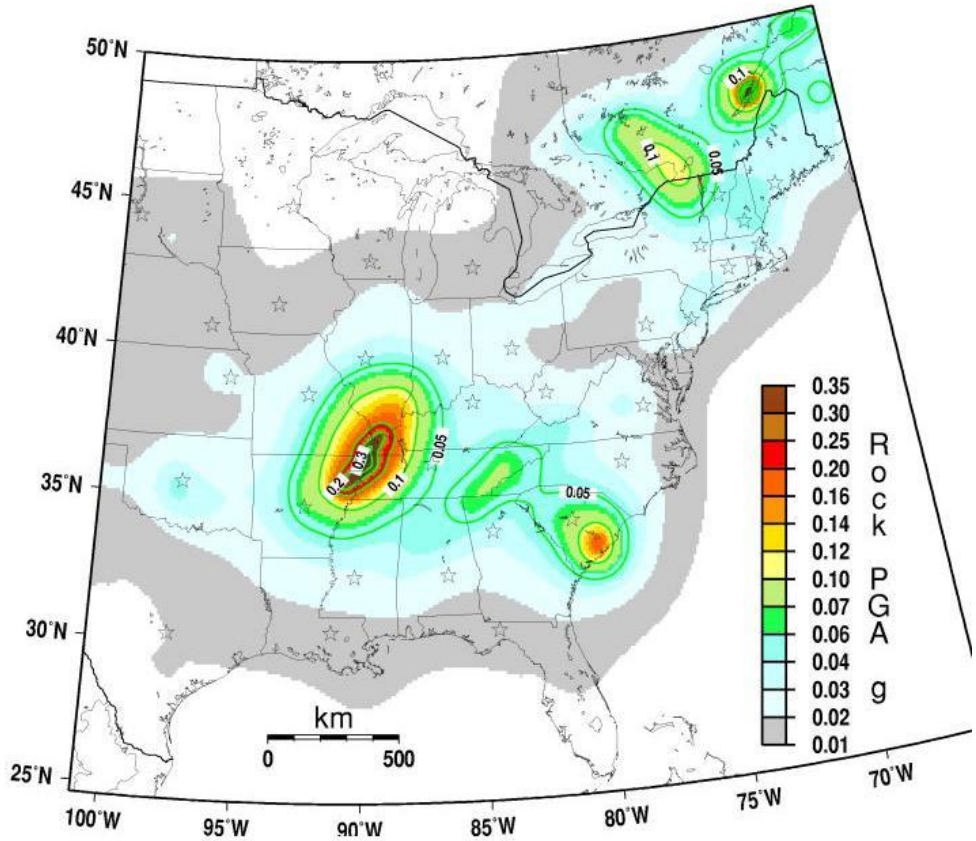
FIGURE 5.8: GEOLOGICAL AND SEISMIC INFORMATION FOR NORTH CAROLINA



Source: North Carolina Geological Survey

Figure 5.9 shows the intensity level associated with Wake County, based on the national USGS map of peak acceleration with 10 percent probability of exceedance in 50 years. It is the probability that ground motion will reach a certain level during an earthquake. The data show peak horizontal ground acceleration (the fastest measured change in speed, for a particle at ground level that is moving horizontally due to an earthquake) with a 10 percent probability of exceedance in 50 years. The map was compiled by the U.S. Geological Survey (USGS) Geologic Hazards Team, which conducts global investigations of earthquake, geomagnetic, and landslide hazards. According to this map, Wake County lies within an approximate zone of level "2" to "3" ground acceleration. This indicates that the region as a whole exists within an area of low to moderate seismic risk.

FIGURE 5.9: PEAK ACCELERATION WITH 10 PERCENT PROBABILITY OF EXCEEDANCE IN 50 YEARS



Source: USGS, 2008

5.11.3 Historical Occurrences

At least 13 earthquakes are known to have affected Wake County since 1811. The strongest of these measured a VIII on the Modified Mercalli Intensity (MMI) scale. **Table 5.37** provides a summary of earthquake events reported by the National Geophysical Data Center between 1638 and 1985. **Table 5.38** presents a detailed occurrence of each event including the date, distance for the epicenter, Modified Mercalli Intensity, and magnitude (if known).[19]

TABLE 5.37: SUMMARY OF SEISMIC ACTIVITY IN WAKE COUNTY

Location	Number of Occurrences	Greatest MMI Reported	Richter Scale Equivalent
Apex	--	--	--
Cary	--	--	--
Fuquay-Varina	--	--	--
Garner	--	--	--
Holly Springs	--	--	--

[19] Due to reporting mechanisms, not all earthquakes events were recorded during this time. Furthermore, some are missing data, such as the epicenter location, due to a lack of widely used technology. In these instances, a value of "unknown" is reported.

Knightdale	--	--	--
Morrisville	--	--	--
Raleigh	13	VIII	7.2
Rolesville	--	--	--
Wake Forest	--	--	--
Wendell	--	--	--
Zebulon	--	--	--
Unincorporated Area	--	--	--
WAKE COUNTY TOTAL	**13**	**VIII**	**7.2**

Source: National Geophysical Data Center

TABLE 5.38: SIGNIFICANT SEISMIC EVENTS IN WAKE COUNTY (1638 -1985)

Location	Date	Epicentral Distance (km)	Magnitude	MMI
Wake County				
None reported				
Apex				
None reported				
Cary				
None reported				
Fuquay-Varina				
None reported				
Garner				
None reported				
Holly Springs				
None reported				
Knightdale				
None reported				
Morrisville				
None reported				
Raleigh				
Raleigh	12/16/1811	987.0	7.2	4
Raleigh	1/23/1812	987.0	7.1	2
Raleigh	3/10/1828			5
Raleigh	8/27/1833			3
Raleigh	4/29/1852			3
Raleigh	9/1/1886	343.0		8
Raleigh	9/1/1886	343.0		7
Raleigh	5/31/1897	249.0		3
Raleigh	11/25/1898			4
Raleigh	1/1/1913	302.0		3
Raleigh	3/5/1914	511.0		3
Raleigh	2/21/1916	350.0		2
Raleigh	11/20/1969	277.0	4.3	4

Location	Date	Epicentral Distance (km)	Magnitude	MMI
Rolesville				
None reported				
Wake Forest				
None reported				
Wendell				
None reported				
Zebulon				
None reported				

Source: National Geophysical Data Center

In addition to those earthquakes specifically affecting Wake County, a list of earthquakes that have caused damage throughout North Carolina is presented below in **Table 5.39.**

TABLE 5.39: EARTHQUAKES WHICH HAVE CAUSED DAMAGE IN NORTH CAROLINA

Date	Location	Richter Scale (Magnitude)	MMI (Intensity)	MMI in North Carolina
12/16/1811 – 1*	NE Arkansas	8.5	XI	VI
12/16/1811 - 2	NE Arkansas	8.0	X	VI
12/18/1811 - 3	NE Arkansas	8.0	X	VI
01/23/1812*	New Madrid, MO	8.4	XI	VI
02/071812	New Madrid, MO	8.7	XII	VI
04/29/1852*	Wytheville, VA	5.0	VI	VI
08/31/1861	Wilkesboro, NC	5.1	VII	VII
12/23/1875	Central Virginia	5.0	VII	VI
08/31/1886*	Charleston, SC	7.3	X	VII
05/31/1897*	Giles County, VA	5.8	VIII	VI
01/01/1913*	Union County, SC	4.8	VII	VI
02/21/1916*	Asheville, NC	5.5	VII	VII
07/08/1926	Mitchell County, NC	5.2	VII	VII
11/03/1928	Newport, TN	4.5	VI	VI
05/13/1957	McDowell County, NC	4.1	VI	VI
07/02/1957	Buncombe County, NC	3.7	VI	VI
11/24/1957	Jackson County, NC	4.0	VI	VI
10/27/1959 **	Chesterfield, SC	4.0	VI	VI
07/13/1971	Newry, SC	3.8	VI	VI
11/30/1973	Alcoa, TN	4.6	VI	VI
11/13/1976	Southwest Virginia	4.1	VI	VI
05/05/1981	Henderson County, NC	3.5	VI	VI

*This event is accounted for in the Wake County occurrences.

** Conflicting reports on this event, intensity in North Carolina could have been either V or VI

Source: This information compiled by Dr. Kenneth B. Taylor and provided by Tiawana Ramsey of NCEM. Information was compiled from the National Earthquake Center, Earthquakes of the US by Carl von Hake (1983), and a compilation of newspaper reports in the Eastern Tennessee Seismic Zone compiled by Arch Johnston, CERI, Memphis State University (1983).

5.11.4 Probability of Future Occurrences

The probability of significant, damaging earthquake events affecting Wake County is unlikely. However, it is possible that future earthquakes resulting in light to moderate perceived shaking and damages ranging from none to very light will affect the county. Therefore, the annual probability level for the county is estimated between 1 and 10 percent (possible).

5.11.5 Consequence Analysis

People (The Public and Public Confidence)

Earthquakes in Wake County generally are not high impact events that cause injury or death as most are moderate. The public typically experiences some shaking in these events and the greatest threat to health and well-being is often from objects falling from shelves. Public confidence would likely not be affected in the event of an earthquake.

Responders

There would be little impact on responders in the event of an earthquake, again, because Wake County is only likely to experience a moderate earthquake magnitude at a maximum. Since there would be very little damage to infrastructure, responders would likely not be impacted in their ability to respond to an earthquake.

Continuity of Operations

During and after an earthquake, continuity of operations could relatively easily be maintained and there would likely be little disruption to services or operations.

Built Environment (Property, Facilities, and Infrastructure)

Ground shaking is the primary cause of damage to the built environment during an earthquake. There are three important variables that determine the amount of damage: the intensity of the quake, local soil characteristics, and the quality of the impacted structures. The amount of damaged caused by an earthquake is strongly influenced by soil characteristics. The velocity at which the rock or soil transmits shear waves is the main contributor to ground shaking. Shaking is increased by soft, thick, or wet soil types.

Certain building types are particularly vulnerable to earthquake damage: wood-frame multi-unit buildings, single-family homes, mobile homes, and unreinforced masonry buildings.[20] The most susceptible structures are wood-frame, multi-story, mixed-use buildings that have large openings on the first floor for garages or commercial space and housing on the upper floors. During an earthquake, these types of structures could sway or even collapse. According to HAZUS-MH, there are approximately 183,668 buildings within the county that are built of wood, which is approximately 75 percent of the total building stock. The latest Wake County property data show 40 properties that are described as "stores with apartments and offices" with a total building value of almost $12 million, but these properties represent much less than 1 percent of county property.

[20] Association of Bay Area Governments. (2012). *Guide to housing vulnerable resources*. Retrieved March 11, 2012, from http://quake.abag.ca.gov/housing/

Single-family homes built prior to the 1970s are often not bolted to their foundations, and walls surrounding crawl spaces are not braced (i.e., cripple walls). Typical earthquake damage to these structures include cracked foundations, chimneys breaking at the roof line, wood frames coming off their foundations, and racking of cripple walls. The latest Wake County property data show there are 39,548 single-family housing units built before the 1970s with a total building value of $4.58 billion. These properties represent 12 percent of the county.

Mobile homes that are built of light-weight metal or a combination of steel frame and wood are easily damaged by a quake. Mobile homes installed prior to 1995 were often not attached to their foundations and could shift off their supports. Based on data from HAZUS-MH, the county contains 13,934 manufactured homes, which make up approximately 5.7 percent of the bounty's building stock.

The last type of susceptible building material is unreinforced masonry—masonry walls that have not been reinforced with steel. These buildings were often built before 1960 in an era when reinforcing was not generally used, anchorage to floors and roofs was missing, and use of low-strength lime mortar was common. Earthquake damage to these buildings can be severe. A lack of reinforcement and tie-downs can result in substantial damage in the form of cracked or leaning walls. Damage may also occur between the walls, and separation between the framing and walls could lead to full collapse due to a lack of vertical support. HAZUS-MH reports a total of 10,997 masonry buildings within the county (4.5 percent), but the number of unreinforced buildings is unknown.

Critical Infrastructure and Key Resources

Critical infrastructure and key resources within Wake County include assets, systems, and networks that are vital to the continued operation of government services. The incapacitation or destruction of these resources would have a debilitating effect on the county's security, economy, and/or public health. There are a handful of key resource categories that could be impacted by an earthquake including transportation systems, communication systems, and utility systems. Historically, the county has not been impacted by an earthquake with more than a moderate intensity so damage to these resources would be very minor; however, an inspection of certain features after a strongly felt earthquake may be necessary.

Economy

There are three sources of economic loss associated with an earthquake: property damage and business interruption costs; cost to repair public transportation, communication, or utility systems; and debris removal costs. Historically, there have been no economic losses from earthquakes felt within the county.

Environment

There would be no substantial impacts to the environment following a large earthquake that is felt in Wake County with a moderate intensity. Secondary effects from the damage of the key resources mentioned above (e.g., utility systems) could impact the environment, but the probability of this type of situation is very small. There is no doubt that a ruptured pipeline would release dangerous materials that could damage the surrounding environment.

5.12 LANDSLIDE

5.12.1 Background

A landslide is the downward and outward movement of slope-forming soil, rock, and vegetation, which is driven by gravity. Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes due to construction or erosion, earthquakes, volcanic eruptions, and changes in groundwater levels.

There are several types of landslides: rock falls, rock topple, slides, and flows. Rock falls are rapid movements of bedrock, which result in bouncing or rolling. A topple is a section or block of rock that rotates or tilts before falling to the slope below. Slides are movements of soil or rock along a distinct surface of rupture, which separates the slide material from the more stable underlying material. Mudflows, sometimes referred to as mudslides, mudflows, lahars or debris avalanches, are fast-moving rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as heavy rainfall or rapid snowmelt, changing the soil into a flowing river of mud or "slurry." Slurry can flow rapidly down slopes or through channels and can strike with little or no warning at avalanche speeds. Slurry can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. As the flows reach flatter ground, the mudflow spreads over a broad area where it can accumulate in thick deposits.

Landslides are typically associated with periods of heavy rainfall or rapid snow melt and tend to worsen the effects of flooding that often accompanies these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.

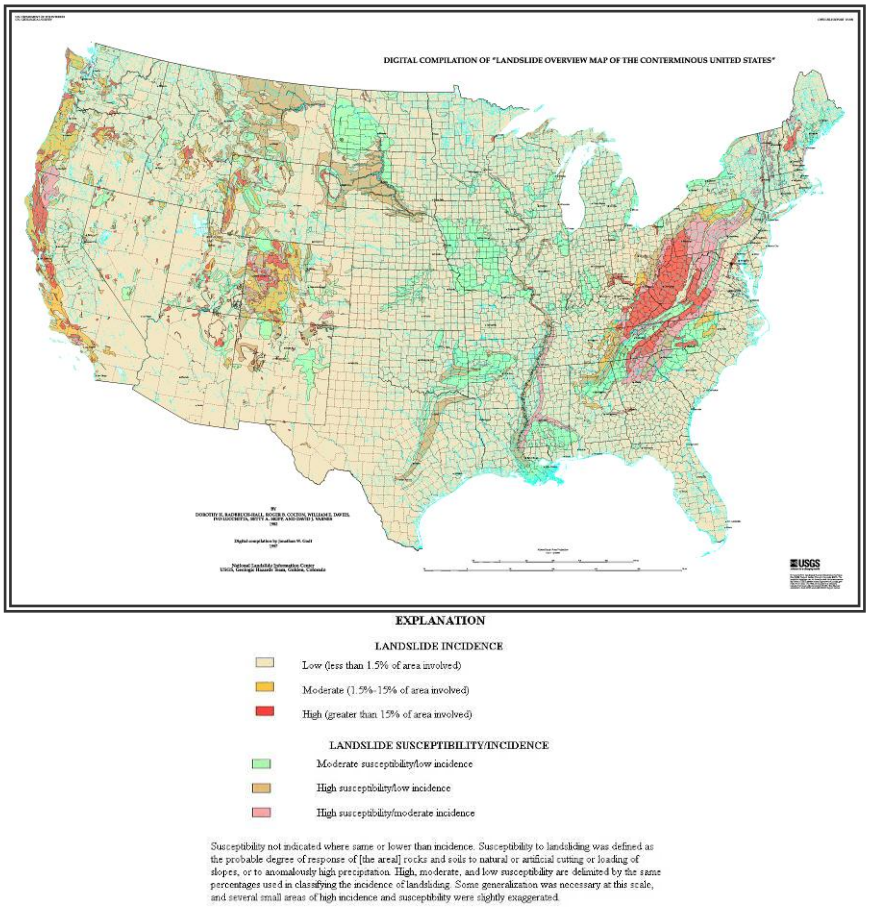
Among the most destructive types of debris flows are those that accompany volcanic eruptions. A spectacular example in the United States was a massive debris flow resulting from the 1980 eruptions of Mount St. Helens, Washington. Areas near the bases of many volcanoes in the Cascade Mountain Range of California, Oregon, and Washington are at risk from the same types of flows during future volcanic eruptions.

Areas that are generally prone to landslide hazards include previous landslide areas, the bases of steep slopes, the bases of drainage channels, and developed hillsides where leach-field septic systems are used. Areas that are typically considered safe from landslides include areas that have not moved in the past, relatively flat-lying areas away from sudden changes in slope, and areas at the top or along ridges set back from the tops of slopes.

According to the United States Geological Survey, each year landslides cause $5.1 billion (2009 dollars) in damage and between 25 and 50 deaths in the United States.[21] **Figure 5.10** delineates areas where large numbers of landslides have occurred and areas that are susceptible to landsliding in the conterminous United States.[22]

[21] United States Geological Survey (USGS). United States Department of the Interior. "Landslide Hazards – A National Threat." 2005.
[22] This map layer is provided in the U.S. Geological Survey Professional Paper 1183, Landslide Overview Map of the Conterminous United States, available online at: http://landslides.usgs.gov/html_files/landslides/nationalmap/national.html.

FIGURE 5.10: LANDSLIDE OVERVIEW MAP OF THE CONTERMINOUS UNITED STATES



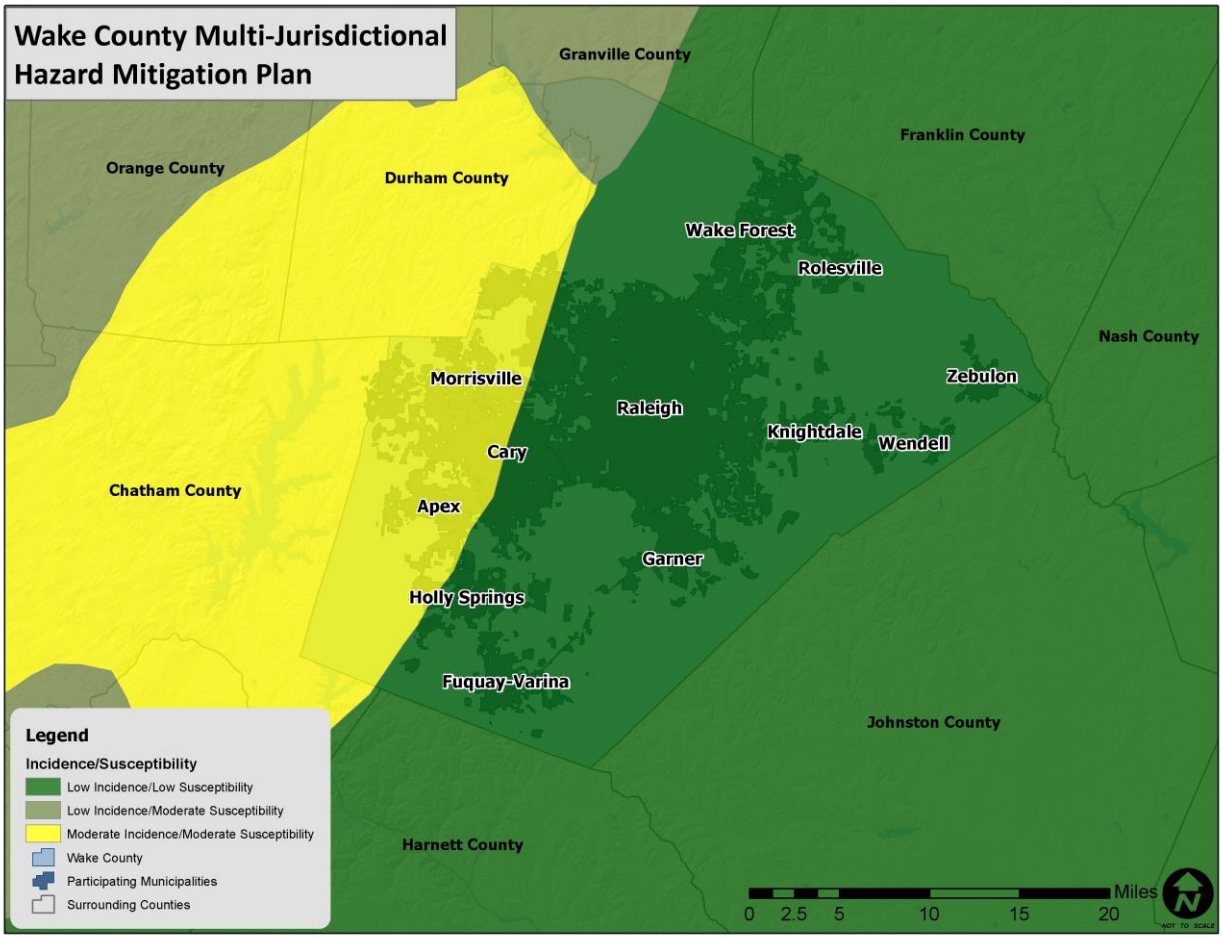
Source: USGS

5.12.2 Location and Spatial Extent

Landslides occur along steep slopes when the pull of gravity can no longer be resisted (often due to heavy rain). Human development can also exacerbate risk by building on previously undevelopable steep slopes and constructing roads by cutting through hills or mountains. Landslides are possible throughout Wake County, though the overall risk is relatively low.

According to **Figure 5.11** below, the majority of the county has relatively low landslide activity. However there is a small area along the western border of the county that has a moderate incidence and moderate susceptibility. In all other areas, there is low susceptibility.

FIGURE 5.11: LANDSLIDE SUSCEPTIBILITY AND INCIDENCE MAP OF WAKE COUNTY



Source: USGS

5.12.3 Historical Occurrences

Steeper topography in some areas of Wake County makes the planning area moderately susceptible to landslides. Most landslides are caused by heavy rainfall combined with building on steeper slopes that was not previously possible. **Table 5.40** presents a summary of the landslide occurrence events as provided by the North Carolina Geological Survey[23]. The locations of the landslide events presented in the aforementioned tables are presented in **Figure 5.12**. Some incidence mapping has also been completed throughout the western portion of North Carolina though none has been done in this area of the state. Therefore, it should be noted that more incidents than what is reported may have occurred.

TABLE 5.40: SUMMARY OF LANDSLIDE ACTIVITY IN WAKE COUNTY

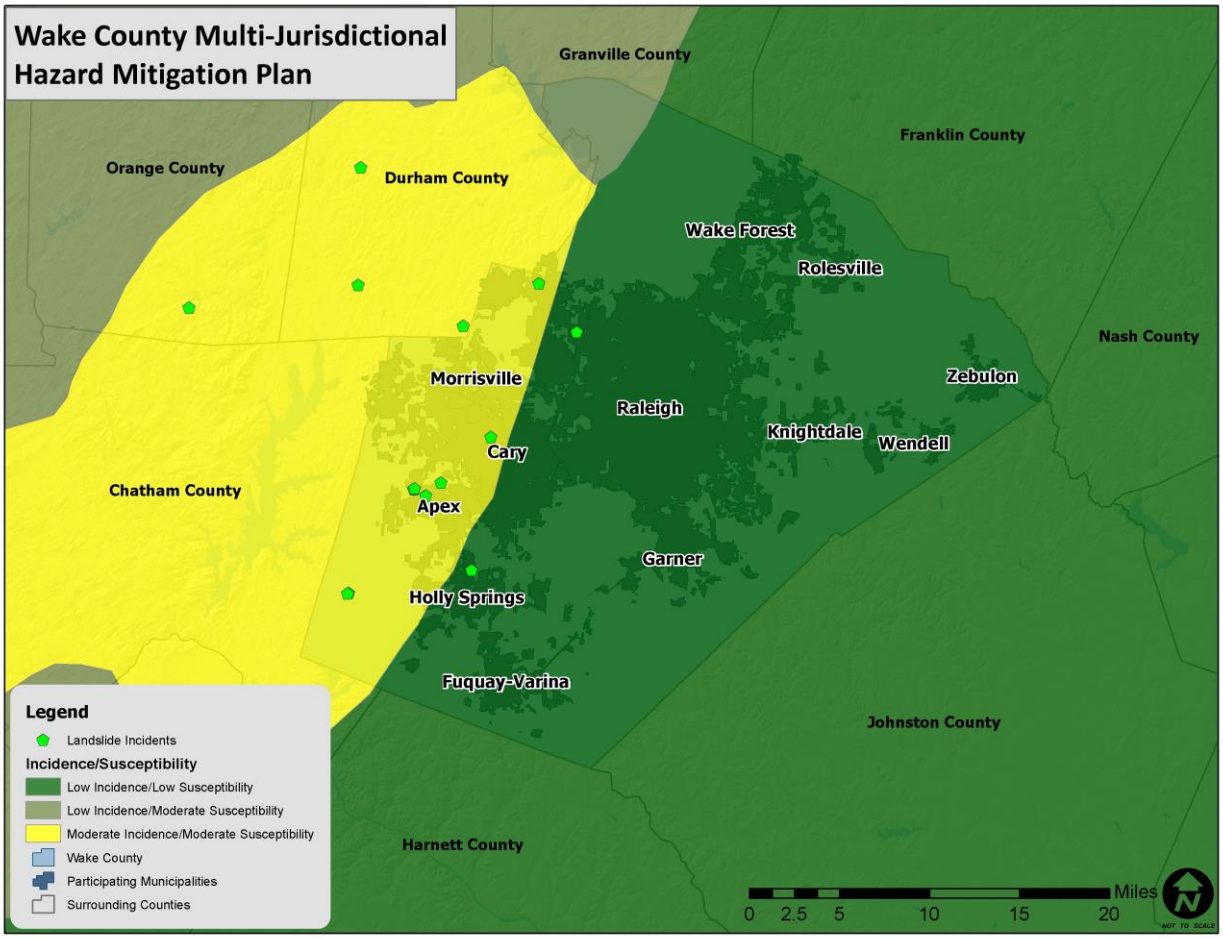
Location	Number of Occurrences
Apex	3
Cary	1

[23] It should be noted that the North Carolina Geological Survey (NCGS) emphasized the dataset provided was incomplete. Therefore, there may be additional historical landslide occurrences. Furthermore, dates were not included for every event. The earliest date reported was 1940. No damage information was provided by NCGS.

Location	Number of Occurrences
Fuquay-Varina	0
Garner	0
Holly Springs	1
Knightdale	0
Morrisville	0
Raleigh	2
Rolesville	0
Wake Forest	0
Wendell	0
Zebulon	0
Unincorporated Area	4
WAKE COUNTY TOTAL	**11**

Source: North Carolina Geological Survey

FIGURE 5.12: LOCATION OF PREVIOUS LANDSLIDE OCCURRENCES IN WAKE COUNTY



Source: North Carolina Geological Survey

5.12.4 Probability of Future Occurrences

Based on historical information and the USGS susceptibility index, the probability of future landslide events is possible (1 to 10 percent probability). Local conditions may become more favorable for landslides due to heavy rain, for example. This would increase the likelihood of occurrence. It should also be noted that some areas in Wake County have greater risk than others given factors such as steepness on slope and modification of slopes.

5.12.5 Consequence Analysis

People (The Public and Public Confidence)

Although there could be some impacts on people from a landslide in Wake County, these impacts would likely be relatively minor, resulting in few injuries. Since the susceptibility is relatively low for most of the county, the likelihood of a major landslide affecting the public is not high and public confidence would probably not be affected by a landslide.

Responders

Since landslides are a relatively low probability event and their extent is likely to be small, impacts on responders are unlikely. However, landslide events often cause the greatest harm when they block roadways, and this would have a negative impact on responders if they were limited in their transportation capacity.

Continuity of Operations

Continuity of operations would probably not be impacted by landslides as it is unlikely that enough personnel or resources would be affected to cause a breakdown of operations.

Built Environment (Property, Facilities, and Infrastructure)

Very little of the built environment is susceptible to the landslide hazard. For a detailed analysis of the impacts on the built environment from landslides, see *Section 6: Hazard Vulnerability.*

Economy

The greatest economic impact from a landslide would occur if roads had to be closed due to the event as this would disrupt the normal flow of business and potentially cost money. However, given the likely nature of landslides in Wake County, economic impacts would be relatively low.

Environment

Environmental impacts from a landslide will likely be minor in Wake County. Although a landslide has the potential to cause debris and dirt to block rivers and dirty waterways or change the terrain and impact farmland and forests, the magnitude of landslide that might affect Wake County is small enough that the impacts would be negligible.

Hydrologic Hazards

5.13 DAM AND LEVEE FAILURE

5.13.1 Background

Worldwide interest in dam and levee safety has risen significantly in recent years. Aging infrastructure, new hydrologic information, and population growth in floodplain areas downstream from dams and near levees have resulted in an increased emphasis on safety, operation, and maintenance.

There are approximately 80,000 dams in the United States today, the majority of which are privately owned. Other owners include state and local authorities, public utilities, and federal agencies. The benefits of dams are numerous: they provide water for drinking, navigation, and agricultural irrigation. Dams also provide hydroelectric power, create lakes for fishing and recreation, and save lives by preventing or reducing floods.

Though dams have many benefits, they also can pose a risk to communities if not designed, operated, and maintained properly. In the event of a dam failure, the energy of the water stored behind even a small dam is capable of causing loss of life and great property damage if development exists downstream. If a levee breaks, scores of properties may become submerged in floodwaters and residents may become trapped by rapidly rising water. The failure of dams and levees has the potential to place large numbers of people and great amounts of property in harm's way.

5.13.2 Location and Spatial Extent

The North Carolina Division of Land Resources provides information on dams, including a hazard potential classification. There are three hazard classifications—high, intermediate, and low—that correspond to qualitative descriptions and quantitative guidelines. **Table 5.41** explains these classifications.

TABLE 5.41: NORTH CAROLINA DAM HAZARD CLASSIFICATIONS

Hazard Classification	Description	Quantitative Guidelines
Low	Interruption of road service, low volume roads	Less than 25 vehicles per day
	Economic damage	Less than $30,000
Intermediate	Damage to highways, Interruption of service	25 to less than 250 vehicles per day
	Economic damage	$30,000 to less than $200,000
High	Loss of human life*	Probable loss of 1 or more human lives
	Economic damage	More than $200,000
	*Probable loss of human life due to breached roadway or bridge on or below the dam.	250 or more vehicles per day

Source: North Carolina Division of Land Resources

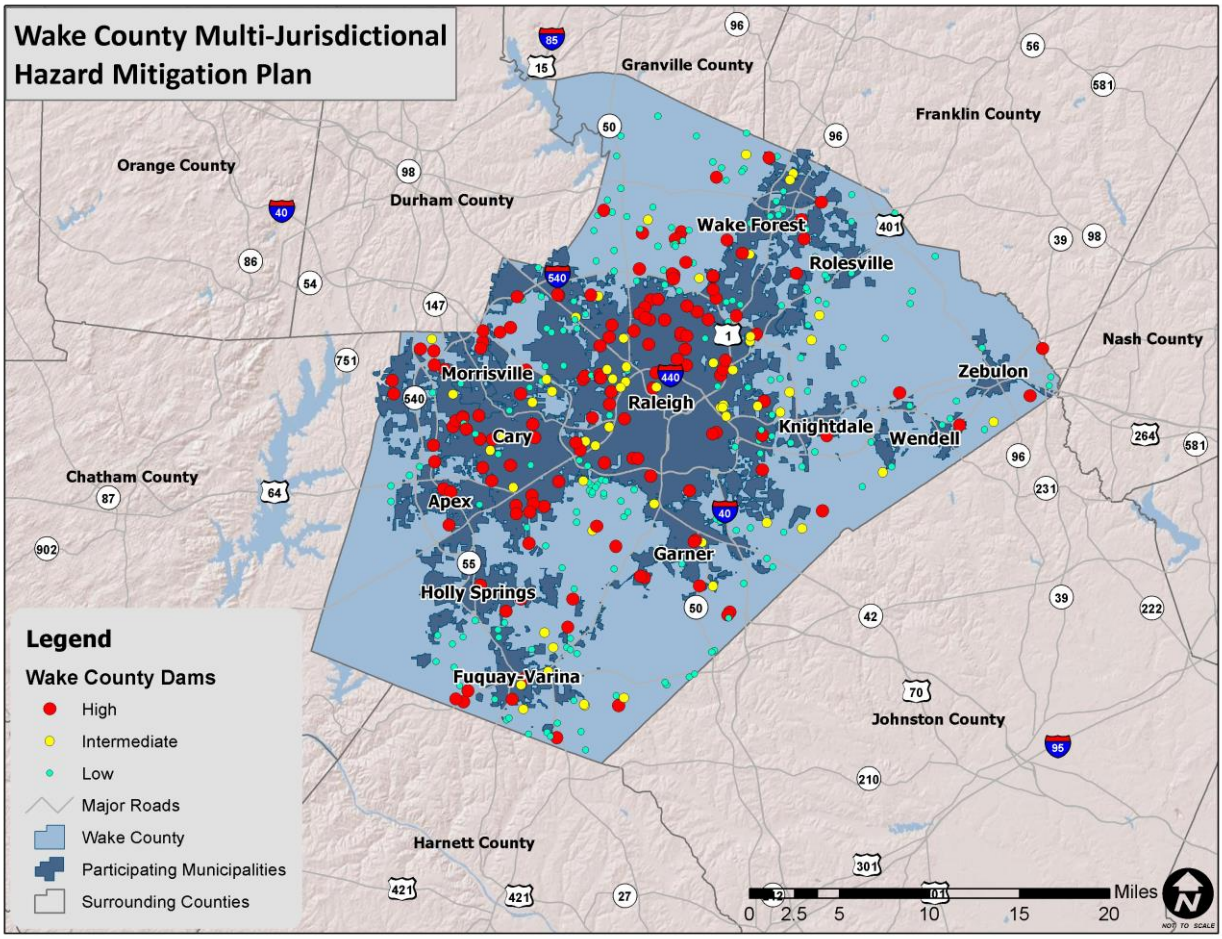
According to the North Carolina Division of Energy, Mineral, and Land Resources, there are 401 dams in Wake County.[24] **Figure 5.13** shows the dam location and the corresponding hazard ranking for each. Of these dams, 144 are classified as high hazard potential. These high hazard dams are summarized by county in **Table 5.42** and listed in **Table 5.43**.

TABLE 5.42: SUMMARY OF HIGH HAZARD DAM LOCATION

Location	Number High Hazard Dams
Apex	3
Cary	23
Fuquay-Varina	2
Garner	4
Holly Springs	2
Knightdale	1
Morrisville	4
Raleigh	57
Rolesville	0
Wake Forest	3
Wendell	1
Zebulon	0
Unincorporated Area	44
WAKE COUNTY TOTAL	**144**

[24] The February 8, 2012 list of high hazard dams obtained from the North Carolina Division of Energy, Mineral, and Land Resources (http://portal.ncdenr.org/web/lr/dams) was reviewed and amended by local officials to the best of their knowledge.

FIGURE 5.13: WAKE COUNTY DAM LOCATION AND HAZARD RANKING



Source: North Carolina Division of Land Resources, 2012

TABLE 5.43: WAKE COUNTY HIGH HAZARD DAMS

Dam Name	Hazard Potential	Surface Area (acres)	Max Capacity (Ac-ft)	Owner Type
Wake County				
Falls Of The Neuse Dam	High	0	1128100	Federal
Lake Benson Dam	High	463	7200	Local Gov
Crabtree Dam 20-A	High	0	2500	Local Gov
Crabtree Creek Dam 5-A	High	0	3010	Local Gov
Garner Ww Lagoon #1	High	25	394	Local Gov
Garner Ww Lagoon #2	High	25	306	Local Gov
Neuse River Waste Water Treatment Plant Equalization Basin	High	7.5	114	Local Gov
Bunn Lake Dam	High	120	975	Private
Johnson Pond Dam	High	9	95	Private
Crossgate Lake Dam #1	High	13.1	207	Private
Crossgate Dam #2	High	0	40	Private

Dam Name	Hazard Potential	Surface Area (acres)	Max Capacity (Ac-ft)	Owner Type
Holding Lake Dam	High	11	145	Private
Panther Lake Dam	High	82	253	Private
Sunset Lake Dam	High	98.1	750	Private
Robertson'S Pond	High	25	259	Private
Rdu Wastewater Dam	High	1.6	22.5	Private
Rtp South Dam	High	77	708	Private
Crooked Creek	High	0	40	Private
Pendleton Lake	High	0	10	Private
Johnson Pond Dam	High	0	5	Private
Coachman Trail Lake Dam Lower	High	2	93	Private
Stonebridge Lake Dam	High	0	45	Private
Herndon Pond Dam	High	0	22	Private
Springdale Estates Upper Dam	High	0	75	Private
Coachman Trail Lake Dam Upper	High	0	180	Private
Byrd Dam	High	1	10	Private
Fuller Lake Dam	High	0	70	Private
Bailey Dam	High	6	76	Private
Marshall Pond #2	High	4	59	Private
Howell Dam	High	3	36	Private
Manchester Dam	High	0	88	Private
Crossgate Dam #3	High	0	12	Private
Chateau Lapointe Dam H	High	0	90	Private
Cozart Pond Dam	High	2	0	Private
Underwood Pond Dam	High	4	27	Private
Betts Pond Dam	High	5	40	Private
Breckenridge Recreation Center Dam	High	3	38	Private
Hasentree Golf Communtiy Dam	High	0	139	Private
RTP W-5 Dam	High	47	700	Private
State Fair H & L Dam	High	6	78	State
Lake Wheeler Dam	High	560	10800	Utility
Burnside Drive Dam	High	3	12	
Seymour Farms Pond Dam	High	0.7	7	
Rosewood Subdivision Dam	High	1	6	
Apex				
Lake Pine Dam	High	0	163	Local Gov
Haddon Hall Dam	High	5	42	Private
Haddon Hall Upper Dam	High	1.1	0	Private
Cary				
Fred G Bond Dam	High	80	666	Local Gov
Tryon Road Dam	High	0	0	Local Gov
Jack Rigsbee Dam	High	2	20	Private
Preston Crossings Dam	High	2	18.8	Private
Rigsbee Dam	High	3	24	Private
Barbee Dam	High	1.9	12	Private
Blackhawk Dam	High	3.2	26	Private

Dam Name	Hazard Potential	Surface Area (acres)	Max Capacity (Ac-ft)	Owner Type
Adams Dam	High	2	17	Private
Coronado Lake Dam	High	4.4	26	Private
Hobby Dam	High	2	16	Private
Regency Park Dam	High	27.3	350	Private
Kildaire Farms Dam	High	30	420	Private
Lochmere Dam	High	70	728	Private
Audubon Parc Dam	High	0.9	8.1	Private
Lake Amberly Dam	High	14.1	0	Private
Searstone	High	1.3	9	Private
Panther Creek Dam	High	24	202	
Lochmere Lake Dam #2	High	16.3	196	
Loch Highlands Dam	High	6.4	59	
Lake Crabtree	High	473	8950	
Huggins Glen Dam	High	0	80	
Powell Tract Dam	High	0	9999	
Woolner Dam	High	1	11	
Fuquay-Varina				
Parker Lake Dam	High	0	75	Private
Jones Pond Dam	High	3	19	Private
Garner				
Massengill Dam	High	6	82	Private
Eagle Ridge Golf Course Dam	High	5.9	0	Private
Weston #1	High	0	10.8	
Weston #2	High	0	10	
Holly Springs				
Bass Lake Dam	High	58.6	910	Local Gov
Windcrest	High	4.2	42	Local Gov
Knightdale				
Myrick Lake Dam	High	0	5	Private
Morrisville				
Crabtree Creek W/S #1 (PL-566)	High	64	480	Local Gov
Crabtree Creek W/S Dam #18	High	16	661	Local Gov
Perimeter Park West Dam	High	1	10	Private
Breckenridge Tract 9 & 10 Dam	High	3	83	Private
Raleigh				
Shelley Lake	High	53	4269	Local Gov
Lake Lynn	High	55.7	2292	Local Gov
Eastgate Park Dam	High	3	27	Local Gov
Crabtree Creek W/S Structure #11a	High	44.5	3327	Local Gov
E.M. Johnson Water Plant B	High	13.1	383	Local Gov
E.M. Johnson Plant A Dam	High	6.4	110	Local Gov
Hedingham Dam #1	High	14.8	152	Private
Gresham Lake Dam	High	65	1755	Private
Shaw Lake Dam	High	4	55	Private

Dam Name	Hazard Potential	Surface Area (acres)	Max Capacity (Ac-ft)	Owner Type
Baker Lake Dam	High	5	60	Private
Turfgrass Lake Dam #3	High	11	85	Private
Lakes Apartment Dam	High	3	21.6	Private
Brentwood Today Lake Dam	High	0	12	Private
Em Johnson Alum Sludge Lagoon Dam	High	6	108.3	Private
Alyson Pond	High	0	40	Private
Lakemont Dam	High	8.3	91	Private
Cedar Hills Lake Dam	High	0	20	Private
Northshore Lake Dam	High	8	63	Private
Bullard And Patterson Dam	High	0.75	2.5	Private
Camp Pond Dam	High	4	24	Private
Wooten Pond Dam	High	0	40	Private
Ammons Lake Dam Upper	High	0	50	Private
Ammons Lake Dam Lower	High	8	352	Private
Longview Lake Dam Lower	High	12	143	Private
Longview Lake Upper Dam	High	5.5	44	Private
North Ridge Lake Dam Upper	High	15	168	Private
North Ridge Lake Dam Lower	High	0	161	Private
North Blvd Comm Center Dam	High	0	20	Private
Hart-George Pond	High	2	18	Private
Williams-Johnson Pond Dam	High	0	44	Private
The Lakes Lower Dam	High	5	41	Private
Summer Lake Dam	High	4.3	18	Private
Meredith College Dam	High	3	34	Private
Underwood Dam	High	3.1	30	Private
Ward Transformer Dike	High	0	13	Private
Martin Marietta #1 Dam	High	3.6	59	Private
Lakeside Dam	High	3	23	Private
Leadmine Lake Dam	High	10	92	Private
Delta Lake	High	3	42	Private
Olde Raleigh Dam #3	High	2.8	24	Private
Olde Raleigh Dam #1	High	1.6	19.7	Private
Olde Raleigh Dam #2	High	3.2	25.1	Private
Landmark Apts. Dam	High	2	18	Private
Remington Park Dam	High	6	84	Private
Newton Commons Dam	High	0.75	8.6	Private
Lake Plaza Dam	High	2	18.4	Private
Lake Raleigh Dam	High	66	781	State
Lake Johnson Dam	High	147.5	3090	Utility
Carolina Country Club Water Harvesting Pond Dam	High	0	0	
Raintree Lake	High	0	0	
NCSU Centennial Campus Farm Pond Dam	High	2	20	
Heathrow Dam	High	0	26	
Mallard Pond Dam	High	0	8	

Dam Name	Hazard Potential	Surface Area (acres)	Max Capacity (Ac-ft)	Owner Type
Art Museum Dam	High	0	10	
Brier Creek Village Center Dam	High	0	0	
Carolina Pines Dam	High	4.3	53	
Bedford at Falls River Dam #1	High	0	4	
Rolesville				
None reported				
Wake Forest				
Wake Forest Water Supply Dam	High	50	945	Local Gov
Lewis Dam	High	10	80	Private
St. Andrews Plantation Dam	High	3	23	Private
Wendell				
Timberlake Dam	High	0	9999	
Zebulon				
None reported				

Source: North Carolina Division of Land Resources, 2012

5.13.3 Historical Occurrences

A total of 36 statewide dams failed as a result of Hurricane Floyd (1999)—14 high-hazard, 5 intermediate, and 12 low-hazard dams were damaged or destroyed.[25] Federal grant funding helped the North Carolina Dam Safety Program develop an Emergency Action Plan that was implemented following the 1999 hurricane season. Dam safety personnel instituted the following measures:

- Inspection of high-hazard dams at least every 2 years and of intermediate and low-hazard dams at least every 5 years
- Notification of dam owners regarding deficiencies found in dams and needed maintenance or engineering and repairs and enforcement of recommendations if needed
- Review of plans for construction of new dams
- Review of plans for dam repairs, modifications, or decommissioning
- Inspection during construction activities as resources permit
- Inspection prior to impoundment once construction is completed
- Inspection during and after extreme events such as floods
- Maintenance of databases and records of dams under North Carolina jurisdiction

Several dam failures have occurred in Wake County, but none have been significant**. Table 5.44** displays the classification of each dam at time of failure and the main cause of the damage. **Figure 5.14** shows the location of dam failure occurrences within the county

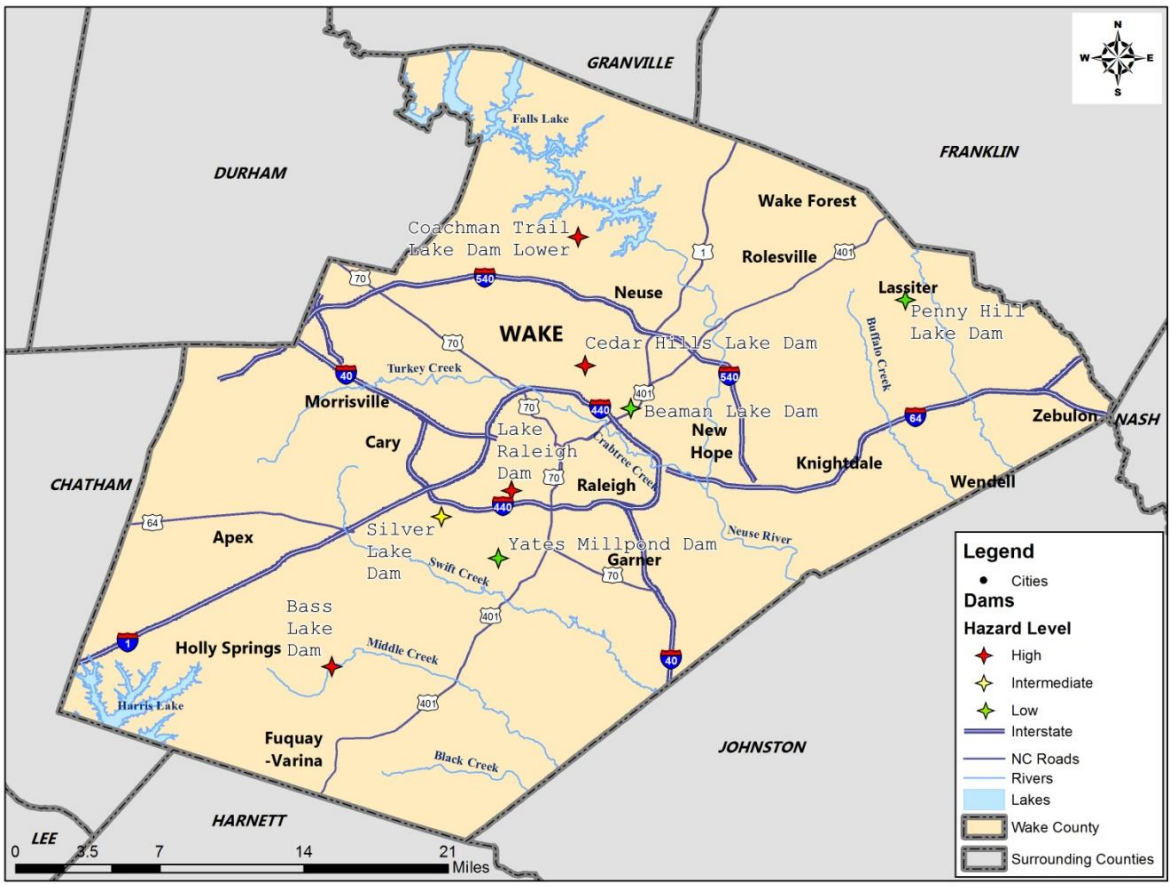
[25] Town of Apex Hazard Mitigation Plan. (2010). *Appendix A: Hazard Identification and Analysis*.

TABLE 5.44: HISTORICAL DAM FAILURES IN WAKE COUNTY

Name	Location	Class at Time of Failure	Current Class	Cause of Failure
Cedar Hills*	Wake County	Intermediate	High	Heavy rain (mid 1970s)
Coachman's Trail Lower	Wake County	High	High	Heavy rain (late 1970s)
Beaman's Lake***	Wake County	Intermediate	Intermediate	Heavy rain (late 1980s)
Bass Lake*	Holly Springs	Low	High	Hurricane Fran (1996)
Lake Raleigh	Raleigh	High	High	Hurricane Fran (1996)
Penny Hill Lake	Zebulon	Low	Low	Hurricane Fran (1996)
Silver Lake**	Raleigh	Intermediate	High	Hurricane Fran (1996)
Yates Mill Pond	Wake County	Intermediate	Intermediate	Hurricane Fran (1996)

*High due to downstream development
**High due to increased traffic on downstream road
***Exempt due to dam height

FIGURE 5.14: WAKE COUNTY DAM FAILURE LOCATIONS WITH HAZARD RANKING



Source: Wake County HIRA Report, 2012

5.13.4 Probability of Future Occurrence

Given the current dam inventory and historic data, a dam breach is unlikely (less than 1 percent annual probability) in the future. However, as has been demonstrated in the past, regular monitoring is necessary to prevent these events and they can occur. No further analysis will be completed in Section 6: *Vulnerability Assessment* as more sophisticated dam breach plans (typically completed by the U.S. Army Corp of Engineers) have been completed for dams of concern in the region.

5.13.5 Consequence Analysis

People (The Public and Public Confidence)

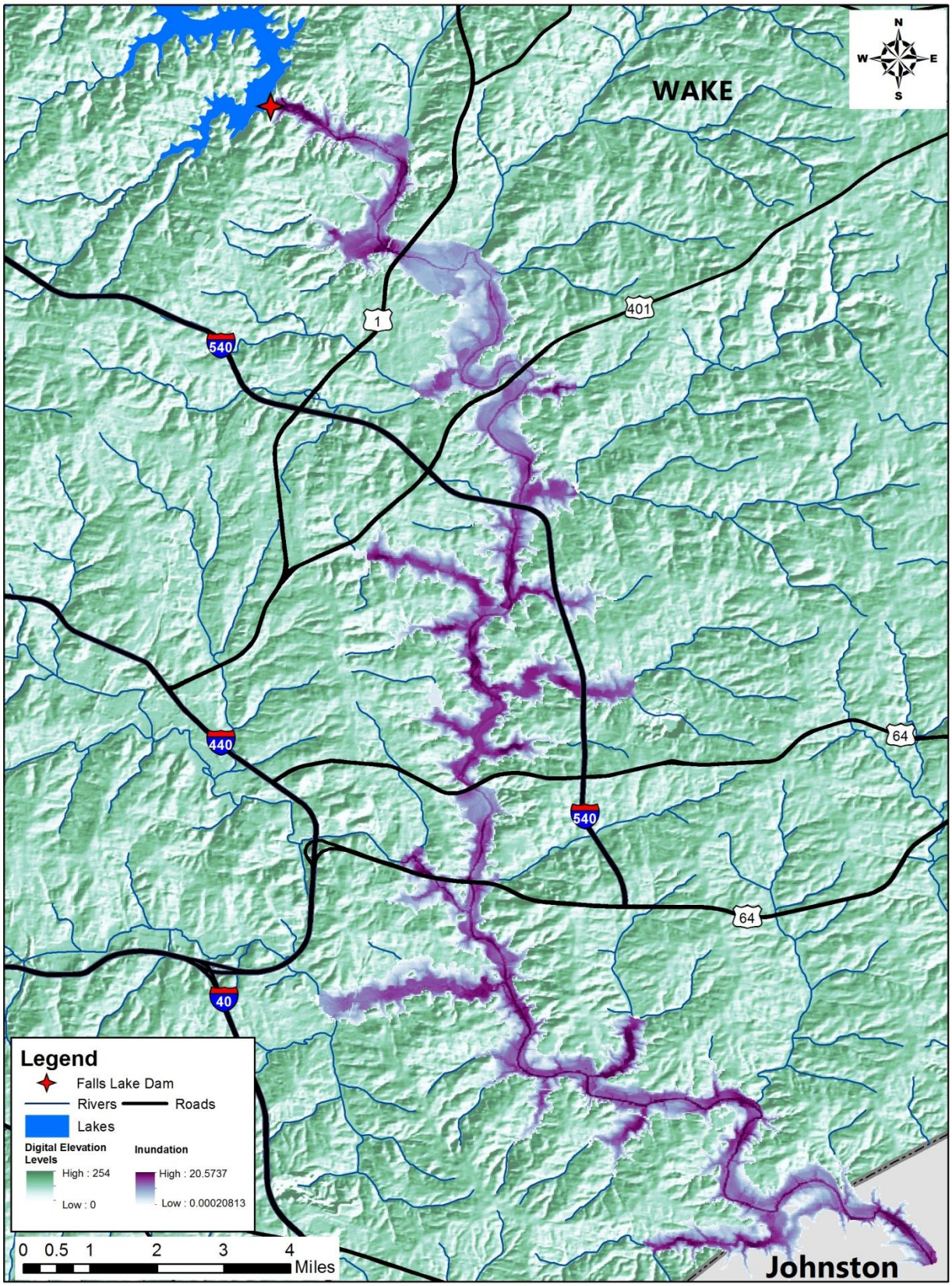
In the case of a dam failure, a person's vulnerability is largely determined by their proximity to a dam and/or a river. The number and characteristics of people that would be impacted by a catastrophic failure of Falls Lake Dam are shown in **Table 5.45**. **Figure 5.15** shows the inundation area for a dam failure at Falls Lake. A dam failure could have a significant effect on public confidence due to the large-scale, perceived impact of the event.

Table 5.45: Age, Sex, Race, and Income of Impacted Population

Name of Variable	Falls Lake Dam Failure	Wake County
Total Number of People	20,366	900,993
Population Under Age 18	6,072	234,613
Population Ages 18–64	13,178	589,831
Population Age 65 and Older	1,116	76,549
Number of Males (all ages)	9,671	438,792
Number of Females (all ages)	10,696	462,201
Median Age (both sexes)	31	35
White Only	9,801	560,536
Black or African American Only	7,431	182,793
American Indian or Alaskan Native Only	122	4,503
Asian Only	909	48,287
Native Hawaiian or Pacific Islander Only	8	387
Other Race	1,457	21,455
Number of People with Hispanic Origins	2,991	87,922
Per Capita Income (5-year estimate)*	$33,435	$35,122

**Only available at the Census tract level*

FIGURE 5.15: FALLS LAKE DAM FAILURE INUNDATION AREA



Emergency Sheltering
HAZUS-MH is able to estimate the number of households that are expected to be displaced from their homes due to the dam failure and may require accommodations in temporary emergency shelters. The model estimates 500 households will be displaced and a total of 1,195 people could seek shelter.

Responders
Response in a dam failure would be similar in many ways to the response in a flood and, as such, responders would be impacted in similar ways, although probably to a lesser degree than in a flood situation as the impact would probably be somewhat more geographically confined. For more information, please see the flood analysis section.

Continuity of Operations
Continuity of operations in a dam failure event would likely be maintained without much difficulty. Although it could be impacted to some degree due to power loss or road closures that would prevent staff from continuing operations, generally there would be minimal disruption to operations.

Built Environment (Property, Facilities, and Infrastructure)
According to the most recent Wake County property data, a total of 7,471 occupied housing units could potentially be impacted but not necessarily displaced by a failure of the Falls Lake Dam, which is approximately 3 percent of the total occupied units in the county. Almost 2 percent of land acreage would be impacted by the same event. A summary of building and property characteristics within the inundation area are shown in **Table 5.46**.

TABLE 5.46: CHARACTERISTICS OF BUILDINGS AND PROPERTIES IMPACTED

Name of Variable	Dam Failure	Wake County
Property Impacted (Acres)	9,846	501,265
Percent of Wake County Property Impacted	1.96%	--
Total Housing Units	7,877	386,187
Number of Occupied Units	7,471	235,493
Number of Vacant Units	407	121,300
Estimated Building Value Losses	$960,990,794	--

The land classification codes of property impacted by the dam failure inundation are listed in **Table 5.47**and show that the inundation area is mostly comprised of exempt, vacant, residential, agricultural-farm, floricultural-farm, and historic-site properties. Residential property (less than or equal to 10 acres) represents the largest estimated building value loss—approximately $818 billion—that could be severely damage. Exempt land represents the second largest estimated building value loss of approximately $57 million. Apartment and commercial properties both represent a loss of approximately $27 million.

TABLE 5.47: LAND CLASSIFICATION OF ESTIMATED BUILDING VALUE LOSSES

Code	Land Classification	Acres Impacted	Estimated Building Value Losses	Estimated Land Value Losses
A	AC-W/IMP	46.37	$139,203.10	$1,300,322.55
B	AC >10 Acres-Home Site	325.88	$3,783,189.87	$8,777,768.35
C	Commercial	270.51	$26,952,290.20	$11,383,768.38

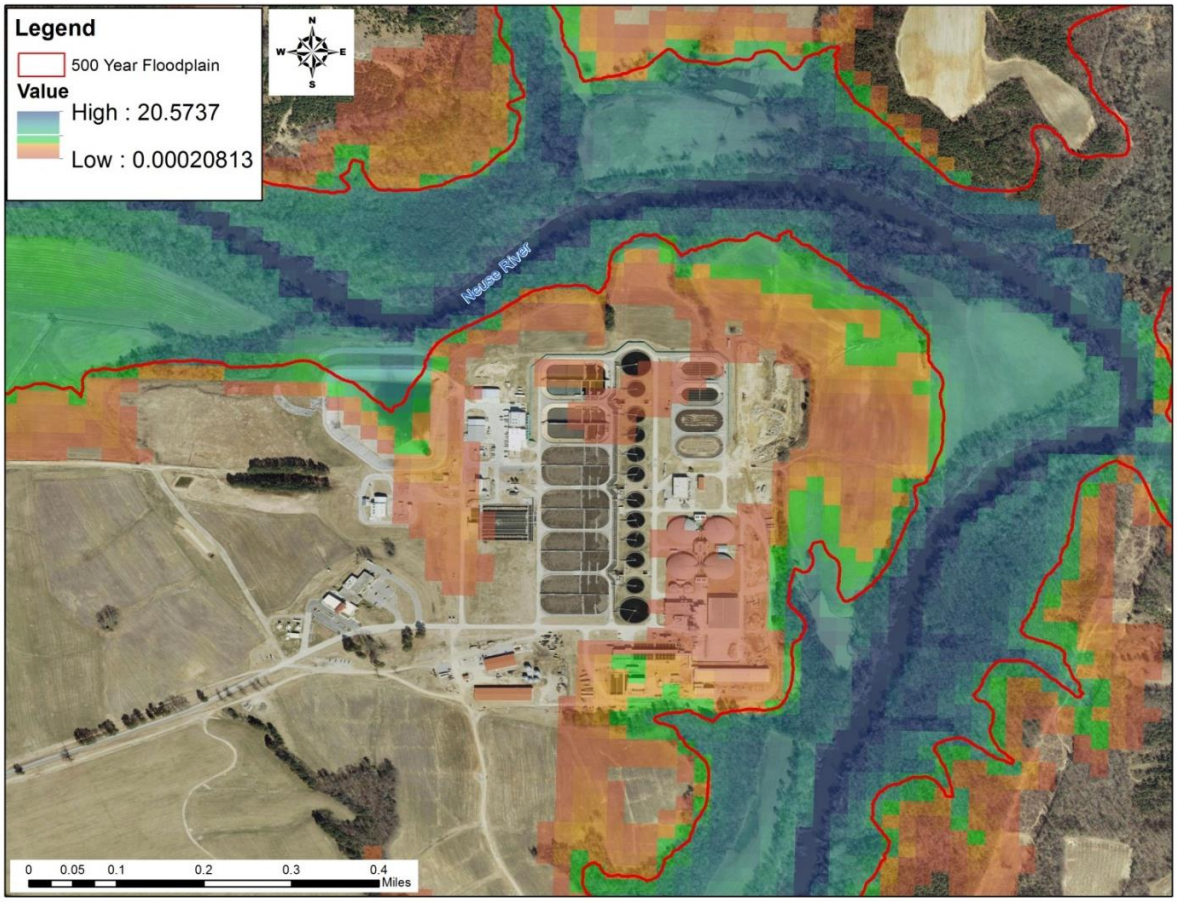
Code	Land Classification	Acres Impacted	Estimated Building Value Losses	Estimated Land Value Losses
D	Industrial	246.81	$13,853,035.63	$8,592,182.85
E	Exempt	2826.22	$57,398,122.30	$123,629,671.86
F	Agricultural-Farm	870.92	$1,050,918.62	$22,593,710.01
G	Apartment	44.87	$26,961,440.89	$3,280,356.55
H	Historic Site	711.12	$382,053.00	$2,439,171.90
I	Homeowners Association	52.81	$1,787.59	$1,733,571.11
O	MA+Condo	2.18	$0.00	$0.00
P	Private Exempt	8.26	$0.00	$0.00
R	Residence -< 10 Acres-Home Site	17.56	$2,495,482.72	$1,285,219.94
S	State-Assessed	1555.04	$817,889,458.69	$236,771,395.06
T	Mobile Home Park	14.21	$0.00	$324,959.98
U	Golf Course	148.67	$6,706,114.88	$7,052,571.22
V	Vacant	246.48	$2,807,422.44	$3,540,036.41
W	Water/Sewer System	1574.25	$1,692.68	$54,577,472.08
Y	Floriculture-Farm	29.31	$49,237.76	$41,630.61
Z	Horticulture-Farm	832.15	$437,079.04	$26,993,004.32

Critical Infrastructure and Key Resources

Critical infrastructure and key resources within Wake County include assets, systems, and networks that are vital to the continued operation of government services. The incapacitation or destruction of these resources would have a debilitating effect on the county's security, economy, and/or public health. One fixed site key resource—the Neuse River Wastewater Treatment Plant—could be damaged by a catastrophic failure of Falls Lake Dam. **Figure 5.16**shows the potential extent of inundation at the plant. Consequences of flooding the treatment plant include cessation of plant services and downstream water quality impacts. Submersion of the plant would cause a continuous discharge of untreated wastewater into the Neuse River. Wastewater usually contains organic matter, pathogens (disease-causing organisms), high concentrations of nutrients such as phosphorus and nitrogen, heavy metals, and some toxic chemicals. All of these could affect the health of people and ecosystems that live downstream from the plant. Life-threatening pathogens carried by sewage include dysentery, schistosomiasis, hepatitis A, and intestinal nematode infections.[26] Downstream wetlands may be impacted by algal blooms from wastewater discharges, which directly influences the penetration of sunlight and reduces the productivity of wetland flora. Destruction of wetland flora and fauna is also a possibility due to various toxic chemicals carried by untreated wastewater from local industrial facilities.

[26] Prüss-Üstün, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safe water, better health*. Geneva: World Health Organization. Retrieved March 10, 2012, from http://www.who.int/quantifying_ehimpacts/publications/saferwater/en/index.html

FIGURE 5.16: INUNDATION OF THE NEUSE RIVER WASTEWATER TREATMENT PLANT



Economy

There would be three main sources of economic loss associated with a dam failure: property damage and business interruption costs, cost of emergency response services, and debris management costs.

Property Damage and Business Interruption

The total economic loss estimated for the dam failure is $78.25 million, which represents 10.69 percent of the total replacement value of the scenario buildings. Building losses are broken into two categories: direct building losses and business interruption losses. Direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. Business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood. The total building-related losses were $77.45 million. One percent of the estimated losses were related to the business interruption of the region. The residential occupancies made almost 59 percent of the total loss.

Debris Management

HAZUS-MH estimates the amount of debris that will be generated by the dam failure. The model separates debris into three general categories:

- Finishes—dry wall, insulation, etc.
- Structural—wood, brick, vinyl, etc.

- Foundation—concrete slab, concrete block, rebar

This distinction is made because of the different types of equipment required to handle the debris. The model estimates that a total of 1,220 tons of debris will be generated by the dam failure. If the debris tonnage is converted into an estimated number of truckloads, this incident would require 49 truckloads (25 tons per truck) to remove the debris.

Environment

The two main environmental concerns from a catastrophic dam failure include total destruction of wetland areas in close proximity to the dam and long-term damage to downstream wetlands. Impacts on wetland areas due to flooding are discussed in the flood hazard profile, and damage from inundation of the Neuse River wastewater treatment plant is covered in the key resources discussion above.

5.14 EROSION

5.14.1 Background

Erosion is the gradual breakdown and movement of land due to both physical and chemical processes of water, wind, and general meteorological conditions. Natural, or geologic, erosion has occurred since the Earth's formation and continues at a very slow and uniform rate each year.

There are two types of soil erosion: wind erosion and water erosion. Wind erosion can cause significant soil loss. Winds blowing across sparsely vegetated or disturbed land can pick up soil particles and carry them through the air, thus displacing them. Water erosion can occur over land or in streams and channels. Water erosion that takes place over land may result from raindrops, shallow sheets of water flowing off the land, or shallow surface flow, which becomes concentrated in low spots. Stream channel erosion may occur as the volume and velocity of water flow increases enough to cause movement of the streambed and bank soils. Major storms, such hurricanes in coastal areas, may cause significant erosion by combining high winds with heavy surf and storm surge to significantly impact the shoreline.

An area's potential for erosion is determined by four factors: soil characteristics, vegetative cover, topography climate or rainfall, and topography. Soils composed of a large percentage of silt and fine sand are most susceptible to erosion. As the clay and organic content of these soils increases, the potential for erosion decreases. Well-drained and well-graded gravels and gravel-sand mixtures are the least likely to erode. Coarse gravel soils are highly permeable and have a good capacity for absorption, which can prevent or delay the amount of surface runoff. Vegetative cover can be very helpful in controlling erosion by shielding the soil surface from falling rain, absorbing water from the soil, and slowing the velocity of runoff. Runoff is also affected by the topography of the area including size, shape, and slope. The greater the slope length and gradient, the more potential an area has for erosion. Climate can affect the amount of runoff, especially the frequency, intensity, and duration of rainfall and storms. When rainstorms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature and rainfall amounts define the period of highest erosion risk of the year.

During the past 20 years, the importance of erosion control has gained the increased attention of the public. Implementation of erosion control measures consistent with sound agricultural and construction operations is needed to minimize the adverse effects associated with harmful chemicals run-off due to wind or water events. The increase in government regulatory programs and public concern has resulted

in a wide range of erosion control products, techniques, and analytical methodologies in the United States. The preferred method of erosion control in recent years has been the restoration of vegetation.

5.14.2 Location and Spatial Extent

Erosion in Wake County is typically caused by flash flooding events. Unlike coastal areas, where the soil is mainly composed of fine grained particles such as sand, Wake County soil has greater organic matter content. Furthermore, vegetation also helps to prevent erosion in the area. Erosion occurs in Wake County, particularly along the banks of rivers and streams, but it is not an extreme threat to any of the participating jurisdictions. No areas of concern were reported by the planning team.

5.14.3 Historical Occurrences

Several sources were vetted to identify areas of erosion in Wake County. This includes searching local newspapers, interviewing local officials, and reviewing previous hazard mitigation plans. Little information could be found beyond the hazard mitigation plans. Although erosion was mentioned in each of the plans and many of the jurisdictions have Erosion and Sedimentation Control Ordinances in effect, erosion was not addressed in any of the previous hazard mitigation plans.

5.14.4 Probability of Future Occurrences

Erosion remains a natural, dynamic, and continuous process for Wake County, and it will continue to occur. The annual probability level assigned for major erosion events is possible (between 1 and 10 percent annually). However, given the lack of historical events, location, data, and threat to life or property, no further analysis will be done in Section 6: *Vulnerability Assessment*.

5.14.5 Consequence Analysis

People (The Public and Public Confidence)

Typically, people are not directly impacted by erosion. However, sudden incidents prompting emergency action, such as a strong storm causing bluff failure, could result in injury or loss of life. People located nearby to waterways and streams in Wake County are most susceptible to erosion. However, since few major erosion areas were noted in the risk assessment, it is unlikely the erosion will have a major impact on the public here as it does in many coastal communities. As such, the impact on public confidence will be very limited.

Responders

Impacts to responder would be very low as erosion in Wake County does not occur at a fast enough rate to truly impact many response operations.

Continuity of Operations

Erosion will have little effect on continuity of operations in Wake County, again, because it is happening at to slow of a rate.

Built Environment (Property, Facilities, and Infrastructure)

Erosion can have an impact on the built environment, especially roads and pipelines and any infrastructure that requires relatively stable ground to exist upon. Erosion near roads will require

consistent repairs that attempt to stabilize the ground. In Wake County, erosion tends to be a far lesser problem than in many coastal communities, however, there are areas in the county where erosion could potentially cause some issues, especially around rivers/streams.

Economy

Erosion impacts the economy when rebuilding of structures must take place in order to stabilize them. This can be especially detrimental if businesses are affected or have to shut down temporarily to deal with erosion issues. Erosion can also impact the economy through productivity losses if the loss of topsoil renders soil less fertile for farming and agriculture.

Environment

Generally, the environment is not impacted by erosion as it is a natural process that occurs over time, so the environment can adapt. However, rapid erosion that takes place as a result of human activity can impact environmental features by changing habitats and ecosystems in which plant and animal life exist.

5.15 FLOOD

5.15.1 Background

Flooding is the most frequent and costly natural hazard in the United States and is a hazard that has caused more than 10,000 deaths since 1900. Nearly 90 percent of presidential disaster declarations result from natural events where flooding was a major component.

Floods generally result from excessive precipitation and can be classified under two categories: general floods, precipitation over a given river basin for a long period of time along with storm-induced wave action, and flash floods, the product of heavy localized precipitation in a short time period over a given location. The severity of a flooding event is typically determined by a combination of several major factors, including stream and river basin topography and physiography, precipitation and weather patterns, recent soil moisture conditions, and the degree of vegetative clearing and impervious surface.

General floods are usually long-term events that may last for several days. The primary types of general flooding include riverine, coastal, and urban flooding. Riverine flooding is a function of excessive precipitation levels and water runoff volumes within the watershed of a stream or river. Coastal flooding is typically a result of storm surge, wind-driven waves, and heavy rainfall produced by hurricanes, tropical storms, and other large coastal storms. Urban flooding occurs where manmade development has obstructed the natural flow of water and decreased the ability of natural groundcover to absorb and retain surface water runoff.

Most flash flooding is caused by slow-moving thunderstorms in a local area or by heavy rains associated with hurricanes and tropical storms. However, flash flooding events may also occur from a dam or levee failure within minutes or hours of heavy amounts of rainfall or from a sudden release of water held by a retention basin or other stormwater control facility. Although flash flooding occurs most often along mountain streams, it is also common in urbanized areas where much of the ground is covered by impervious surfaces.

The periodic flooding of lands adjacent to rivers, streams, and shorelines (land known as a floodplain) is a natural and inevitable occurrence that can be expected to take place based upon established

recurrence intervals. The recurrence interval of a flood is defined as the average time interval, in years, expected between a flood event of a particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval.

Floodplains are designated by the frequency of the flood that is large enough to cover them. For example, the 10-year floodplain will be covered by the 10-year flood and the 100-year floodplain by the 100-year flood. Flood frequencies, such as the 100-year flood, are determined by plotting a graph of the size of all known floods for an area and determining how often floods of a particular size occur. Another way of expressing the flood frequency is the chance of occurrence in a given year, which is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1 percent chance of occurring in any given year and the 500-year flood has a 0.2 percent chance of occurring in any given year.

5.15.2 Location and Spatial Extent

There are areas in Wake County that are susceptible to flood events. Special flood hazard areas in the Wake County were mapped using Geographic Information System (GIS) and FEMA Digital Flood Insurance Rate Maps (DFIRM).[27] This includes Zone A (1-percent annual chance floodplain), Zone AE (1-percent annual chance floodplain with elevation), Zone X500 (0.2-percent annual chance floodplain). According to GIS analysis, of the 835 square miles that make up Wake County, there are 76.8 square miles of land in zones A and AE (1-percent annual chance floodplain/100-year floodplain) and 5.5 square miles of land in zone X500 (0.2-percent annual chance floodplain/500-year floodplain). The jurisdictional totals are presented below in **Table 5.48**.

TABLE 5.48: SUMMARY OF FLOODPLAIN AREAS IN WAKE COUNTY

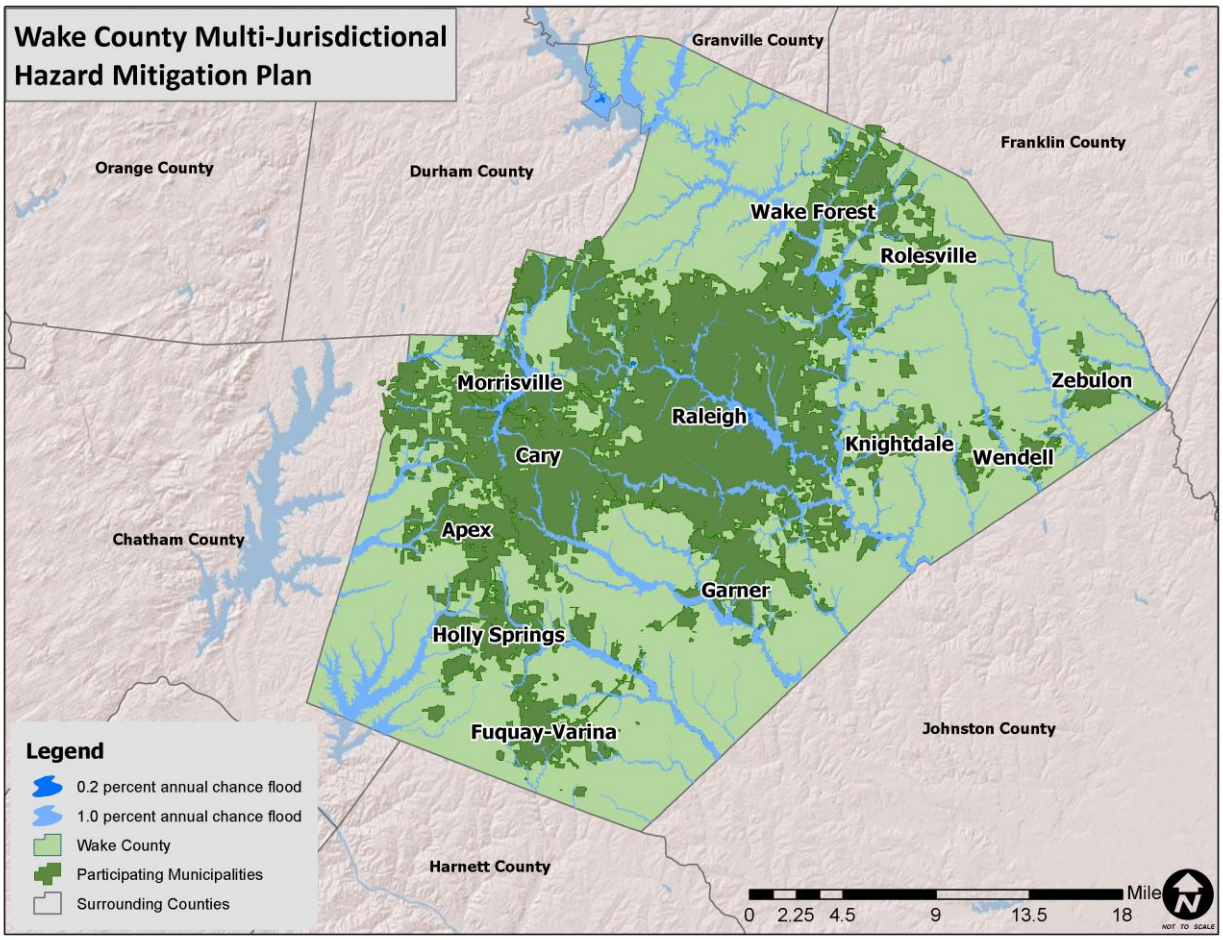
Location	100-year area (square miles)
Apex	0.68
Cary	4.49
Fuquay-Varina	0.54
Garner	1.10
Holly Springs	0.98
Knightdale	0.31
Morrisville	0.60
Raleigh	11.35
Rolesville	0.07
Wake Forest	1.56
Wendell	0.28
Zebulon	0.13
Unincorporated Area	54.68
WAKE COUNTY TOTAL	**76.77**

These flood zone values account for 9.2 percent of the total land area in Wake County. It is important to note that while FEMA digital flood data is recognized as best available data for planning purposes, it does not always reflect the most accurate and up-to-date flood risk. Flooding and flood-related losses

[27] The county-level DFIRM data used for Wake County was updated in 2013 for each of the jurisdictions.

often do occur outside of delineated special flood hazard areas. **Figure 5.17** illustrates the location and extent of currently mapped special flood hazard areas for Wake County based on best available FEMA DFIRM data.

FIGURE 5.17: SPECIAL FLOOD HAZARD AREAS IN WAKE COUNTY



Source: Federal Emergency Management Agency

Additional, more detailed jurisdiction-level maps can be found in the annexes.

5.15.3 Historical Occurrences

Information from the National Climatic Data Center was used to ascertain historical flood events. The National Climatic Data Center reported a total of 100 events throughout Wake County since 1993.[28] A summary of these events is presented in **Table 5.49**. These events accounted for over $10.6 million (2013 dollars) in property damage throughout the region.[29] Specific information on flood events for each county, including date, type of flooding, and deaths and injuries, can be found in **Table 5.50**.

[28] These events are only inclusive of those reported by NCDC. It is likely that additional occurrences have occurred and have gone unreported.
[29] The total damage amount was averaged over the number of affected counties when multiple counties were involved in the flood event.

TABLE 5.49: SUMMARY OF FLOOD OCCURRENCES IN WAKE COUNTY

Location	Number of Occurrences	Deaths/Injuries	Property Damage (2013)
Apex	2	0/0	$0
Cary	4	0/0	$0
Fuquay-Varina	3	0/0	$0
Garner	1	0/0	$0
Holly Springs	1	0/0	$0
Knightdale	0	0/0	$0
Morrisville	7	0/0	$0
Raleigh	36	0/0	$10,416,787
Rolesville	0	0/0	$0
Wake Forest	3	0/0	$0
Wendell	0	0/0	$0
Zebulon	0	0/0	$0
Unincorporated Area	43	0/0	$220,101
WAKE COUNTY TOTAL	**100**	**0/0**	**$10,636,888**

Source: National Climatic Data Center

TABLE 5.50: HISTORICAL FLOOD EVENTS IN WAKE COUNTY

	Date	Type	Deaths/ Injuries	Property Damage*
Wake County				
SRN	10/5/1995	FLASH FLOOD	0/0	$0
Northern	6/24/1995	FLASH FLOOD	0/0	$85,344
COUNTYWIDE	7/24/1997	FLASH FLOOD	0/0	$0
COUNTYWIDE	9/27/1999	FLASH FLOOD	0/0	$0
COUNTYWIDE	9/15/1999	FLASH FLOOD	0/0	$0
COUNTYWIDE	9/5/1999	FLASH FLOOD	0/0	$0
COUNTYWIDE	9/28/1999	FLASH FLOOD	0/0	$0
COUNTYWIDE	6/16/2001	FLASH FLOOD	0/0	$0
SOUTH PORTION	7/9/2001	FLASH FLOOD	0/0	$0
SOUTH PORTION	7/4/2001	FLASH FLOOD	0/0	$0
EAST PORTION	8/1/2003	FLASH FLOOD	0/0	$0
CENTRAL PORTION	8/8/2003	FLASH FLOOD	0/0	$0
CENTRAL PORTION	8/8/2003	FLASH FLOOD	0/0	$0
COUNTYWIDE	8/12/2004	FLASH FLOOD	0/0	$0
COUNTYWIDE	6/14/2006	FLASH FLOOD	0/0	$0
BRENTWOOD	4/27/2008	FLASH FLOOD	0/0	$0
MILLBROOK	4/27/2008	FLASH FLOOD	0/0	$0
MILLBROOK	9/6/2008	FLASH FLOOD	0/0	$119,405
ECHO HGTS	8/30/2008	FLASH FLOOD	0/0	$0
CARIO	8/28/2008	FLASH FLOOD	0/0	$0
ASBURY	5/5/2009	FLOOD	0/0	$0
MILLBROOK	5/5/2009	FLASH FLOOD	0/0	$0
BRENTWOOD	5/5/2009	FLASH FLOOD	0/0	$0

	Date	Type	Deaths/ Injuries	Property Damage*
COLLEGE VIEW	12/2/2009	FLASH FLOOD	0/0	$0
CAMP POLK	12/2/2009	FLASH FLOOD	0/0	$0
WESTOVER	12/2/2009	FLASH FLOOD	0/0	$0
CARALEIGH	1/25/2010	FLASH FLOOD	0/0	$0
WESTOVER	6/16/2009	FLASH FLOOD	0/0	$0
WILLOW	9/22/2009	FLASH FLOOD	0/0	$0
CARALEIGH	8/24/2010	FLASH FLOOD	0/0	$0
LEESVILLE	8/5/2010	FLASH FLOOD	0/0	$0
ASBURY	6/1/2010	FLASH FLOOD	0/0	$0
WILLIAMS XRDS	9/30/2010	FLASH FLOOD	0/0	$0
STARMOUNT	8/6/2011	FLASH FLOOD	0/0	$0
COLLEGE VIEW	9/21/2011	FLASH FLOOD	0/0	$5,464
MILLBROOK	7/30/2012	FLASH FLOOD	0/0	$0
MILLBROOK	9/6/2012	FLASH FLOOD	0/0	$0
MILLBROOK	9/18/2012	FLASH FLOOD	0/0	$0
MILLBROOK	9/8/2012	FLASH FLOOD	0/0	$9,888
COLLEGE VIEW	9/8/2012	FLASH FLOOD	0/0	$0
Apex				
APEX	7/27/2010	FLASH FLOOD	0/0	$0
APEX	7/27/2010	FLASH FLOOD	0/0	$0
Cary				
CARY	6/23/2006	FLASH FLOOD	0/0	$0
CARY	7/17/2007	FLASH FLOOD	0/0	$0
CARY	8/6/2011	FLASH FLOOD	0/0	$0
CARY	7/24/2011	FLASH FLOOD	0/0	$0
Fuquay-Varina				
FUQUAY SPGS	8/4/2000	FLASH FLOOD	0/0	$0
FUQUAY SPGS	7/17/2003	FLASH FLOOD	0/0	$0
FUQUAY SPGS	6/4/2004	FLASH FLOOD	0/0	$0
Garner				
Garner	6/11/2006	FLASH FLOOD	0/0	$0
Holly Springs				
Holly Springs	8/11/2001	FLASH FLOOD	0/0	$0
Knightdale				
None Reported				
Morrisville				
MORRISVILLE	7/29/2004	FLASH FLOOD	0/0	$0
MORRISVILLE	6/23/2006	FLASH FLOOD	0/0	$0
MORRISVILLE	6/23/2006	FLASH FLOOD	0/0	$0
MORRISVILLE	6/23/2006	FLASH FLOOD	0/0	$0
MORRISVILLE	8/30/2006	FLASH FLOOD	0/0	$0
MORRISVILLE	8/30/2008	FLASH FLOOD	0/0	$0
MORRISVILLE	5/5/2009	FLASH FLOOD	0/0	$0
Raleigh				
NE Raleigh	8/27/1995	FLASH FLOODING	0/0	$10,241298

	Date	Type	Deaths/ Injuries	Property Damage*
Raleigh	10/4/1995	FLASH FLOOD	0/0	$0
RALEIGH	9/6/1996	FLASH FLOOD	0/0	$0
RALEIGH	9/10/1996	FLASH FLOOD	0/0	$0
RALEIGH, WENDELL	9/10/1996	FLASH FLOOD	0/0	$0
RALEIGH	9/11/1996	FLASH FLOOD	0/0	$0
RALEIGH	10/8/1996	FLASH FLOOD	0/0	$0
RALEIGH	4/28/1997	FLASH FLOOD	0/0	$0
RALEIGH	1/16/1998	FLASH FLOOD	0/0	$79,768
RALEIGH	1/23/1998	URBAN/SML STREAM FLD	0/0	$0
RALEIGH	3/9/1998	FLASH FLOOD	0/0	$0
RALEIGH	3/19/1998	FLASH FLOOD	0/0	$0
RALEIGH	8/8/1998	URBAN/SML STREAM FLD	0/0	$31,907
RALEIGH	8/16/1998	URBAN/SML STREAM FLD	0/0	$63,814
RALEIGH	7/29/2000	FLASH FLOOD	0/0	$0
RALEIGH	8/1/2000	FLASH FLOOD	0/0	$0
RALEIGH	8/4/2000	FLASH FLOOD	0/0	$0
RALEIGH	9/3/2000	FLASH FLOOD	0/0	$0
RALEIGH	9/4/2000	FLASH FLOOD	0/0	$0
RALEIGH	9/25/2000	FLASH FLOOD	0/0	$0
RALEIGH	3/31/2002	FLASH FLOOD	0/0	$0
RALEIGH	6/28/2002	FLASH FLOOD	0/0	$0
RALEIGH	8/26/2002	FLASH FLOOD	0/0	$0
RALEIGH	10/11/2002	FLASH FLOOD	0/0	$0
RALEIGH	6/7/2003	FLASH FLOOD	0/0	$0
RALEIGH	7/29/2003	FLASH FLOOD	0/0	$0
RALEIGH	8/13/2004	FLASH FLOOD	0/0	$0
RALEIGH	8/30/2004	FLASH FLOOD	0/0	$0
RALEIGH	6/7/2005	FLASH FLOOD	0/0	$0
RALEIGH	6/7/2005	FLASH FLOOD	0/0	$0
RALEIGH	6/23/2006	FLASH FLOOD	0/0	$0
RALEIGH	6/16/2009	FLASH FLOOD	0/0	$0
RALEIGH	1/25/2010	FLASH FLOOD	0/0	$0
RALEIGH	9/30/2010	FLASH FLOOD	0/0	$0
RALEIGH	9/30/2010	FLASH FLOOD	0/0	$0
RALEIGH	8/6/2011	FLASH FLOOD	0/0	$0
Rolesville				
None Reported				
Wake Forest				
WAKE FOREST	8/26/1999	FLASH FLOOD	0/0	$0
WAKE FOREST	9/10/2001	FLASH FLOOD	0/0	$0
WAKE FOREST	12/2/2009	FLASH FLOOD	0/0	$0
Wendell				
None Reported				
Zebulon				
None Reported				

	Date	Type	Deaths/ Injuries	Property Damage*

Source: National Climatic Data Center

5.15.4 Historical Summary of Insured Flood Losses

According to FEMA flood insurance policy records as of December 2013, there have been 910 flood losses reported in Wake County through the National Flood Insurance Program (NFIP) since 1978, totaling over $21 million in claims payments. A summary of these figures for each jurisdiction is provided in **Table 5.51**. It should be emphasized that these numbers include only those losses to structures that were insured through the NFIP policies, and for losses in which claims were sought and received. It is likely that many additional instances of flood loss in Wake County were either uninsured, denied claims payment, or not reported.

TABLE 5.51: SUMMARY OF INSURED FLOOD LOSSES IN WAKE COUNTY

Location	Flood Losses	Claims Payments
Apex	0	$0
Cary	83	$1,297,771
Fuquay-Varina	1	$5,783
Garner	18	$107,854
Holly Springs	3	$32,312
Knightdale	2	$17,361
Morrisville	3	$66,219
Raleigh	725	$18,503,795
Rolesville	0	$0
Wake Forest	0	$0
Wendell	6	$77,232
Zebulon	7	$183,092
Unincorporated Area	62	$787,324
WAKE COUNTY TOTAL	**910**	**$21,078,743**

Source: FEMA, NFIP

5.15.5 Repetitive Loss Properties

FEMA defines a repetitive loss property as any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period, since 1978. A repetitive loss property may or may not be currently insured by the NFIP. Currently there are over 140,000 repetitive loss properties nationwide.

Currently (as of July 2013), there are 131 non-mitigated repetitive loss properties located in Wake County, which accounted for 374 losses and more than $12.5 million in claims payments under the NFIP. The average claim amount for these properties is $33,471. Seventy-five of the one hundred and thirty-one properties are single family residential and the remaining are either multi-family residential, commercial, or government owned. Without mitigation these properties will likely continue to experience flood looses. **Table 5.52** presents summary information on repetitive loss properties and NFIP claims and policies for Wake County.

TABLE 5.52: REPETITIVE LOSS PROPERTIES IN WAKE COUNTY

Location	Number of Properties	Number of Losses	Total Payments
Apex	0	0	$0
Cary	13	33	$635,412
Fuquay-Varina	0	0	$0
Garner	4	8	$65,416
Holly Springs	0	0	$0
Knightdale	0	0	$0
Morrisville	0	0	$0
Raleigh	109	316	$11,500,659
Rolesville	0	0	$0
Wake Forest	0	0	$0
Wendell	0	0	$0
Zebulon	0	0	$0
Unincorporated Area	5	17	$316,761
WAKE COUNTY TOTAL	**131**	**374**	**$12,518,248**

REPETITIVE LOSS PROPERTIES IN WAKE COUNTY

Location	Number of Properties	Types of Properties	Number of Losses	Building Payments	Content Payments	Total Payments	Average Payment
Apex	0	-	0	$0	$0	$0	$0
Cary	13	13 single family	33	$460,622	$174,791	$635,412	$19,255
Fuquay-Varina	0	-	0	$0	$0	$0	$0
Garner	4	4 single family	8	$64,119	$1,297	$65,416	$8,177
Holly Springs	0	-	0	$0	$0	$0	$0
Knightdale	0	-	0	$0	$0	$0	$0
Morrisville	0	-	0	$0	$0	$0	$0
Raleigh	109	54 single family, 23 multi-family residential, 32 non-residential,	316	$8,969,656	$2,531,003	$11,500,659	$36,394
Rolesville	0	-	0	$0	$0	$0	$0
Wake Forest	0	-	0	$0	$0	$0	$0
Wendell	0	-	0	$0	$0	$0	$0
Zebulon	0	-	0	$0	$0	$0	$0
Unincorporated Area	5	4 single family, 1 multi-family residential	17	$260,683	$56,078	$316,761	$18,633
WAKE COUNTY TOTAL	**131**		**374**	**$9,755,080**	**$2,763,169**	**$12,518,248**	**$33,471**

Source: National Flood Insurance Program

5.15.6 Probability of Future Occurrences

Flood events will remain a threat in Wake County, and the probability of future occurrences will remain likely (between 10 and 100 percent annual probability). The probability of future flood events based on magnitude and according to best available data is illustrated in the figures above, which indicates those areas susceptible to the 1-percent annual chance flood (100-year floodplain) and the 0.2-percent annual chance flood (500-year floodplain).

5.15.7 Consequence Analysis

People (The Public and Public Confidence)

The number and characteristics of people that would be impacted by a 100-year and a 500-year flood event are shown in **Table 5.53**. Public confidence is often impacted by flood events, especially when impacted people do not have flood insurance and are not covered by their home insurance policy. This can create public relations issues for the government.

Table 5.53: Age, Sex, Race, and Income of the Impacted Population

Name of Variable	100-year Flood	500-year Flood	Wake County
Total Number of People	38,428	43,446	900,993
Population Under Age 18	10,440	11,772	234,613
Population Ages 18–64	24,978	28,255	589,831
Population Age 65 and Older	3,009	3,419	76,549
Number of Males (all ages)	18,576	21,001	438,792
Number of Females (all ages)	19,851	22,444	462,201
Median Age (both sexes)	25	31	35
White Only	24,502	27,558	560,536
Black or African American Only	8,940	10,226	182,793
American Indian or Alaskan Native Only	219	242	4,503
Asian Only	1,756	2,047	48,287
Native Hawaiian or Pacific Islander Only	14	16	387
Other Race	1,986	2,200	21,455
Number of People with Hispanic Origins	4,309	4,813	87,922
Per Capita Income (5-year estimate)*	$33,167	$33,167	$35,122

**Only available at the Census tract level*

Responders

Responders are often affected by flooding because floods can trap people in their homes or in other locations, forcing responders to put their lives at risk to return members of the public to safety. Often responders in flood situations face blocked roads and have difficulty safely protecting citizens.

Continuity of Operations

Flooding can impact continuity of operations by knocking out power sources and preventing emergency management personnel from being able to do their jobs properly. Floods typically have some impact on continuity of operations as they can cause severe disruption to normal operations and have done so in the past in Wake County.

Built Environment (Property, Facilities, and Infrastructure)

Many buildings and structures could be impacted by a flood event. For a detailed analysis of flood prone properties, see *Section 6: Hazard Vulnerability.*

The land classification codes of property impacted by the floodplains are listed in **Table 5.54** and show that the floodplains are mostly comprised of exempt, vacant, State-assessed, agricultural-farm, and residential properties. Exempt land represents the largest estimated value—just more than $1 billion—that could be destroyed by a 500-year flood. Residential land is the second greatest estimated loss around $379 million and agricultural farm land losses is estimated at $98 million.

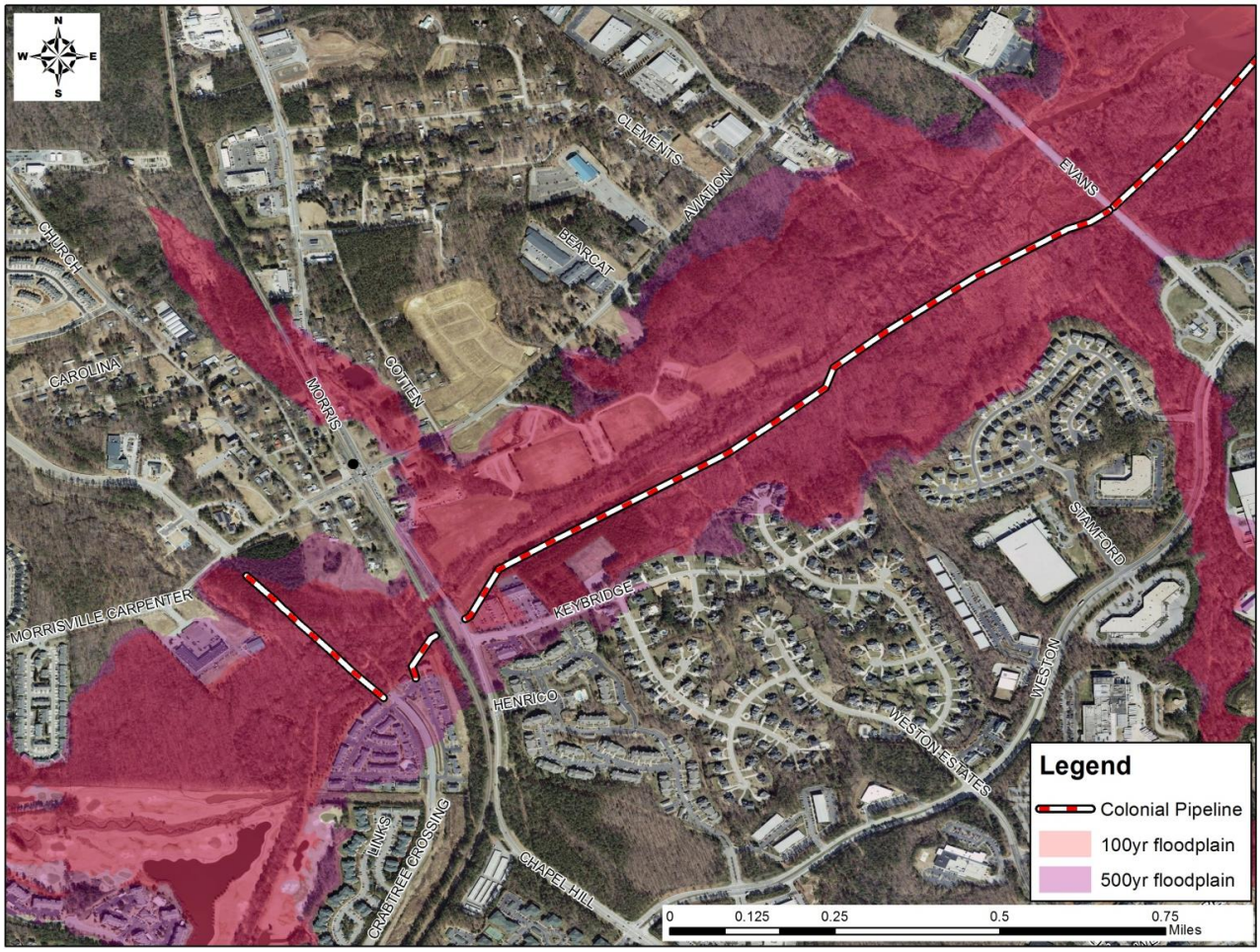
TABLE 5.54: CLASSIFICATION OF PROPERTY IMPACTED BY THE 1.0 AND 0.2 PERCENT ANNUAL CHANCE FLOOD

Code	Land Classification	Acres Impacted by 100-year Flood	Acres Impacted by 500-year Flood
A	AC-W/IMP	267.85	287.11
B	AC >10 Acres-Home Site	1,187.31	1,264.05
C	Commercial	1,210.27	1,430.99
D	Industrial	250.95	306.49
E	Exempt	20,361.70	21,242.41
F	Agricultural-Farm	4,707.99	5,003.75
G	Apartment	306.22	384.90
H	Historic Site	9.60	10.33
I	Homeowners Association	1,970.23	2,090.25
J	Cemetery	4.61	5.11
K	Retirement Home	2.09	2.09
M	Manufactured Home	115.28	125.27
N	Condominium	12.09	15.48
O	MA+Condo	46.85	61.60
P	Private Exempt	59.32	65.42
R	Residence -< 10 Acres-Home Site	2,756.90	3,242.25
S	State-Assessed	5,486.97	5,496.74
T	Mobile Home Park	189.67	210.32
U	Golf Course	895.10	972.44
V	Vacant	6,241.22	6,811.22
W	Water/Sewer System	34.14	39.57
Y	Floriculture-Farm	2,595.65	2,757.16
Z	Horticulture-Farm	81.66	87.26

Critical Infrastructure and Key Resources

Critical infrastructure and key resources (CIKR) within Wake County include assets, systems, and networks that are vital to the continued operation of government services. The incapacitation or destruction of these resources would have a debilitating effect on the county's security, economy, and/or public health. One CIKR that could be impacted by a 100-year or 500-year flood event are the Cardinal, Colonial, and Dixie pipeline systems. An example of a Colonial product (PRD) pipeline residing within floodplain area is shown in **Figure 5.18**, just northeast of Crabtree Lake.

FIGURE 5.18: COLONIAL PIPELINE IMPACTED BY 1.0 AND 0.2 PERCENT CHANCE ANNUAL FLOODPLAIN



Economy

There are a variety of economic impacts that could result from a large-scale flood event. According to a GIS-based spatial analysis of Wake County property, about 7,848 acres of agricultural land may be affected by a 500-year flood. The most major impact on soil that is covered by flood waters is the rapid depletion of oxygen, which is essential for plant growth and development. Secondly, flooding may modify nutrients within the soil either by leaching or changing their availability to the plant. Impact from submersion will vary with duration and temperature. The full extent of injury to seedlings would be determined by the current stage of development at the time of flooding, duration of the flood event, air and soil temperatures, and the presence of axillary buds.

Most research indicates that wheat can withstand water-logged soils for up to 24 hours without severe damage, but barley would not last as long under these conditions. When a small-grain crop such as wheat or barley survives flooding, recovery may be very slow and yield will be much less than normal. Corn is very sensitive to prolonged saturation prior to the fifth- or sixth-leaf stage; however, after the sixth-leaf stage, corn can survive approximately 2–4 days of flooded conditions; once the silting stage is reached, shallow flooding would not cause a noticeable amount of damage.

Environment

The fluctuation of water levels in a wetland, especially flood waters, supports the biological diversity of low-lying areas by releasing nutrients into the soil and germinating wetland flora. Flooding also offers some control of invasive water weeds.

Other Hazards

5.16 HAZARDOUS MATERIALS INCIDENTS

5.16.1 Background

Hazardous materials can be found in many forms and quantities that can potentially cause death; serious injury; long-lasting health effects; and damage to buildings, homes, and other property in varying degrees. Such materials are routinely used and stored in many homes and businesses and are also shipped daily on the nation's highways, railroads, waterways, and pipelines. This subsection on the hazardous material hazard is intended to provide a general overview of the hazard, and the threshold for identifying fixed and mobile sources of hazardous materials is limited to general information on rail, highway, and FEMA-identified fixed HAZMAT sites determined to be of greatest significance as appropriate for the purposes of this plan.

Hazardous material (HAZMAT) incidents can apply to fixed facilities as well as mobile, transportation-related accidents in the air, by rail, on the nation's highways, and on the water. Approximately 6,774 HAZMAT events occur each year, 5,517 of which are highway incidents, 991 are railroad incidents, and 266 are due to other causes.[30] In essence, HAZMAT incidents consist of solid, liquid, and/or gaseous contaminants that are released from fixed or mobile containers, whether by accident or by design as with an intentional terrorist attack. A HAZMAT incident can last hours to days, while some chemicals can be corrosive or otherwise damaging over longer periods of time. In addition to the primary release, explosions and/or fires can result from a release, and contaminants can be extended beyond the initial area by persons, vehicles, water, wind, and possibly wildlife as well.

HAZMAT incidents can also occur as a result of or in tandem with natural hazard events, such as floods, hurricanes, tornadoes, and earthquakes, which in addition to causing incidents can also hinder response efforts. In the case of Hurricane Floyd in September 1999, communities along the Eastern United States were faced with flooded junkyards, disturbed cemeteries, deceased livestock, floating propane tanks, uncontrolled fertilizer spills, and a variety of other environmental pollutants that caused widespread toxological concern.

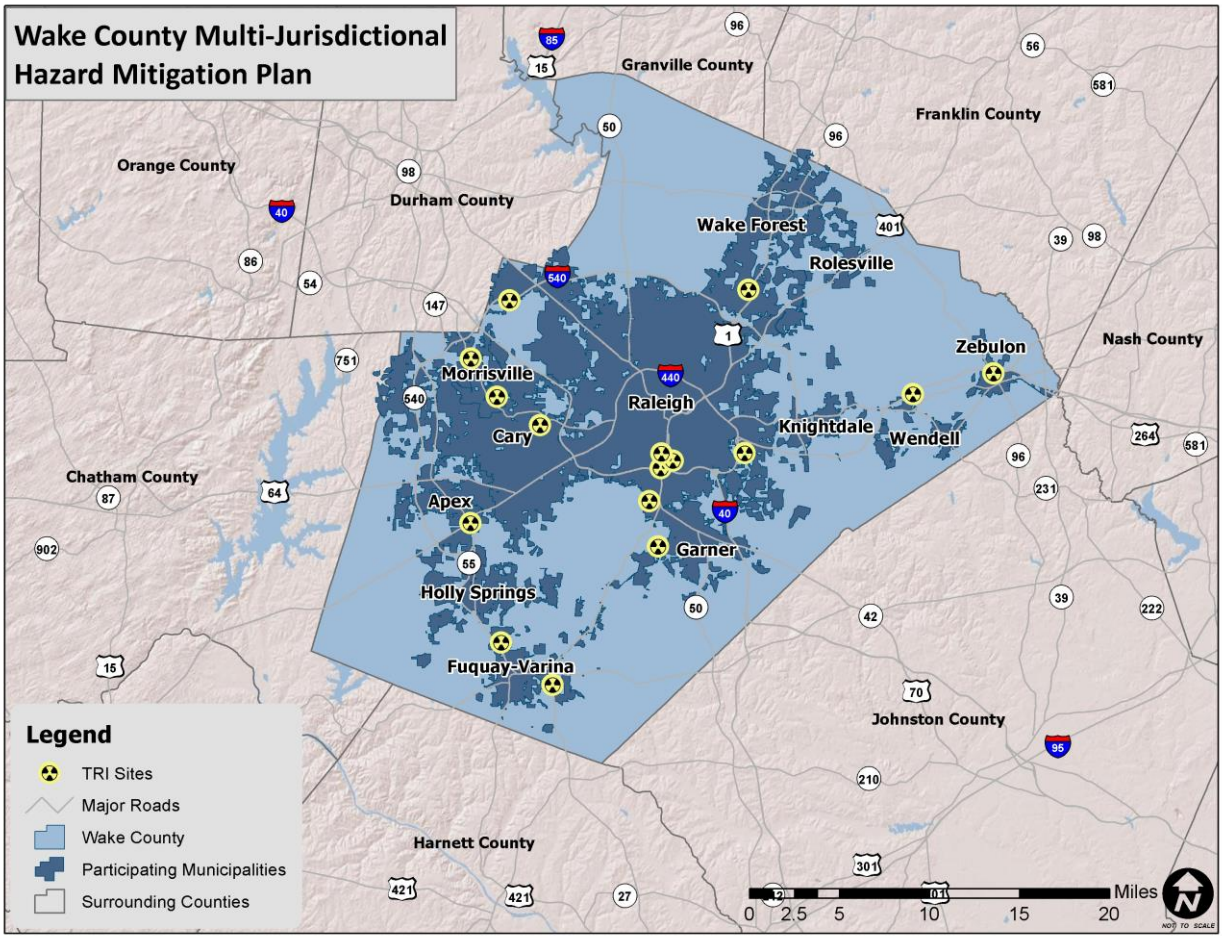
Hazardous material incidents can include the spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment of a hazardous material, but exclude: (1) any release which results in exposure to poisons solely within the workplace with respect to claims which such persons may assert against the employer of such persons; (2) emissions from the engine exhaust of a motor vehicle, rolling stock, aircraft, vessel or pipeline pumping station engine; (3) release of source, byproduct, or special nuclear material from a nuclear incident; and (4) the normal application of fertilizer.

[30] FEMA, 1997.

5.16.2 Location and Spatial Extent

As a result of the 1986 Emergency Planning and Community Right to Know Act (EPCRA), the Environmental Protection Agency provides public information on hazardous materials. One facet of this program is to collect information from industrial facilities on the releases and transfers of certain toxic agents. This information is then reported in the Toxic Release Inventory (TRI). TRI sites indicate where such activity is occurring. Wake County has twenty-nine TRI sites. These sites are shown in **Figure 5.19.**

FIGURE 5.19: TOXIC RELEASE INVENTORY (TRI) SITES IN WAKE COUNTY



Source: EPA

In addition to "fixed" hazardous materials locations, hazardous materials may also impact the region via roadways and rail. Many roads in the region are subject to hazardous material transport and all roads that permit hazardous material transport are considered potentially at risk to an incident.

5.16.3 Historical Occurrences

The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) lists historical occurrences throughout the nation. A "serious incident" (highlighted in yellow in **Table 5.37** below) is a hazardous materials incident that involves:

- a fatality or major injury caused by the release of a hazardous material,
- the evacuation of 25 or more persons as a result of release of a hazardous material or exposure to fire,
- a release or exposure to fire which results in the closure of a major transportation artery,
- the alteration of an aircraft flight plan or operation,
- the release of radioactive materials from Type B packaging,
- the release of over 11.9 galls or 88.2 pounds of a severe marine pollutant, or
- the release of a bulk quantity (over 199 gallons or 882 pounds) of a hazardous material.

However, prior to 2002, a hazardous materials "serious incident" was defined as follows:

- a fatality or major injury due to a hazardous material,
- closure of a major transportation artery or facility or evacuation of six or more person due to the presence of hazardous material, or
- a vehicle accident or derailment resulting in the release of a hazardous material.

Table 5.55 presents summary information on historic HAZMAT incidents reported in Wake County.

TABLE 5.55: SUMMARY OF HAZMAT INCIDENTS IN WAKE COUNTY

Location	Number of Occurrences	Deaths/ Injuries	Damages ($)
Apex	0	0/0	$0
Cary	1	0/0	$0
Fuquay-Varina	0	0/0	$0
Garner	0	0/0	$0
Holly Springs	0	0/0	$0
Knightdale	0	0/0	$0
Morrisville	31	0/0	$0
Raleigh	91	0/0	$0
Rolesville	0	0/0	$0
Wake Forest	0	0/0	$0
Wendell	1	0/0	$0
Zebulon	1	0/0	$0
Unincorporated Area	0	0/0	$0
WAKE COUNTY TOTAL	**125**	**0/0**	**$0**

TABLE 5.56: SUMMARY OF HAZMAT INCIDENTS IN WAKE COUNTY

Report Number	Date	City	Mode	Serious Incident?	Fatalities/ Injuries	Damages ($)	Quantity Released
Wake County							
None reported							
Apex							
N/A	10/5/2006	APEX	Fixed facility	Yes	0/30	-	>50 gallons
Cary							
I-2000060136	5/25/2000	CARY	Highway	No	0/0	$0	20 LGA

Report Number	Date	City	Mode	Serious Incident?	Fatalities/ Injuries	Damages ($)	Quantity Released
Fuquay-Varina							
None reported							
Garner							
None reported							
Holly Springs							
None reported							
Knightdale							
None reported							
Morrisville							
I-1980080433	8/1/1980	MORRISVILLE	Air	No	0/0	$0	1 LGA
I-1992080023	6/25/1992	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-1993110976	10/8/1993	MORRISVILLE	Air	No	0/0	$0	0.1875 SLB
I-1994041339	3/18/1994	MORRISVILLE	Highway	No	0/0	$0	0.132086 LGA
I-1994060939	5/10/1994	MORRISVILLE	Highway	No	0/0	$0	10 SLB
I-1994070600	6/14/1994	MORRISVILLE	Highway	No	0/0	$0	0.08375 LGA
I-1994101619	9/29/1994	MORRISVILLE	Highway	No	0/0	$0	2.5 LGA
I-1994120661	11/17/1994	MORRISVILLE	Highway	No	0/0	$0	0.1875 SLB
I-1997080070	7/17/1997	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-1997080773	8/5/1997	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-1999030620	2/17/1999	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-2000070193	6/18/2000	MORRISVILLE	Highway	No	0/0	$0	2.63 LGA
I-2000070205	6/25/2000	MORRISVILLE	Highway	No	0/0	$0	0.004688 LGA
I-2001030835	3/12/2001	MORRISVILLE	Highway	No	0/0	$0	0.046875 LGA
I-2002050797	4/11/2002	MORRISVILLE	Highway	No	0/0	$0	0.007813 LGA
I-2003060466	5/21/2003	MORRISVILLE	Highway	No	0/0	$0	0.007813 LGA
I-2004040070	2/13/2004	MORRISVILLE	Highway	No	0/0	$0	2 LGA
I-2004050082	4/2/2004	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-2005020957	2/1/2005	MORRISVILLE	Air	No	0/0	$0	0.26418 LGA
I-2005100167	8/10/2005	MORRISVILLE	Highway	No	0/0	$0	3 LGA
I-2006060230	5/22/2006	MORRISVILLE	Highway	No	0/2	$0	0.5 LGA
I-2006080263	7/24/2006	MORRISVILLE	Highway	No	0/0	$0	0.007812 LGA
I-2006091247	8/22/2006	MORRISVILLE	Highway	No	0/0	$0	1.125 LGA
I-2007061257	6/6/2007	MORRISVILLE	Highway	No	0/0	$0	0.5 LGA
E-2009010088	1/8/2009	MORRISVILLE	Air	No	0/0	$0	0.26418 LGA
I-2009020410	2/19/2009	MORRISVILLE	Highway	No	0/0	$0	1 LGA
X-2009060140	5/28/2009	MORRISVILLE	Highway	No	0/0	$0	0.5 LGA
I-2011020202	1/21/2011	MORRISVILLE	Highway	No	0/0	$0	2 SLB
I-2004040070	2/13/2004	MORRISVILLE	Highway	No	0/0	$0	1 LGA
I-2006091247	8/22/2006	MORRISVILLE	Highway	No	0/0	$0	4 LGA
I-2001030835	3/12/2001	MORRISVILLE	Highway	No	0/0	$0	0.26418 LGA
Raleigh							
I-1977080716	7/30/1977	RALEIGH	Rail	No	0/0	$0	75 LGA
I-1978110327	11/1/1978	RALEIGH	Highway	No	0/0	$0	0
I-1979100080	9/26/1979	RALEIGH	Highway	No	0/0	$0	0
I-1981010515	12/11/1980	RALEIGH	Highway	No	0/0	$0	0

Report Number	Date	City	Mode	Serious Incident?	Fatalities/ Injuries	Damages ($)	Quantity Released
I-1981060498	6/1/1981	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1981060461	6/5/1981	RALEIGH	Highway	No	0/0	$0	0
I-1981070578	6/29/1981	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1981070804	7/15/1981	RALEIGH	Highway	No	0/0	$0	0
I-1981100173	9/24/1981	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1982040236	3/31/1982	RALEIGH	Highway	No	0/0	$0	4 LGA
I-1983070353	7/13/1983	RALEIGH	Highway	No	0/0	$0	0
I-1983110081	10/12/1983	RALEIGH	Highway	No	0/0	$0	0
I-1984020005	1/27/1984	RALEIGH	Highway	No	0/0	$0	0.084 LGA
I-1984020007	1/31/1984	RALEIGH	Highway	No	0/0	$0	0.028 LGA
I-1984060124	5/29/1984	RALEIGH	Highway	No	0/0	$0	0.75 LGA
I-1984070014	6/20/1984	RALEIGH	Highway	No	0/0	$0	0.75 LGA
I-1984080225	7/30/1984	RALEIGH	Highway	No	0/0	$0	0.028 LGA
I-1984100136	9/20/1984	RALEIGH	Highway	No	0/0	$0	2 LGA
I-1984100442	10/5/1984	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1984110124	10/26/1984	RALEIGH	Highway	No	0/0	$0	0.025 LGA
I-1985010128	12/18/1984	RALEIGH	Highway	No	0/0	$0	0.063 LGA
I-1985020178	1/25/1985	RALEIGH	Highway	No	0/1	$0	0.063 LGA
I-1985020241	2/1/1985	RALEIGH	Highway	No	0/0	$0	6 LGA
I-1985030198	2/26/1985	RALEIGH	Highway	No	0/0	$0	2 LGA
I-1985030265	3/4/1985	RALEIGH	Highway	No	0/0	$0	0.25 LGA
I-1985050360	5/7/1985	RALEIGH	Highway	No	0/0	$0	0.12 LGA
I-1985060205	5/29/1985	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1985100019	9/16/1985	RALEIGH	Highway	No	0/0	$0	11.03 SLB
I-1986030006	2/17/1986	RALEIGH	Highway	No	0/0	$0	0.5 LGA
I-1986070259	6/26/1986	RALEIGH	Highway	No	0/0	$0	2.5 LGA
I-1986080269	7/29/1986	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1986100005	9/16/1986	RALEIGH	Highway	No	0/0	$0	0.1 LGA
I-1987070563	7/1/1987	RALEIGH	Highway	No	0/0	$0	0
I-1987100297	9/24/1987	RALEIGH	Highway	No	0/0	$0	3.63 LGA
I-1987100321	10/6/1987	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1987100343	10/7/1987	RALEIGH	Highway	No	0/0	$0	5 LGA
I-1988010146	12/18/1987	RALEIGH	Highway	No	0/0	$0	0.028 LGA
I-1988010148	12/22/1987	RALEIGH	Highway	No	0/0	$0	0.25 LGA
I-1988080461	7/21/1988	RALEIGH	Highway	No	0/0	$0	30 LGA
I-1989020160	1/31/1989	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1990030107	1/26/1990	RALEIGH	Air	No	0/0	$0	0
I-1990030232	2/20/1990	RALEIGH	Highway	No	0/0	$0	5 LGA
I-1990120159	10/25/1990	RALEIGH	Highway	No	0/0	$0	50 LGA
I-1993081588	8/2/1993	RALEIGH	Air	No	0/0	$0	0.039063 LGA
I-1993081357	8/2/1993	RALEIGH	Highway	No	0/0	$0	0
I-1993100673	8/9/1993	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1994080300	7/21/1994	RALEIGH	Rail	Yes	0/0	$0	40000 SLB
I-1994101389	10/18/1994	RALEIGH	Highway	No	0/0	$0	50 LGA
I-1995100985	4/14/1995	RALEIGH	Highway	No	0/0	$0	1.056688 LGA
I-1995071497	4/28/1995	RALEIGH	Highway	No	0/0	$0	0.03125 LGA

Report Number	Date	City	Mode	Serious Incident?	Fatalities/ Injuries	Damages ($)	Quantity Released
I-1995071494	5/8/1995	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1995071554	5/25/1995	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1995101404	6/27/1995	RALEIGH	Highway	No	0/0	$0	0.25 LGA
I-1995071499	7/12/1995	RALEIGH	Highway	No	0/0	$0	0.015625 LGA
I-1995120430	11/1/1995	RALEIGH	Highway	No	0/0	$0	0.015625 LGA
I-1996020469	1/16/1996	RALEIGH	Highway	No	0/0	$0	1 LGA
I-1996071223	7/23/1996	RALEIGH	Highway	No	0/0	$0	0.023438 LGA
I-1996080443	7/30/1996	RALEIGH	Highway	No	0/0	$0	0.078125 LGA
I-1996080442	8/5/1996	RALEIGH	Highway	No	0/0	$0	0.25 LGA
I-1996090297	8/29/1996	RALEIGH	Highway	No	0/0	$0	0.007813 LGA
I-1996110026	10/29/1996	RALEIGH	Air	No	0/0	$0	0.007925 LGA
I-1996120028	11/25/1996	RALEIGH	Highway	No	0/0	$0	10 SLB
I-1997040453	3/4/1997	RALEIGH	Highway	No	0/0	$0	0.125 LGA
I-1997040455	3/11/1997	RALEIGH	Highway	No	0/0	$0	0.125 LGA
I-1997040454	3/11/1997	RALEIGH	Highway	No	0/0	$0	0.125 LGA
I-1997100264	9/24/1997	RALEIGH	Air	No	0/0	$0	0
I-1999100328	9/9/1999	RALEIGH	Highway	No	0/0	$0	4 LGA
I-2000121256	7/17/2000	RALEIGH	Highway	No	0/0	$0	0.015625 LGA
I-2000110296	7/17/2000	RALEIGH	Highway	No	0/0	$0	1 LGA
I-2000091202	9/7/2000	RALEIGH	Air	No	0/0	$0	0
I-2001081264	8/14/2001	RALEIGH	Air	No	0/0	$0	0.007925 LGA
I-2002021296	12/4/2001	RALEIGH	Highway	No	0/0	$0	1 LGA
I-2002100659	9/21/2002	RALEIGH	Air	No	0/0	$0	0.528344 LGA
I-2003020893	2/7/2003	RALEIGH	Highway	No	0/0	$0	0.000011 SLB
I-2003040684	4/1/2003	RALEIGH	Highway	No	0/0	$0	1.41 LGA
I-2003080356	7/21/2003	RALEIGH	Highway	No	0/0	$0	1.5 LGA
I-2004061482	6/11/2004	RALEIGH	Highway	No	0/0	$0	2 SLB
I-2004070869	6/23/2004	RALEIGH	Highway	No	0/0	$0	0.000654 LGA
I-2004071381	7/8/2004	RALEIGH	Highway	No	0/0	$0	0.007813 LGA
I-2004100076	9/24/2004	RALEIGH	Highway	No	0/0	$0	0.132086 LGA
I-2005050548	5/11/2005	RALEIGH	Highway	No	0/0	$0	0.25 LGA
I-2006050673	4/17/2006	RALEIGH	Highway	No	0/0	$0	0.007812 LGA
I-2006060671	5/16/2006	RALEIGH	Highway	No	0/0	$0	0.015625 LGA
I-2006090269	7/27/2006	RALEIGH	Highway	No	0/0	$0	0.023438 LGA
I-2007051141	4/26/2007	RALEIGH	Highway	No	0/0	$0	0.5 LGA
I-2007090012	8/1/2007	RALEIGH	Highway	No	0/0	$0	2 LGA
I-2007100362	10/4/2007	RALEIGH	Highway	No	0/0	$0	0.125 LGA
E-2008050190	4/25/2008	RALEIGH	Rail	No	0/0	$0	5 LGA
I-2008090672	8/8/2008	RALEIGH	Highway	No	0/0	$0	25 LGA
I-2011070414	7/7/2011	RALEIGH	Highway	No	0/0	$0	0.066045 LGA
E-2013040047	3/15/2013	RALEIGH	Highway	No	0/0	$0	8 SLB
Rolesville							
None reported							
Wake Forest							
None reported							
Wendell							

Report Number	Date	City	Mode	Serious Incident?	Fatalities/ Injuries	Damages ($)	Quantity Released
I-1982080279	8/3/1982	WENDELL	Highway	No	0/0	$0	1 LGA
Zebulon							
I-2004090250	4/1/2004	ZEBULON	Highway	No	0/0	$0	0.125 LGA

Source: USDOT PHMSA

5.16.4 Probability of Future Occurrence

Given the location of twenty-nine toxic release inventory sites in Wake County and several serious roadway incidents, it is likely (10-100 percent probability) that a hazardous material incident may occur in the county, though a major incident is less likely. County and municipal officials are mindful of this possibility and take precautions to prevent such an event from occurring. Furthermore, there are detailed plans in place to respond to an occurrence.

5.16.5 Consequence Analysis

People (The Public and Public Confidence)

In the case of a HazMat release, a person's vulnerability is largely determined by his or her proximity to dangerous sites and the type(s) of HazMat being stored or used in daily processes. Hazardous materials incidents often have a strong impact on public confidence as the impacts of this type of event can cause serious and sometimes gruesome effects on people. Since hazardous materials are man-made, there is also often some understanding on the part of the public that they can be more easily prevented than natural disasters.

Responders

One of the challenges for responders in a hazardous materials incident is preventing the impact that the incident has on their personal health and well-being. Responders must balance their responsibilities to control the incident with their responsibilities to protect themselves.

Continuity of Operations

There could be an impact to continuity of operations in the event of a hazardous materials spill, although most HazMat events are relatively small-scale, there is always a potential for a large event that would disrupt the normal flow of operations.

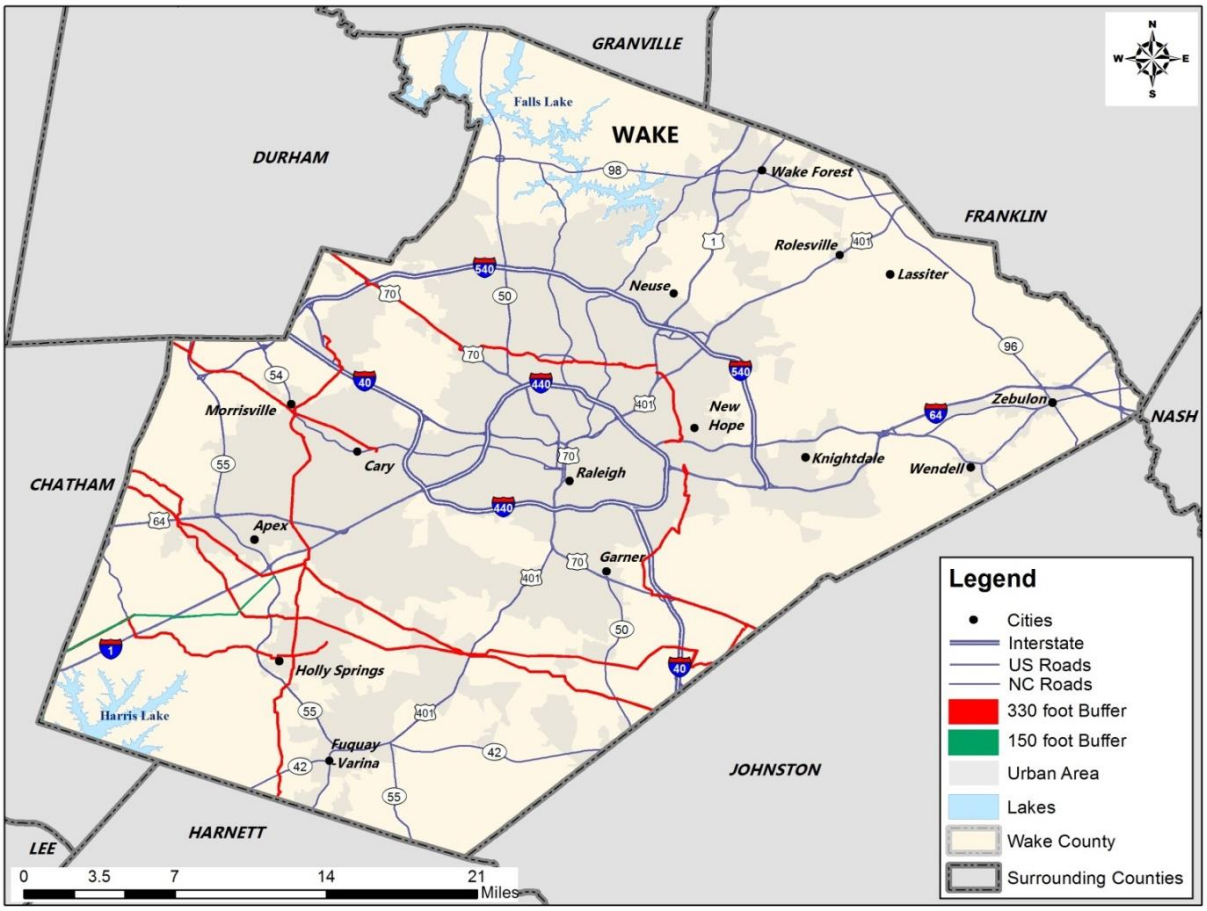
Built Environment (Property, Facilities, and Infrastructure)

Pipelines

According to a State-level hazardous materials study conducted in 2011, highly volatile liquids (HVLs), other non-volatile liquid products (PRDs), and natural gas are transported by pipeline in the county. Based on the Emergency Response Guide,[31] the isolation buffer zone for HVL pipelines should be 150 feet, and the isolation buffer for PRD and natural gas pipelines should be 330 feet. To analyze the area around each pipeline that could be impacted by a release of these materials, a buffer was created for each pipeline segment within the county based on the distances mentioned above. **Figure 5.20**depicts these buffer zones in relation to urban areas and roadways in the county.

[31] U.S. Department of Transportation. (2008). *Emergency Response Guide*.

FIGURE 5.20: ISOLATION BUFFER ZONES FOR PIPELINES IN WAKE COUNTY



For additional analysis of Hazardous Materials incidents and their impact on the built environment, please see *Section 6: Hazard Vulnerability* which describes impacts on property from fixed HazMat sites and a mobile HazMat analysis.

Economy

Myriad economic impacts may result from a HazMat release within the county. Many of these factors could not be calculated from historic incidents or predicted, but they are listed here for consideration.

- Property damage from an explosion
- Emergency protective actions
- HazMat response
- Debris removal and disposition
- Repair to facility, critical facilities, and vulnerable facilities
- Environmental remediation

Environment

The environmental consequences of a HazMat release vary considerably by substance. Under the Emergency Planning and Community Right to Know Act (EPCRA) of 1986, the federal government has designated several hundred chemicals as "extremely hazardous substances" based on their acute lethal toxicity. Under the law, releases of EHS chemicals trigger reporting requirements to local, state, and

federal authorities. **Table 5.56** shows the hazard form and major uses for each EHS chemical reported in Wake County.

Table 5.57: Hazard Form and Major Uses of Extremely Hazardous Substances

Chemicals	Isolation Distance	Environmental Concern	Hazard form/ Major use(s)
Aldicarb	75 feet	Acute and persistent	Toxic solid/pesticide
Anhydrous ammonia	500 feet	Acute but transient	Toxic gas/refrigerant and fertilizer
Aniline	150 feet	Acute but transient	Toxic liquid/feedstock for pharmaceutical production
Bromadiolone	75 feet	Acute and persistent	Toxic solid/rodenticide
Chlorine	2,000 feet	Acute but transient	Toxic gas/disinfectant
Chlorophacinone	75 feet	Acute and persistent	Toxic solid/rodenticide
Cyclohexylamine	150 feet	Acute but transient	Toxic liquid/feedstock for pharmaceutical production
Dimethyl 4-(methylthio)phenyl ester	150 feet	Acute and persistent	Toxic liquid/pesticide
Diphacinone	75 feet	Acute and persistent	Toxic solid/rodenticide
Disulfoton	75 feet	Acute and persistent	Toxic solid/pesticide
Ethylene oxide	500 feet	Acute but transient	Toxic gas/feedstock for chemical production and disinfectant
Fenamiphos	150 feet	Acute and persistent	Toxic liquid/pesticide
Formaldehyde	150 feet	Acute but transient	Toxic liquid/feedstock for adhesive production
Hydrazine	150 feet	Acute but transient	Toxic liquid/water treatment and chemical production
Hydrogen chloride (gas only)	200 feet	Acute but transient	Toxic gas/chemical production
Hydrogen peroxide (conc >52%)	150 feet	Acute but transient	Reactive liquid/wastewater treatment and bleaching
Nitric acid	500 feet	Acute but transient	Corrosive and toxic liquid/feedstock for chemical production and metal cleaning
Nitric oxide	330 feet	Acute but transient	Toxic gas/feedstock for chemical production
Nitrobenzene	150 feet	Acute and persistent	Toxic liquid/feedstock for pharmaceutical production
Paraquat dichloride	150 feet	Acute and persistent	Toxic liquid/herbicide
Sulfuric acid	150 feet	Acute but transient	Corrosive liquid/batteries, and feedstock chemical and industrial production
Vinyl acetate monomer	150 feet	Acute but transient	Toxic and flammable liquid/feedstock for chemical production and glue

5.17 WILDFIRE

5.17.1 Background

A wildfire is any outdoor fire (i.e. grassland, forest, brush land) that is not under control, supervised, or prescribed.[32] Wildfires are part of the natural management of forest ecosystems, but may also be caused by human factors.

Nationally, over 80 percent of forest fires are started by negligent human behavior such as smoking in wooded areas or improperly extinguishing campfires. The second most common cause for wildfire is lightning. In North Carolina, a majority of fires are caused by debris burning.

There are three classes of wildland fires: surface fire, ground fire, and crown fire. A surface fire is the most common of these three classes and burns along the floor of a forest, moving slowly and killing or damaging trees. A ground fire (muck fire) is usually started by lightning or human carelessness and burns on or below the forest floor. Crown fires spread rapidly by wind and move quickly by jumping along the tops of trees. Wildfires are usually signaled by dense smoke that fills the area for miles around.

Wildfire probability depends on local weather conditions, outdoor activities such as camping, debris burning, and construction, and the degree of public cooperation with fire prevention measures. Drought conditions and other natural hazards (such as tornadoes, hurricanes, etc.) increase the probability of wildfires by producing fuel in both urban and rural settings.

Many individual homes and cabins, subdivisions, resorts, recreational areas, organizational camps, businesses, and industries are located within high wildfire hazard areas. Furthermore, the increasing demand for outdoor recreation places more people in wildlands during holidays, weekends, and vacation periods. Unfortunately, wildland residents and visitors are rarely educated or prepared for wildfire events that can sweep through the brush and timber and destroy property within minutes.

Wildfires can result in severe economic losses as well. Businesses that depend on timber, such as paper mills and lumber companies, experience losses that are often passed along to consumers through higher prices and sometimes jobs are lost. The high cost of responding to and recovering from wildfires can deplete state resources and increase insurance rates. The economic impact of wildfires can also be felt in the tourism industry if roads and tourist attractions are closed due to health and safety concerns.

State and local governments can impose fire safety regulations on home sites and developments to help curb wildfire. Land treatment measures such as fire access roads, water storage, helipads, safety zones, buffers, firebreaks, fuel breaks, and fuel management can be designed as part of an overall fire defense system to aid in fire control. Fuel management, prescribed burning, and cooperative land management planning can also be encouraged to reduce fire hazards.

[32] Prescription burning, or "controlled burn," undertaken by land management agencies is the process of igniting fires under selected conditions, in accordance with strict parameters.

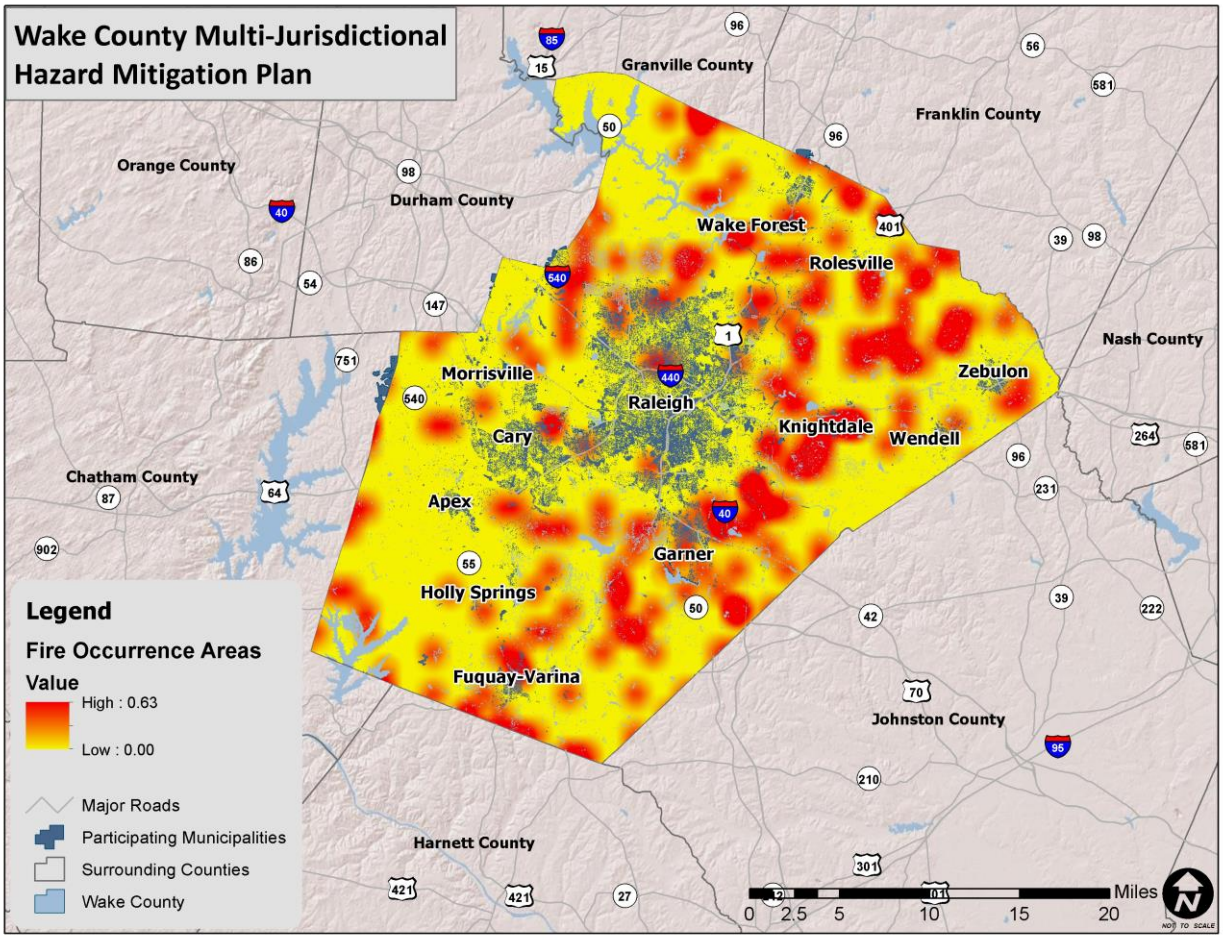
5.17.2 Location and Spatial Extent

The entire county is at risk to a wildfire occurrence. However, several factors such as drought conditions or high levels of fuel on the forest floor, may make a wildfire more likely. Furthermore, areas in the urban-wildland interface are particularly susceptible to fire hazard as populations abut formerly undeveloped areas. Many areas within the Wake County are highly urbanized, reducing the amount forested area and thus the potential for wildfire to occur. The Fire Occurrence Areas in the figure below give an indication of historic locations impacted. Although it should be noted that the scale is relative to other areas of the county and does not necessarily indicate a high risk when compared to other regions of the state or country.

5.17.3 Historical Occurrences

Figure 5.21 shows the Fire Occurrence Areas (FOA) in Wake County based on data from the Southern Wildfire Risk Assessment. This data is based on historical fire ignitions and is reported as the number of fires that occur per 1,000 acres each year. As indicated in this figure, the highest level reached in the county is less than 1, which indicates a very sparse history of wildfires in the county.

FIGURE 5.21: HISTORIC WILDFIRE EVENTS IN WAKE COUNTY



Source: Southern Wildfire Risk Assessment

Based on data from the North Carolina Division of Forest Resources from 2003 to 2012, Wake County experiences an average of roughly 15wildfires annually which burn a combined 98 acres, on average. The data indicates that most of these fires are small, averaging six acres per fire. **Table 5.57** provides a summary table for wildfire occurrences in Wake County. **Table 5.58** lists the number of reported wildfire occurrences in the participating counties between the years 2003 and 2012.

TABLE 5.58: SUMMARY TABLE OF ANNUAL WILDFIRE OCCURRENCES (2003-2012)*

	Wake County
Average Number of Fires per year	15.5
Average Number of Acres Burned per year	98.2
Average Number of Acres Burned per fire	6

TABLE 5.59: HISTORICAL WILDFIRE OCCURRENCES IN WAKE COUNTY

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Wake County										
Number of Fires	8	13	18	23	28	12	2	21	17	13
Number of Acres	52.3	28.7	65.0	167.4	120.9	74.6	17.3	130.2	225.0	101.0

Source: North Carolina Division of Forest Resources

5.17.4 Probability of Future Occurrences

Wildfire events will be an ongoing occurrence in Wake County. The likelihood of wildfires increases during drought cycles and abnormally dry conditions. Fires are likely to stay small in size but could increase due local climate and ground conditions. Dry, windy conditions with an accumulation of forest floor fuel (potentially due to ice storms or lack of fire) could create conditions for a large fire that spreads quickly. It should also be noted that some areas do vary somewhat in risk. For example, highly developed areas are less susceptible unless they are located near the urban-wildland boundary. The risk will also vary due to assets. Areas in the urban-wildland interface will have much more property at risk, resulting in increased vulnerability and need to mitigate compared to rural, mainly forested areas. The probability assigned to Wake County for future wildfire events is possible (a 1 to 10 percent annual probability).

5.17.5 Consequence Analysis

People (The Public and Public Confidence)

There are a number of potential losses from a wildland fire in Wake County. Potential losses include human life, structures, and natural resources. Health hazards from smoke caused by wildland fires within or outside the county can include breathing difficulties and worsening of chronic breathing and/or cardiovascular disease. Smoke and air pollution pose a risk for children, the elderly, and those with respiratory and cardiovascular problems. First responders are also at risk for exposure to dangers

from the initial incident and after-effects such as smoke inhalation and/or heat stroke. Wildfire tends to create some issues with public confidence because of the very visible impacts that the fire has on the community.

Responders

Responders are often at great risk when addressing a wildfire, especially firefighters who are responsible for putting out the blaze. All response personnel are potentially at risk when dealing with a wildfire and often changing winds and a number of other factors can cause a fire to spread rapidly. Although much of Wake County has been urbanized and is not at a high risk to wildfire, the more rural areas that are located in the wildland urban interface may require response personnel to be ready to act.

Continuity of Operations

Since wildfire often moves quickly and can affect infrastructure that is important to maintaining continuity of operations, there is some level of concern for maintaining continuity. However, operations in Wake County, which are generally run from urbanized areas, will probably not be impacted in a major way.

Built Environment (Property, Facilities, and Infrastructure)

The WUI area is composed of both interface and intermix communities where structures and other human developments meet or intermingle with undeveloped wildland or vegetative fuel.[33] In both interface and intermix communities, housing must meet or exceed a minimum density of 1 structure per 40 acres (16 hectares [ha]). Intermix communities are places where housing and vegetation intermingle and vegetation is continuous with more than 50 percent vegetation in areas with more than 1 house per 16 ha.[34] Interface communities are areas with housing in the vicinity of contiguous vegetation that have more than 1 house per 40 acres, have less than 50 percent vegetation, and are within 1.5 miles of an area (made up of one or more contiguous census blocks) over 1,325 acres (500 ha) that is more than 75 percent vegetated.[35] The minimum size limit ensures that areas surrounding small urban parks are not classified as interface WUI.

Table 5.59 shows WUI areas by land classification in Wake County. In Wake County, 28.9 percent of land is classified as intermix areas, and 22.9 percent of land is classified as interface areas.

Table 5.60: Wake County Wildland Urban Interface Land Classification

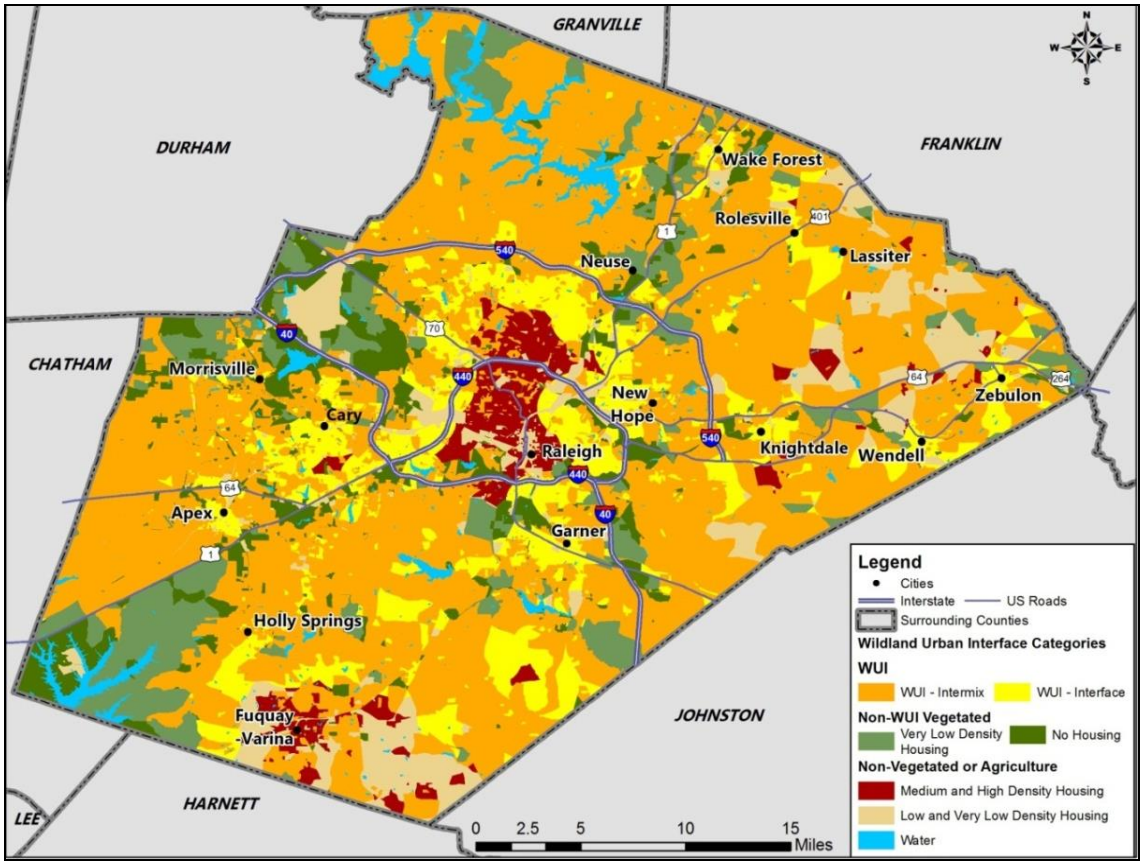
Land Classification	Acres	Percentage of Total
High Density Interface	711	5.98%
High Density Intermix	550	4.63%
High Density No Vegetation	570	4.79%
Low Density Interface	259	2.18%
Low Density Intermix	904	7.60%
Low Density No Vegetation	167	1.40%
Medium Density Interface	1753	14.74%
Medium Density Intermix	1982	16.67%

[33] *Ibid.*
[34] *Ibid.*
[35] *Ibid.*

Land Classification	Acres	Percentage of Total
Medium Density No Vegetation	800	6.73%
Uninhabited No Vegetation	1678	14.11%
Uninhabited Vegetation	1676	14.09%
Very Low Density No Vegetation	35	0.29%
Very Low Density Vegetation	182	1.53%
Water	624	5.25%
Total	11891	

Figure 5.22shows the spatial location of the WUI and intermix areas within the county in relation to developed areas. Interface and intermix areas appear evenly dispersed throughout the county. A significant portion of the WUI interface area is located around the medium- and high-density housing areas located inside the beltline and in sections of north Raleigh. The WUI and intermix area is dispersed throughout Wake County, primarily outside the beltline.

FIGURE 5.22: WAKE COUNTY WILDLAND URBAN INTERFACE AND INTERMIX AREA



Wildland fires have the potential to substantially burn forested areas as well as private residences. Damage and destruction to State, county, private, and municipal structures and facilities are major losses that are attributed to wildland fires. Private residences and communities that are located within the WUI are particularly susceptible to the threat. Population increases in North Carolina's WUI areas, for example, can create significant challenges for firefighters and residents.

Many new homes are constructed without considering community wildland fire planning. This creates neighborhoods with limited accessibility, flammable building construction, and landscaping. A lack of firewise planning can also greatly increase the probability of a wildland fire occurrence with more homes and emergency personnel being threatened.

Impacts to agricultural crops are other direct property losses that Wake County could face in the event of a wildland fire. Some structural losses that might result include private property. These include business properties and homes, vehicles, and livestock. Damage to capital goods and equipment as well as evacuation expenses and other losses are directly related to fire and smoke damage. Additional potential losses include building and landscape maintenance expenses, firefighting equipment purchases, and fire-related business closures. Additional post-fire losses include cleanup, rehabilitation and repair expenses, equipment and capital goods replacement, drinking water pollution, smoke damage, deflated real estate values, and an increase in fire insurance premiums.

Economy

Given the fact that some homes, businesses, and infrastructure are located in areas that could be impacted by wildfire, there could be some significant economic impacts of a wildfire in Wake County. If homes or businesses are burned, the cost of rebuilding could be substantial.

Environment

Wildland fires have the potential to damage or destroy forage on grazing lands, secondary forest products destruction, and/or degradation and loss of wildlife habitat on public lands. On private lands, vegetation losses could include agricultural crops that are either burned or impacted by wildland fire smoke. Indirect losses could include loss of growing stock as well as irrigation systems. Another potential loss includes damage and destruction to a wide variety of common or protected habitats in Wake County.

Additional factors that contribute to wildland fire susceptibility in Wake County include long growing seasons with frequent rainfall and wind, which can significantly affect vegetation growth.

5.18 NUCLEAR ACCIDENT

5.18.1 Background

A nuclear and radiation accident is defined by the International Atomic Energy Agency as “an event that has led to significant consequences to people, the environment or the facility. Often, this type of incident results from damage to the reactor core of a nuclear power plant which can release radioactivity into the environment. The degree of exposure from nuclear accidents has varied from serious to catastrophic.

By some estimates, over 50 percent of nuclear accidents that have ever occurred were in the United States.[36] However, it is also important to note that generally, nuclear accidents are a rare occurrence. Many incidents are extremely well known due to their large-scale impact and serious effects on people and the environment.

[36] Benjamin K. Sovacool. A Critical Evaluation of Nuclear Power and Renewable Electricity in Asia *Journal of Contemporary Asia*, Vol. 40, No. 3, August 2010, pp. 393–400.

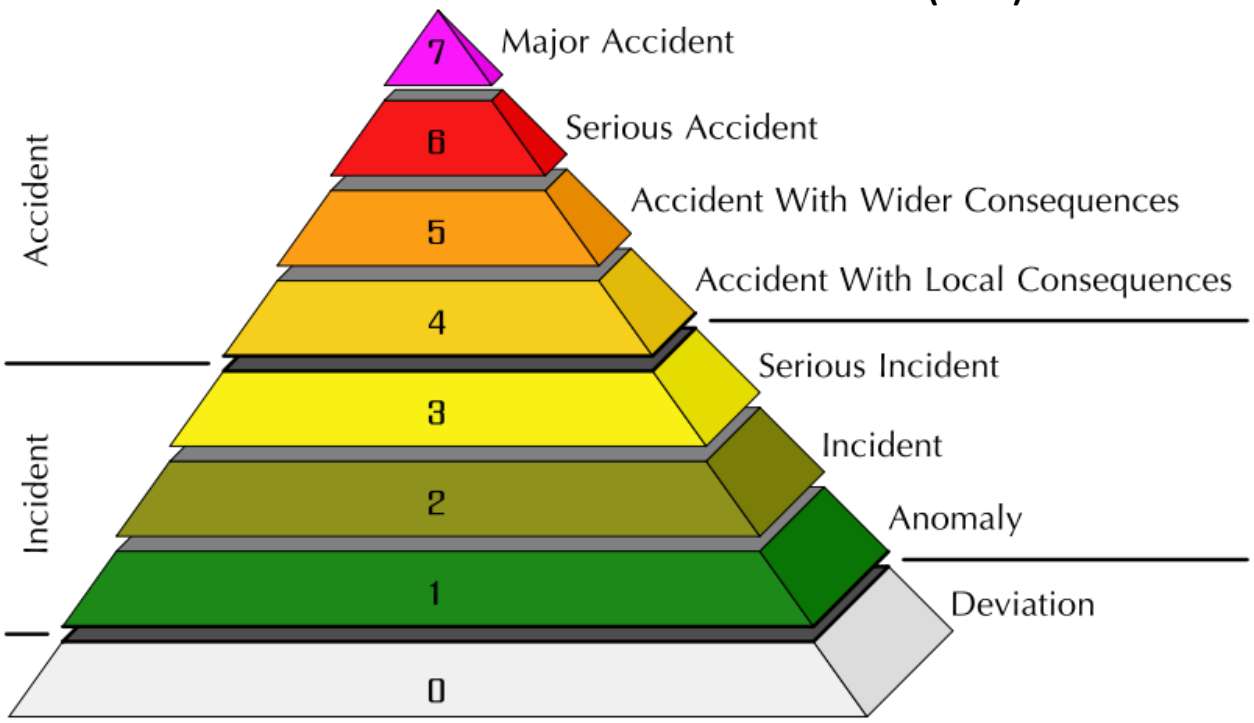
One of the most notorious accidents in the United States was the Three Mile Island accident which occurred in 1979 and released small amounts of radioactive gases and iodine into the environment. Although no deaths have been directly attributed to the accident, it invoked a strong public reaction and demonstrated the potential dangers associated with nuclear power generation.

Shearon Harris Nuclear Station, which is located in southwest Wake County, is a 2,948 megawatt power plant that began commercial operation in 1987. Its reactor is a pressurized water reactor and the plant operates with a very high level of security. This is the location from which the most catastrophic nuclear accident might occur in Wake County and will be the focal point of the nuclear analysis in this plan. However, it should also be noted that there is a 1 megawatt PULSTAR reactor located on North Carolina State University's campus in downtown Raleigh. Although its impacts would potentially be less far-reaching than Shearon Harris' in the event of an accident, it should still be noted that the effects could be extremely detrimental, especially to citizens and property within Raleigh.

5.18.2 Location and Spatial Extent

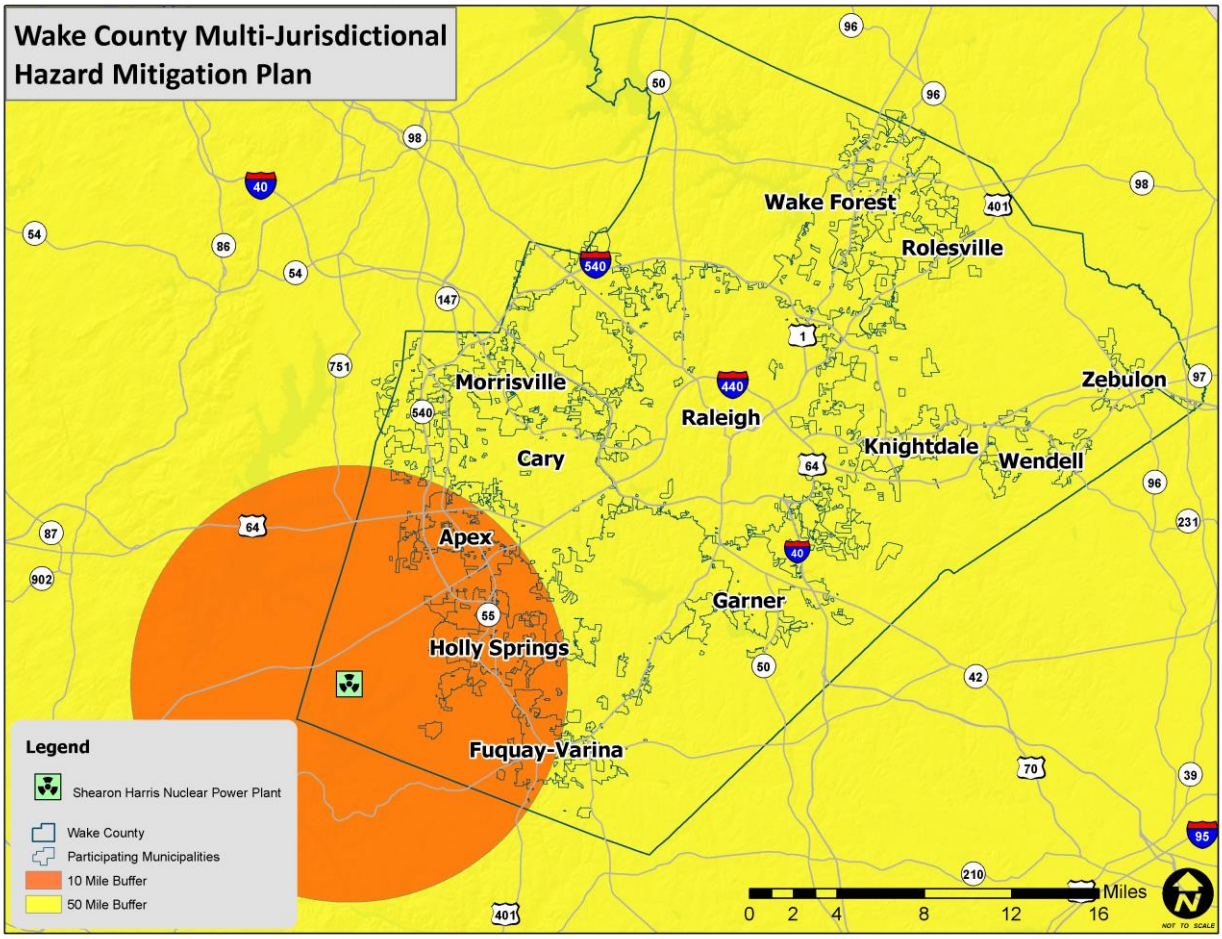
The entire county is at risk to a nuclear incident. However, areas in the southwest part of the region are more susceptible due to their proximity to the Shearon Harris Nuclear Station. The International Atomic Energy Association has developed a scale called the International Nuclear and Radiological Event Scale (INES) which provides a quantitative means of assessing the extent of a nuclear event. This scale, like the MMI used for earthquakes, is logarithmic which means that each increasing level on the scale represents an event 10 times more severe than the previous level (**Figure 5.23**).

FIGURE 5.23: INTERNATIONAL NUCLEAR EVENT SCALE (IAEA)



The Nuclear Regulatory Commission defines two emergency planning zones around nuclear plants. Areas located within 10 miles of the station are considered to be within the zone of highest risk to a nuclear incident and this radius is the designated evacuation radius recommended by the Nuclear Regulatory Commission (**Figure 5.24**). Within the 10 mile zone, the primary concern is exposure to and inhalation of radioactive contamination. The most concerning effects in the secondary 50 mile zone are related to ingestion of food and liquids that may have been contaminated. All areas of the county that are not located within the 10 mile radius are located within this 50 mile radius that is still considered to be at risk from a nuclear incident.

FIGURE 5.24: SHEARON HARRIS NUCLEAR POWER STATION INCIDENT HAZARD ZONES



Source: International Atomic Energy Agency

5.18.3 Historical Occurrences

Although there have been no major nuclear events at the Shearon Harris Nuclear Station, there is some possibility that one could occur as there have been incidents in the past in the United States at other facilities and at facilities around the world. In May of 2013, there was an unplanned shutdown of the plant which resulted from the discovery of a ¼ inch crack in the Reactor Pressure Vessel Head.

Shearon Harris has declared 2 "Alerts" and 28 "Notice of Unusual Events" since 1986, which are shown in **Table 5.60**. There have also been 338 additional incidents reported to the NRC since 1986, but they did not necessitate an emergency declaration and therefore were not included in this analysis.

Table 5.61: Shearon Harris Emergency Declaration History

Emergency Declaration	Date	Description
Alert	08/12/1988	Loss of greater than 50% of main control board (MCB) alarms due to electrical problems; normal power supply to annunciator panel failed and did not transfer to its backup inverter.
Alert	10/09/1988	Fire on "B" Main Electrical Transformer; release of flammable gas in the Protected Area.
Unusual Event	11/28/1986	Loss of ERFIS computer system to display Safety Parameter Display System (SPDS) (55 lapsed minutes).
Unusual Event	11/29/1986	Loss of ERFIS computer system to display SPDS (58 lapsed minutes).
Unusual Event	11/30/1986	Loss of ERFIS computer system to display SPDS (48 lapsed minutes).
Unusual Event	12/03/1986	Loss of ERFIS computer system to display SPDS (27 lapsed minutes).
Unusual Event	12/11/1986	Safety Injection (an Emergency Core Cooling System) actuated while testing electronic circuitry.
Unusual Event	01/27/1987	Loss of ERFIS computer system to display SPDS (23 lapsed minutes).
Unusual Event	07/11/1987	Loss of ERFIS computer system to display SPDS (22 lapsed minutes).
Unusual Event	07/24/1987	Loss of ERFIS computer system to display SPDS (32 lapsed minutes).
Unusual Event	07/25/1987	Loss of ERFIS computer system to display SPDS (28 lapsed minute).
Unusual Event	02/04/1988	Fire within the Protected Area greater than 10 minutes; smoke observed coming from the motor for the reactor auxiliary building supply fan.
Unusual Event	10/06/1988	RCS leakage in excess of Tech Specs (unidentified leakage > 1.0 gpm).
Unusual Event	10/20/1988	RCS leakage in excess of Tech Specs; pressure operated relief valve opened and admitted RCS inventory to the pressurized relief tank (PRT).
Unusual Event	11/17/1988	Loss of ERFIS computer system to display SPDS for > 60 minutes.
Unusual Event	12/01/1988	Reactor coolant system (RCS) leakage in excess of Tech Specs (unidentified leakage > 1.0 gpm).
Unusual Event	12/16/1988	High level alarm on radiological effluent release monitor the (Treated Laundry and Hot Shower high level alarm was set just above background).
Unusual Event	03/13/1989	Loss of ERFIS computer system to display SPDS for > 60 minutes.
Unusual Event	01/24/1991	Plant shutdown required by Technical Specifications. Excessive leakage of a containment penetration; leakage discovered during surveillance testing.
Unusual Event	02/15/1991	Loss of ERFIS computer system to display SPDS for > 4 hours.
Unusual Event	03/05/1991	Plant shutdown required by Technical Specifications (testing of "A" Reactor Coolant Pump (RCP) electrical protection function).
Unusual Event	04/14/1992	Loss of ERFIS computer system to display SPDS for > 4 hours.
Unusual Event	02/06/1993	Loss of ERFIS computer system to display SPDS for > 4 hours.
Unusual Event	02/17/1994	Loss of ERFIS computer system to display SPDS for > 4 hours.
Unusual Event	07/22/1994	Loss of both emergency diesel generators - "B" diesel generator was being worked on; in accordance with test procedures, "A" diesel generator is required to be tested within 24 hours following having redundant diesel out-of-service; did not pass test.
Unusual Event	11/05/1995	Unplanned emergency core cooling system (ECCS) discharge to the reactor vessel; reactor trip and safety injection (SI) occurred during the performance of testing.
Unusual Event	12/14/1995	Train derailment on site - while removing empty cask car from the Protected Area, the rail cars were moved onto the Engine Spur to allow passage of the CSX engine on adjacent Plant Spur; cask car shifted; 4 wheels of the car left the rails.
Unusual Event	01/22/1997	Security Event - while working Work Request and Authorization (WR&A), I&C Tech investigation found cut wire in a Turbine Building radiation monitor. Later determined to not be vandalism (i.e., not a security threat).

Emergency Declaration	Date	Description
Unusual Event	04/02/2000	Loss of Emergency Response Facility Information System (ERFIS) computer system to display Safety Parameter Display System (SPDS) for more than 4 hours.
Unusual Event	08/23/2011	Seismic activity at the site due to a magnitude 5.8 earthquake near Mineral, VA.

The PULSTAR Nuclear Research Reactor has one reported "Notice of Unusual Events" since 1986, which is shown in **Table 5.61**. This event occurred on August 23, 2011, and was due to seismic activity from the magnitude 5.8 earthquake near Mineral, Virginia. There were two additional known events in which an emergency declaration was not made and assistance was not required from the City of Raleigh or Wake County. One event occurred on July 2, 2011, and resulted in a shutdown of the reactor due to a 10-gallon-per-hour leak. The second event was reported on December 13, 2010, when a radiography technician walked in front of a 30 rem per hour beam of radiation for 60 seconds due to a shutter being left open.

Table 5.62: PULSTAR NUCLEAR RESEARCH REACTOR INCIDENT HISTORY

Emergency Declaration	Date	Description
None	12/13/2010	A radiography technician walked in front of a 30 REM per hour beam of radiation for 60 seconds due to a shutter being left open. This incident was reported to the Nuclear Regulatory Commission (NRC), but no assistance was required from the City of Raleigh or Wake County.
None	07/02/2011	PULSTAR shut down due to a 10 gallon per hour leak. No emergency was declared (less than 350 gallons per hour reporting threshold), and no action was required from the City of Raleigh or Wake County.
Unusual Event	08/23/2011	Seismic activity at the site due to a magnitude 5.8 earthquake near Mineral, VA.

5.18.4 Probability of Future Occurrences

A major nuclear event is a very rare occurrence in the United States due to the intense regulation of the industry. There have been incidents in the past, but it is considered unlikely (less than 1 percent annual probability).

5.18.5 Consequence Analysis

People (The Public and Public Confidence)

Evacuation time Estimate for Permanent Residents

Table 5.62 shows the estimate of permanent residents from the most recent Evacuation Time Estimate (ETE) along with the associated population change for Wake County subzones A through G. Subzone A is the immediate area surrounding the facility and zones ascend upward alphabetically as distance from the plant increases.

The estimate of permanent residents in 2010 is not available through the ETE; however, 2000 Census Block data and 2010 Census Block data are available for comparison. Total population in the Wake County EPZ (subzones A–G) was 49,889 in 2000 and 92,667 in 2010. The annual population growth rate

for Wake County based on this 10-year period was calculated as 25 percent ([92,667-49,889]/49889*100/10 years equals 8.57 percent).

Table 5.63: ETE Permanent Residents in Wake County

Sub-Zone	2000 Population	2010 Population
A	143	121
B	1,113	1,180
C	331	2,085
D	258	243
E	26,146	45,267
F	10,764	22,348
G	12,324	21,423
Total	51,079	92,667
Population Growth: 8.57%		

Population Characteristics

Table 5.63 outlines the population characteristics for each EPZ subzone (A–G) that falls within Wake County against the total population within the entire county. Population characteristics were collected from the 2010 U.S. Census at the block level and sorted by EPZ subzone. Approximately 30.83 percent of the total population in the 7 subzones combined comprises the total population in Wake County. Of these 7 subzones, 48.8 percent of the population falls within subzone E; while 24.1 percent of the population falls within subzone F.

Subzone E has the highest concentration of people in the 65 and older age group (42.8 percent) as well as the 18–64 age group (49.1 percent). Another insight that can be gleamed from this table is that subzone E has the highest number of people in the 18 and under age bracket of the 7 subzones combined (49.6 percent).

Table 5.64: Age Characteristics of Impacted Population

Sub-Zone	Population under Age 18	Population 18–64	Population 65 and over
A	19	73	29
B	276	749	155
C	731	1,268	86
D	67	150	26
E	14,744	27,702	2,821
F	7,659	13,453	1,236
G	6,227	12,963	2,233
Subzone (A–G) Total Population	29,723	56,358	6,586
Wake County Total Population	234,613	589,831	76,549
Percent of Total	12.67%	9.55%	8.60%

The number and characteristics of people that would be impacted by radiological release by subzone is shown in **Table 5.64**.

Table 5.65: Age, Sex, and Race of Impacted Population

Subzone	White Only	Black or African American Only	American Indian or Alaskan Native Only	Asian Only	Native Hawaiian or Pacific Islander Only	Other Race	Number of People with Hispanic Origins
A	67	37	3	0	0	14	22
B	997	88	11	14	4	19	44
C	1712	255	3	39	1	17	123
D	186	42	0	2	0	6	15
E	35,382	4,149	145	3,045	41	1,434	3,309
F	17,565	3,024	116	656	20	421	1,393
G	16,032	3,764	161	339	8	593	1,903
Subzone (A-G)Total Population	71,941	11,359	439	4,095	74	2,504	6,809
Wake County Total Population	560,536	182,793	4,503	48,287	387	21,455	87,922

Shadow Evacuation Area

For planning purposes, the area between the 10-mile EPZ border to a 25-mile radius from the plant is known as the Shadow Evacuation Area. The location and extent of the Shadow Evacuation Area is shown in **Figure 5.25**.

FIGURE 5.25: WAKE COUNTY SHADOW EVACUATION AREA

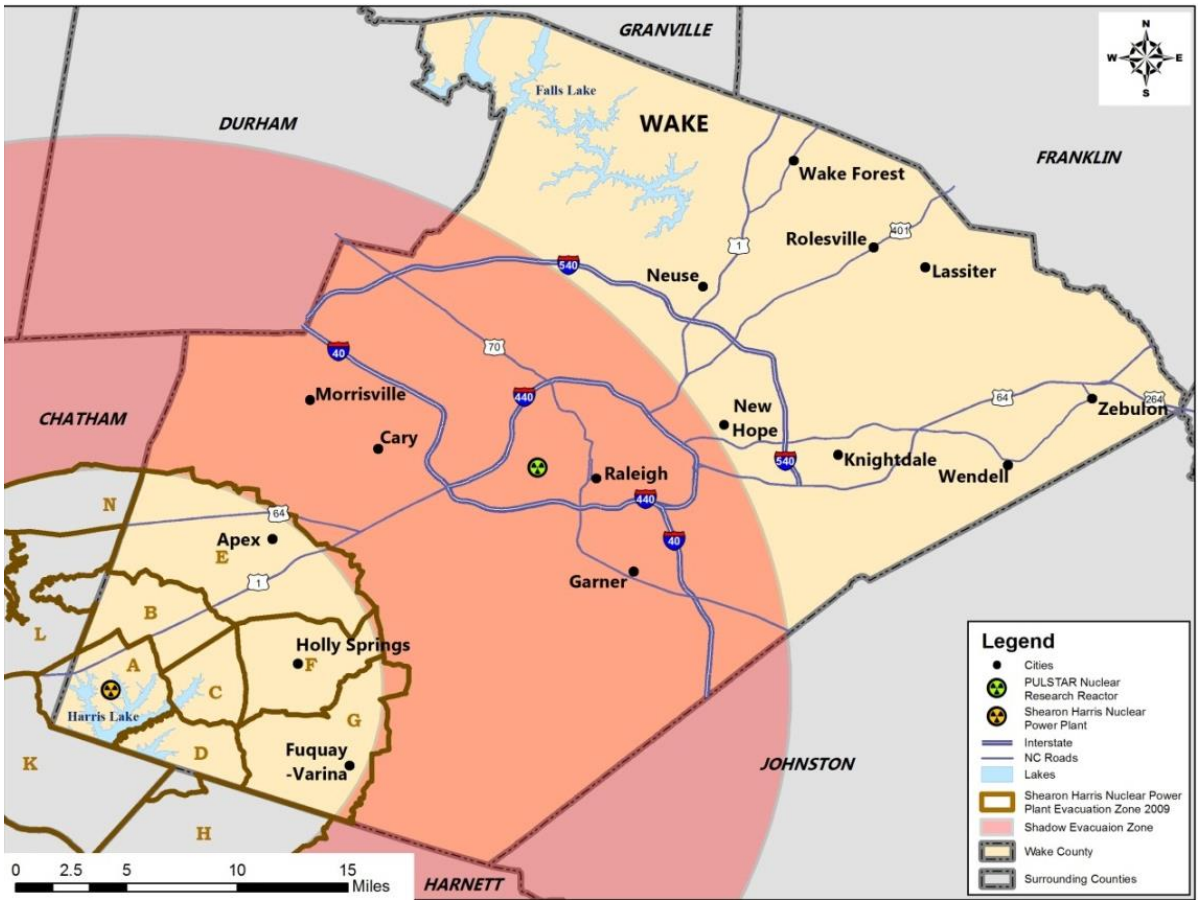


Table 5.65 shows the population between the 10-mile EPZ border to a 25-mile radius from the plant. 65.8 percent of the total population falls within the shadow evacuation area in Wake County. In addition, 44.1 percent of people within this area are in the 18–64 age range, 15.8 percent are under 18, and 5.82 percent are 65 and older.

Table 5.66: SHADOW EVACUATION AREA

Sub-Zone	2010 Population
Population under 18	142,624 (15.8%)
Population 18-64	398,159(44.1%)
Population 65 and over	52,506 (5.82%)
Total Population	593,289 (65.8%)
Wake County Total Population	900,993

Public confidence in the wake of a nuclear accident would be severe and intense given that the hazard is man-made and highly regulated. With past events as an example, reaction to a nuclear event would cause a great loss of in public confidence.

Responders

Responders in a nuclear event would face many issues, not the least of which is exposure to radiation from the nuclear accident. The long-term effects of this exposure are severe and are generally chronic

illnesses and death. Additionally, since radiation is not visible to the naked eye, responders may have difficulty recognizing safe zones in a nuclear event.

Continuity of Operations

Given the expected magnitude of the response that would be necessary in the event of a nuclear accident, it is relatively certain that there will be some disruption to operations in the county. Continuity of operations will likely be maintained, but there is at least a moderate risk that some breakdown in normal operations will occur.

Built Environment (Property, Facilities, and Infrastructure)

Wake County critical facilities include fire stations, emergency medical service stations, and hospitals among others. These facilities are critical to overall emergency management and incident stabilization. Direct impacts to these facilities would put stress on the government's ability to respond to a disaster. A number of critical facilities, as well as homes and infrastructure would be impacted by a nuclear event. For a more in depth look at impacts to the built environment, please see *Section 6: Hazard Vulnerability.*

Economy

In the short term, the economy will be impacted by a shutdown of businesses and government operations. However, the long term economic concerns are more devastating as, unlike many natural hazards, the remnants from a nuclear accident (radiation) remain for many years to come. This could potentially reduce the likelihood that new businesses will move to the area in the future and will impact perceptions about current businesses. Moreover, farmland may be unusable and water supply will be affected in many areas.

Environment

The short-term impacts of a radioactive release in Wake County are primarily from direct exposure of humans and animals to dangerous levels of radiation from a radioactive plume and its deposited material. The long-term impacts from a radioactive release include chronic exposure of humans and animals to radiation from radioactive material deposited by a plume, by eating or drinking contaminated food, milk, or water.

5.19 TERROR THREAT

5.19.1 Background

Terrorism is defined in the United States by the Code of Federal Regulations as: "the unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives."[37] Academic literature identifies some overarching political goals that terrorism seeks to achieve, including spreading anxiety and alarm among immediate victims, families, and the general public; eliminating opponents and destroying symbolic targets; and generating direct damage on society, such as affecting business confidence. In the following sections, some general background information about terrorism is presented prior to the county's hazard identification and risk assessment findings.

[37] U.S. Code of Federal Regulations. 23 C.F.R. Section 0.85

There are two general types of terrorist groups: network and hierarchical. The type of organization a group adopts largely depends on how long the group has existed. More recently developed groups tend to organize or adapt to the possibilities of the network model. Older, more established groups lean toward the hierarchical structure and are often more associated with violence of a political nature.[38] Terrorist acts can be committed by large, formally organized groups with terrorist cells in different parts of the world, or they can originate from smaller groups or individuals from a small city or domestic "homegrown" location. In the United States, terrorists that are "homegrown" do not belong to a defined group, may operate very effectively "under the radar," and may pose the biggest threat initially at the local level.[39] In 2009, for example, seven longtime residents (now known as the "Tarheel Terrorists") who were suspected of plotting terrorism and for providing money, training, transportation, and men to help terrorists, were arrested in the rural Wake County subdivision of Shadow Oaks.[40] They are currently awaiting trial for terrorist activities documented between 2006 and 2009.[41]

5.19.2 Location and Spatial Extent

A terror threat could potentially occur at any location in the county. However, the very definition of a terrorist event indicates that it is most likely to be targeted at a critical or symbolic resource/location. Ensuring and protecting the continuity of critical infrastructure and key resources (CIKR) of the United States is essential to the Nation's security, public health and safety, economic vitality, and way of life. CIKR includes physical and/or virtual systems or assets that, if damaged, would have a detrimental impact on national security, including large-scale human casualties, property destruction, economic disruption, and significant damage to morale and public confidence. **Table 5.66** shows the U.S. Department of Homeland Security's (DHS) identified main critical infrastructure sectors.

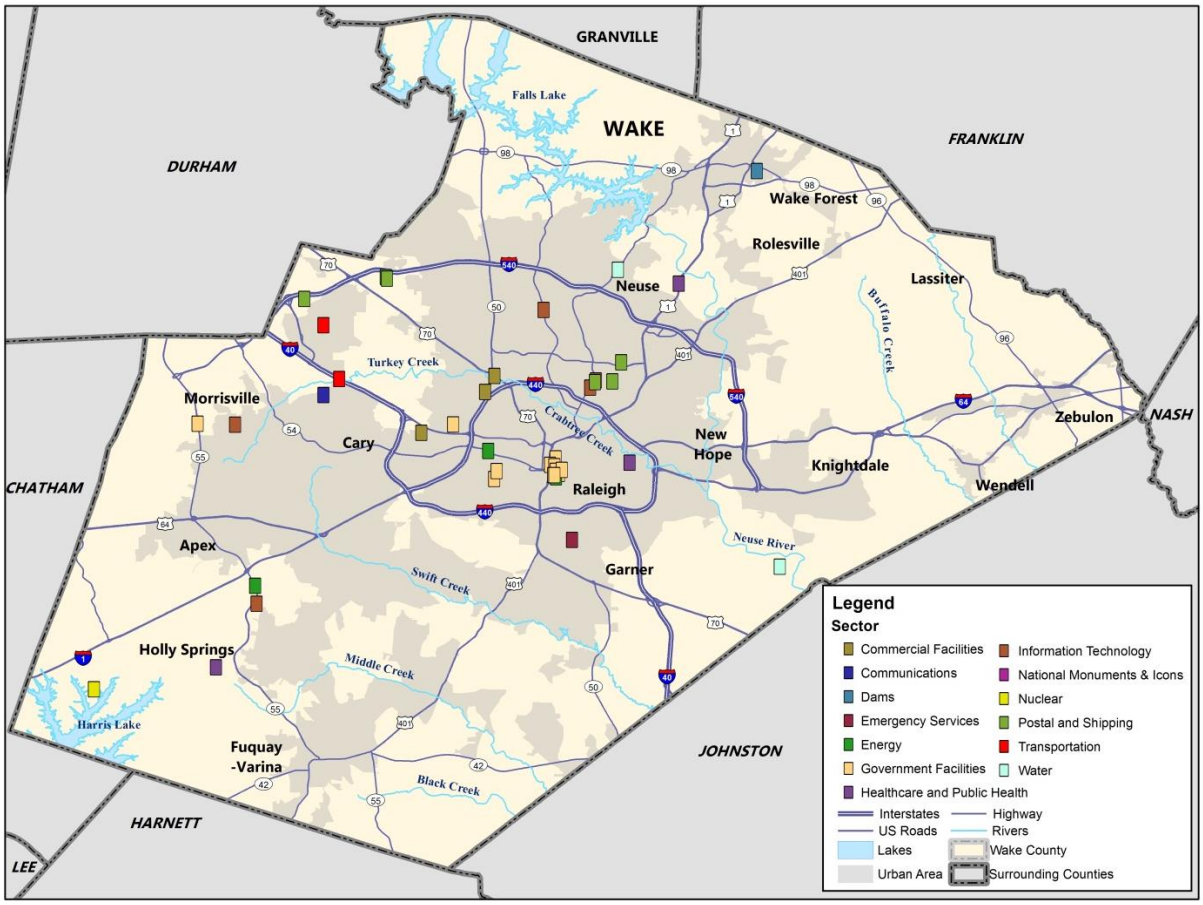
TABLE 5.67 U.S. DEPARTMENT OF HOMELAND SECURITY CRITICAL INFRASTRUCTURE SECTORS

- Agriculture and Food
- Banking and Finance
- Chemical
- Commercial Facilities
- Communications
- Critical Manufacturing
- Dams
- Defense Industrial Base
- Emergency Services
- Energy
- Government Facilities
- Healthcare and Public Health
- Information Technology
- National Monuments and Icons
- Nuclear Reactors, Materials, and Waste
- Postal and Shipping
- Transportation Systems
- Water

In Wake County, there are 43 identified critical infrastructure and key resource assets in Wake County, shown in **Figure 5.26**.

[38] Terrorism Research. *Terrorist groups*. Retrieved December 27, 2011, from http://www.terrorism-research.com/groups/
[39] *Ibid*.
[40] WTVD-TV. (2009, July 29). "8th terror suspect wanted." Retrieved May 8, 2012, from http://abclocal.go.com/wtvd/story?section=news/local&id=6935151
[41] Book, S. (2011, Sept. 20). "Jury pool picked for terrorism trial in New Bern." *ENC Today*. Retrieved May 8, 2012, from http://www.enctoday.com/articles/bern-76417-kfpress-jury-court.html

FIGURE 5.26: WAKE COUNTY CRITICAL INFRASTRUCTURE AND KEY RESOURCES (CIKR)



Source: Wake County HIRA Report (2012)

5.19.3 Historical Occurrences

Although there have been no major terror events in Wake County, there is some possibility that one could occur as there have been incidents in the past in the United States and the county is a population center that is home to the capital of North Carolina and has potential targets.

5.19.4 Probability of Future Occurrences

Wake County has had no recorded terrorist events. Due to no recorded incidents against Wake County, the probability of future occurrences of a terrorist attack is rated as unlikely with less than 1 percent annual probability of an incident occurring.

5.19.5 Consequence Analysis

People (The Public and Public Confidence)

A biological or chemical attack may go undetected for hours, days, or potentially weeks until people, animals, or plants show symptoms. The first source of detection for such an attack will likely be by local

healthcare workers observing a pattern of unusual illness or by early warning monitoring systems that detect airborne pathogens.

For an aerosol release, an area affected would depend on the quantity of agent release whether the release is indoors or outdoors, and on specific weather conditions. Agents that are released outdoors would disperse in the direction of the wind, while agents released indoors could have a higher concentration overall.

The main effect that a significant food (whether through processing, transport, or distribution) or water contamination (whether through backflow contamination or disabling or sabotaging the drinking water system) could have is the resulting health effects on the general public as well as the public anxiety created from such an attack. The extent of health impacts would depend on the concentration of the chemical or toxin present and the associated effects.

Biological and chemical attacks were identified as potential threats for the North Carolina State Fairgrounds, the North Carolina State Government Complex, and the Wake Medical Center Raleigh Campus. **Table 5.67** shows the estimated effects from the total destruction of these facilities without consideration for the threat, while the percentages show the area that is anticipated to be affected by a biological or a chemical attack given the total destruction values assigned.

Table 5.68: Biological and Chemical Impact Results: People

CIKR	Death and Injury	Public Health and Public Safety	Psychological Influence, Public Confidence and Morale
North Carolina State Government Complex/Capitol building/State Legislative Building	10,000–100,000 (about 60%)	Medium (about 40%)	Significant (about 100%)
North Carolina State Fairgrounds	10,000–100,000 (about 60%)	Medium (about 40%)	Small (about 80%)
Wake Medical Center Raleigh Campus	1,000–10,000 (about 60%)	Significant (about 20%)	Significant (about 60%)

Responders

Responders to a terror threat will face danger themselves as they attempt to control the current threat which is often ongoing in the wake of the first signs of a terrorist act. While attempting to control an event, first responders may also become the targets of terrorist threats and their lives and safety will almost certainly be at risk.

Continuity of Operations

Continuity of operations during a terror threat will be maintained on a large scale, however, on a small scale at the ground level, there will probably be some breakdown of operations as responders attempt to address this event. The rapid onset of an act of terror makes it difficult to react to and often disrupts the normal flow of emergency operations.

Built Environment (Property, Facilities, and Infrastructure)

The area affected by a terrorist incident would depend upon factors such as the type and amount of the biological or chemical agent, means of dispersal, local topography, and local weather conditions. Lethal or life-threatening results could be seen close to where the agent is released where the concentration is the highest, while severe to moderate symptoms could be seen at a distance from the actual event.

Biological and chemical attacks were identified as potential threats for the North Carolina State Fairgrounds, the North Carolina State Government Complex, and the Wake Medical Center Raleigh Campus. **Table 5.68** shows the estimated effects from the total destruction of these facilities—destruction of property and additional CIKR impacts—without consideration for the threat, while the percentages show the area that is anticipated to be affected by a biological or a chemical attack given the total destruction values assigned.

Table 5.69: Biological and Chemical Impact Results: Built Environment

CIKR	Destruction of Property	State/National Government Operations and Security	Additional CIKR Impacts
North Carolina State Government Complex/Capitol Building/State Legislative Building	$1 billion to $100 billion (about 0%)	Medium (about 60%)	Medium (about 40%)
North Carolina State Fairgrounds	$1 million to $100 million (about 0%)	Medium (about 60%)	Medium (about 40%)
Wake Medical Center Raleigh Campus	$100 million to $1 billion (about 0%)	Small (about 0%)	Significant (about 20%)

Economy

There are a series of economic impacts that could result from a terrorist attack on Wake County. Economic impacts could result from deaths, illnesses, loss of jobs, and destruction of workplaces and homes. Cleanup, rebuilding, and replacement of lost property and goods could cost many billions of dollars. In addition, local economic impacts could continue even after the site has been cleaned up if people are concerned about returning to the affected area.

Biological and chemical attacks were identified as potential threats for the North Carolina State Fairgrounds, the North Carolina State Government Complex, and the Wake Medical Center Raleigh Campus. **Table 5.69** shows the estimated economic effects from the total destruction of these facilities without consideration for the threat, while the percentages show the area that is anticipated to be affected by a biological or a chemical attack given the total destruction values given.

Table 5.70: Biological and Chemical Impact Results: Economy

CIKR	Economic Impact
North Carolina State Government Complex/Capitol Building/State Legislative Building	Medium (about 20%)
North Carolina State Fairgrounds	Small (about 20%)

CIKR	Economic Impact
Wake Medical Center Raleigh Campus	Small (about 20%)

Environment

The environmental consequences of a biological or chemical attack within Wake County vary considerably depending on the type of incident and the extent of the incident. In the case of a water- or food-borne attack (e.g., a nerve agent that is readily absorbed through foods but does not change the appearance or taste of the food), agricultural land and livestock as well as drinking water supplies (with the exception of deep groundwater reservoirs and protected water resources, which are safeguarded) could be compromised. Depending on the chemical agent or toxin used, the surrounding physical environment and wildlife could be contaminated or impacted.

In addition, the physical environment could be destroyed or severely damaged by such an attack. If the attack is within the vicinity of wetlands or ecosystems, these areas could also be destroyed or severely compromised. Again, the extent of damage would depend on the concentration of the toxin or the chemical, biological, or radiological agent that is released during the explosion or incident.

Biological and chemical attacks were identified as potential threats for the North Carolina State Fairgrounds, the North Carolina State Government Complex and the Wake Medical Center-Raleigh Campus. **Table 5.70** shows the estimated environmental damage effects from the total destruction of these facilities without consideration for the threat, while the percentages show the area that is anticipated to be affected by a biological or a chemical attack given the total destruction values given.

Table 5.71: BIOLOGICAL AND CHEMICAL IMPACT RESULTS: ENVIRONMENT

CIKR	Environmental damage
North Carolina State Government Complex/Capitol Building/State Legislative Building	Medium (about 0%)
North Carolina State Fairgrounds	Small (about 0%)
Wake Medical Center Raleigh Campus	Medium (about 0%)

5.20 CONCLUSIONS ON HAZARD RISK

The hazard profiles presented in this section were developed using best available data and result in what may be considered principally a qualitative assessment as recommended by FEMA in its "How-to" guidance document titled *Understanding Your Risks: Identifying Hazards and Estimating Losses* (FEMA Publication 386-2). It relies heavily on historical and anecdotal data, stakeholder input, and professional and experienced judgment regarding observed and/or anticipated hazard impacts. It also carefully considers the findings in other relevant plans, studies, and technical reports.

5.20.1 Hazard Extent

Table 5.71 describes the extent of each natural hazard identified for Wake County. The extent of a hazard is defined as its severity or magnitude, as it relates to the planning area.

TABLE 5.72 EXTENT OF WAKE COUNTY HAZARDS

Atmospheric Hazards	
Drought	Drought extent is defined by the North Carolina Drought Monitor Classifications which include Abnormally Dry, Moderate Drought, Severe Drought, Extreme Drought, and Exceptional Drought (page 5:6). According to the North Carolina Drought Monitor Classifications, the most severe drought condition is Exceptional. The county received this ranking (at least three times) over the fourteen year reporting period. Although drought information from the North Carolina Drought Monitor is not specifically reported at the municipal level, it can be assumed that each jurisdiction experienced similar conditions due to its location and the regional impact of the hazard.
Extreme Heat	The extent of extreme heat can be defined by the maximum temperature reached. The highest temperature recorded in Wake County is 107 degrees Fahrenheit in Raleigh in 1898.
Hailstorm	Hail extent can be defined by the size of the hail stone. The largest hail stone reported in Wake County was 4.0 inches. It should be noted that future events may exceed this.
Hurricane and Tropical Storm	Hurricane extent is defined by the Saffir-Simpson Scale which classifies hurricanes into Category 1 through Category 5 (Table 5.10). The highest magnitude hurricanes to traverse directly through Wake County were two storms which carried tropical force winds of 70 knots upon arrival in Wake County. Both an Unnamed Storm in 1893 and Hurricane Hazel in 1954 carried this maximum sustained wind speed. It should also be noted that Hurricane Fran, which struck more recently, attained maximum sustained winds of 57 knots.
Lightning	According to the NOAA flash density map (Figure 5.5), the majority of Wake County is located in an area that experiences 4 to 5 lightning flashes per square kilometer per year. It should be noted that future lightning occurrences may exceed these figures.
Severe Thunderstorm/High Wind	Thunderstorm extent is defined by the number of thunderstorm events and wind speeds reported. According to a 60-year history from the National Climatic Data Center, the strongest recorded wind event in Wake County was reported on September 17, 2004 at 69 knots (approximately 79 mph). It should be noted that future events may exceed these historical occurrences.
Tornado	Tornado hazard extent is measured by tornado occurrences in the US provided by FEMA (Figure 5.6) as well as the Fujita/Enhanced Fujita Scale (Tables 5.18 and 5.19). The greatest magnitude reported was an F4 (last reported on November 28, 1988).
Winter Storm and Freeze	The extent of winter storms can be measured by the amount of snowfall received (in inches). The greatest snowfall reported in Wake County was around 20-24 inches during the Blizzard of 1996. Due to variations in storm systems, extent totals will vary for each participating jurisdiction and reliable data on snowfall totals is not available.

Geologic Hazards	
Earthquake	Earthquake extent can be measured by the Richter Scale (Table 5.24) and the Modified Mercalli Intensity (MMI) scale (Table 5.25) and the distance of the epicenter from Wake County. According to data provided by the National Geophysical Data Center, the greatest MMI to impact the region was reported in Raleigh with a MMI of VIII (destructive) with a correlating Richter Scale measurement of approximately 7.2.
Landslide	As noted above in the landslide profile, the landslide data provided by the North Carolina Geological survey is incomplete. This provides a challenge when trying to determine an accurate extent for the landslide hazard. However, when using the USGS landslide susceptibility index, extent can be measured with incidence, which is between low and moderate. There is also moderate susceptibility in some parts of the county.
Hydrologic Hazards	
Dam Failure	Dam failure extent is defined using the North Carolina Division of Land Resources criteria (Table 5.30). Of the 401 dams in Wake County, 144 are classified as high-hazard.
Erosion	The extent of erosion can be defined by the measurable rate of erosion that occurs. There are no erosion rate records available for Wake County.
Flood	Flood extent can be measured by the amount of land and property in the floodplain as well as flood height and velocity. The amount of land in the floodplain accounts for 9.2 percent of the total land area in the Wake County. Flood depth and velocity are recorded via United States Geological Survey stream gages throughout the region. While a gage does not exist for each participating jurisdiction, there is one at or near many areas. The greatest peak discharge recorded for the area was at Crabtree Creek at Ebenezer Church Road (Raleigh) in 1973. Water reached a discharge of 117,007 cubic feet per second. Additional peak discharge readings and gage heights are in the table below.

Location	Date	Peak Discharge (cfs)	Gage Height (ft)
BEAVERDAM CREEK AT DAM NEAR CREEDMOOR, NC	--	--	--
LOWER BARTON CREEK TRIB NR RALEIGH, NC	7/28/1965	355	24.34
FALLS LAKE ABOVE DAM NR FALLS, NC	--	--	--
NEUSE RIVER NEAR FALLS, NC	7/17/1975	13,600	25.21
NEUSE RIVER NEAR NEUSE, NC	9/21/1945	--	26.00
CRABTREE CR AT EBENEZER CHURCH RD NR RALEIGH, NC	9/6/1996	82,007	22.4
CRABTREE CREEK AT HWY 70 AT RALEIGH, NC	6/27/1973	117,007	27.69

CRABTREE CREEK AT ANDERSON DRIVE AT RALEIGH, NC	--	--	--
CRABTREE CR AT OLD WAKE FOREST RD AT RALEIGH, NC	--	--	--
CRABTREE CREEK AT US 1 AT RALEIGH, NC	9/6/1996	12,700	18.23
PIGEON HOUSE CR AT CAMERON VILLAGE AT RALEIGH, NC	8/21/1999	622	8.23
MARSH CREEK NEAR NEW HOPE, NC	9/6/1999	3,900	13.33
ROCKY BRANCH AT DAN ALLEN DRIVE AT RALEIGH, NC	6/18/1967	225	23.8
ROCKY BRANCH AT CARMICHAEL GYM AT RALEIGH, NC	6/18/1967	485	24.85
ROCKY BRANCH BELOW PULLEN DRIVE AT RALEIGH, NC	7/24/1997	2,590	9.23
WALNUT CREEK AT SUNNYBROOK DRIVE NR RALEIGH, NC	9/6/1996	6,760	17.03
NEUSE R TRIB AT NRWWTP (CMP SITE) NR AUBURN, NC	10/27/2007	276	5.4
SWIFT CREEK NEAR APEX, NC	5/11/1957	3,105	24.02
SWIFT CREEK NEAR MCCULLARS CROSSROADS, NC	9/6/1996	67,906	14.15
UNNAMED TRIB TO SWIFT CR NR YATES MILL POND, NC	8/8/2003	60	2.48
MIDDLE CREEK NEAR HOLLY SPRINGS, NC	7/28/1965	2,520	26.2
LITTLE RIVER NEAR ZEBULON, NC	3/29/2009	1,050	2.7
WHITE OAK CR AT MOUTH NEAR GREEN LEVEL, NC	6/14/2006	5,920	13.5

Other Hazards

Hazardous Materials Incident	According to USDOT PHMSA, the largest hazardous materials incident reported in the county is 50 LGA released on the highway in Raleigh. It should be noted that larger events are possible.

Wildfire	Wildfire data was provided by the North Carolina Division of Forest Resources and is reported annually by county from 2003-2012. Analyzing the data indicates the following wildfire hazard extent. The greatest number of fires to occur in any year was 28 in 2007. The greatest number of acres to burn in a single year occurred in 2011 when 225 acres were burned. Although this data lists the extent that has occurred, larger and more frequent wildfires are possible throughout the region.
Nuclear Accident	Although there is not any historic precedent for a nuclear accident in Wake County, it is possible that a serious to major accident could occur. This would result in severe exposure to radiation for southwest Wake County (in the 10 mile buffer) and much of the rest of the county would also be impacted (50 mile buffer).
Terror Threat	There is no history of terror threats in Wake County however; it is possible that one of these events could occur. If this were to take place, the magnitude of the event could range on the scale of catastrophic with many fatalities and injuries to the population.

5.20.2 Priority Risk Index

In order to draw some meaningful planning conclusions on hazard risk for Wake County, the results of the hazard profiling process were used to generate countywide hazard classifications according to a "Priority Risk Index" (PRI). The purpose of the PRI is to categorize and prioritize all potential hazards for Wake County as high, moderate, or low risk. Combined with the asset inventory and quantitative vulnerability assessment provided in the next section, the summary hazard classifications generated through the use of the PRI allows for the prioritization of those high hazard risks for mitigation planning purposes, and more specifically, the identification of hazard mitigation opportunities for the jurisdictions in Wake County to consider as part of their proposed mitigation strategy.

The prioritization and categorization of identified hazards for Wake County is based principally on the PRI, a tool used to measure the degree of risk for identified hazards in a particular planning area. The PRI is used to assist the Wake County Regional Work Groups in gaining consensus on the determination of those hazards that pose the most significant threat to Wake County and its municipalities based on a variety of factors. The PRI is not scientifically based, but is rather meant to be utilized as an objective planning tool for classifying and prioritizing hazard risks in Wake County based on standardized criteria.

The application of the PRI results in numerical values that allow identified hazards to be ranked against one another (the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard (probability, impact, spatial extent, warning time, and duration). Each degree of risk has been assigned a value (1 to 4) and an agreed upon weighting factor[42], as summarized in **Table 5.72**. To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

[42] The Regional Work Groups, based upon any unique concerns or factors for the planning area, may adjust the PRI weighting scheme during future plan updates.

PRI VALUE = [(PROBABILITY x .30) + (IMPACT x .30) + (SPATIAL EXTENT x .20) + (WARNING TIME x .10) + (DURATION x .10)]

According to the weighting scheme and point system applied, the highest possible value for any hazard is 4.0. When the scheme is applied for Wake County, the highest PRI value is 3.1 (thunderstorm/high wind hazard). Prior to being finalized, PRI values for each identified hazard were reviewed and accepted by the members of the Regional Work Groups.

TABLE 5.73: PRIORITY RISK INDEX FOR WAKE COUNTY

PRI Category	Degree of Risk			Assigned Weighting Factor
	Level	Criteria	Index Value	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	Between 1 and 10% annual probability	2	
	Likely	Between 10 and 100% annual probability	3	
	Highly Likely	100% annual probability	4	
Impact	Minor	Very few injuries, if any. Only minor property damage and minimal disruption on quality of life. Temporary shutdown of critical facilities.	1	30%
	Limited	Minor injuries only. More than 10% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one day.	2	
	Critical	Multiple deaths/injuries possible. More than 25% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50% of property in affected area damaged or destroyed. Complete shutdown of critical facilities for 30 days or more.	4	
Spatial Extent	Negligible	Less than 1% of area affected	1	20%
	Small	Between 1 and 10% of area affected	2	
	Moderate	Between 10 and 50% of area affected	3	
	Large	Between 50 and 100% of area affected	4	
Warning Time	More than 24 hours	Self explanatory	1	10%
	12 to 24 hours	Self explanatory	2	
	6 to 12 hours	Self explanatory	3	
	Less than 6 hours	Self explanatory	4	
Duration	Less than 6 hours	Self explanatory	1	10%
	Less than 24 hours	Self explanatory	2	
	Less than one week	Self explanatory	3	
	More than one week	Self explanatory	4	

5.20.3 Priority Risk Index Results

Table 5.73 summarizes the degree of risk assigned to each category for all initially identified hazards based on the application of the PRI. Assigned risk levels were based on the detailed hazard profiles developed for this section, as well as input from the Regional Work Groups. The results were then used in calculating PRI values and making final determinations for the risk assessment.

TABLE 5.74: SUMMARY OF PRI RESULTS FOR WAKE COUNTY

Hazard	Category/Degree of Risk					
	Probability	Impact	Spatial Extent	Warning Time	Duration	PRI Score
Atmospheric Hazards						
Drought	Likely	Minor	Large	More than 24 hours	More than 1 week	**2.5**
Extreme Heat	Likely	Minor	Large	More than 24 hours	Less than 1 week	**2.4**
Hailstorm	Highly Likely	Minor	Moderate	6 to 12 hours	Less than 6 hours	**2.5**
Hurricane and Tropical Storm	Likely	Critical	Large	More than 24 hours	Less than 24 hours	**2.9**
Lightning	Highly Likely	Minor	Negligible	6 to 12 hours	Less than 6 hours	**2.1**
Thunderstorm/High Wind	Highly Likely	Critical	Moderate	6 to 12 hours	Less than 6 hours	**3.1**
Tornado	Likely	Critical	Small	Less than 6 hours	Less than 6 hours	**2.7**
Winter Storm and Freeze	Likely	Limited	Moderate	More than 24 hours	Less than 1 week	**2.5**
Geologic Hazards						
Earthquake	Possible	Minor	Moderate	Less than 6 hours	Less than 6 hours	**2.0**
Landslide	Possible	Minor	Small	Less than 6 hours	Less than 6 hours	**1.8**
Hydrologic Hazards						
Dam and Levee Failure	Unlikely	Critical	Small	Less than 6 hours	Less than 6 hours	**2.1**
Erosion	Possible	Minor	Small	More than 24 hours	More than 1 week	**1.8**
Flood	Likely	Critical	Moderate	6 to 12 hours	Less than 1 week	**3.0**
Other Hazards						
Hazardous Materials Incident	Likely	Limited	Small	Less than 6 hours	Less than 24 hours	**2.5**
Wildfire	Possible	Minor	Small	Less than 6 hours	Less than 1 week	**2.0**
Nuclear Accident	Unlikely	Critical	Large	6 to 12 hours	Less than 1 week	**2.6**
Terror Threat	Unlikely	Critical	Moderate	Less than 6 hours	Less than 24 hours	**2.4**

5.21 FINAL DETERMINATIONS

The conclusions drawn from the hazard profiling process for Wake County, including the PRI results and input from the Regional Work Groups, resulted in the classification of risk for each identified hazard according to three categories: High Risk, Moderate Risk, and Low Risk (**Table 5.74**). For purposes of these classifications, risk is expressed in relative terms according to the estimated impact that a hazard will have on human life and property throughout all of Wake County. A more quantitative analysis to

estimate potential dollar losses for each hazard has been performed separately, and is described in Section 6: *Vulnerability Assessment*. It should be noted that although some hazards are classified below as posing low risk, their occurrence of varying or unprecedented magnitudes is still possible in some cases and their assigned classification will continue to be evaluated during future plan updates.

TABLE 5.75: CONCLUSIONS ON HAZARD RISK FOR WAKE COUNTY

HIGH RISK	Severe Thunderstorm/High Wind Hurricane/Tropical Storm Tornado Flood
MODERATE RISK	Drought Extreme Heat Hailstorm Winter Storm and Freeze Hazardous Materials Incident Nuclear Accident Terror Threat
LOW RISK	Lightning Earthquake Landslide Dam and Levee Failure Erosion Wildfire