Section

5

RISK ASSESSMENT OVERVIEW

The goal of mitigation is to reduce the future impacts of a hazard including loss of life, property damage, disruption to local and regional economies, and the expenditure of public and private funds for recovery. Sound mitigation must be based on a sound risk assessment. A risk assessment involves quantifying the potential loss resulting from a disaster by assessing the vulnerability of buildings, infrastructure, and people.

This assessment identifies the characteristics and potential consequences of a disaster, how much of the community could be affected by a disaster, and the impact on community assets. A risk assessment consists of three steps: 1) identify hazards, 2) assess vulnerability, and 3) profile hazards and analyze.

5.1 Identify Hazards

5.1.1 Existing Plans

To facilitate the planning process, Brown County reviewed pre-existing plans and data, such as the 2007 Brown County Natural Hazards Mitigation Plan and Ohio digital flood maps. A component of these plans included a determination of the current primary hazards to Brown County. For a full list of reviewed resources, see Table 3-2 in Section 3 of this plan.

Planning efforts during development of the 2007 Hazard Mitigation Plan identified the principal natural hazards to the county as:

- Flooding
- Tornadoes
- Severe thunderstorms
- Severe winter storms
- Earthquakes
- Mudslides
- Drought

Recent planning efforts for the 2015 Brown County Multi-Hazard Mitigation Plan updated the most concerning current hazards to:

- Flooding
- Tornadoes
- Thunderstorms (Hail/Wind/Lightning)
- Winter Storms
- Extreme Temperatures (both hot and cold)
- Drought
- Landslides
- Earthquake
- Fire
- Dam/Levee Failure
- HAZMAT/chemical spill

5.1.2 Historical Hazards Records

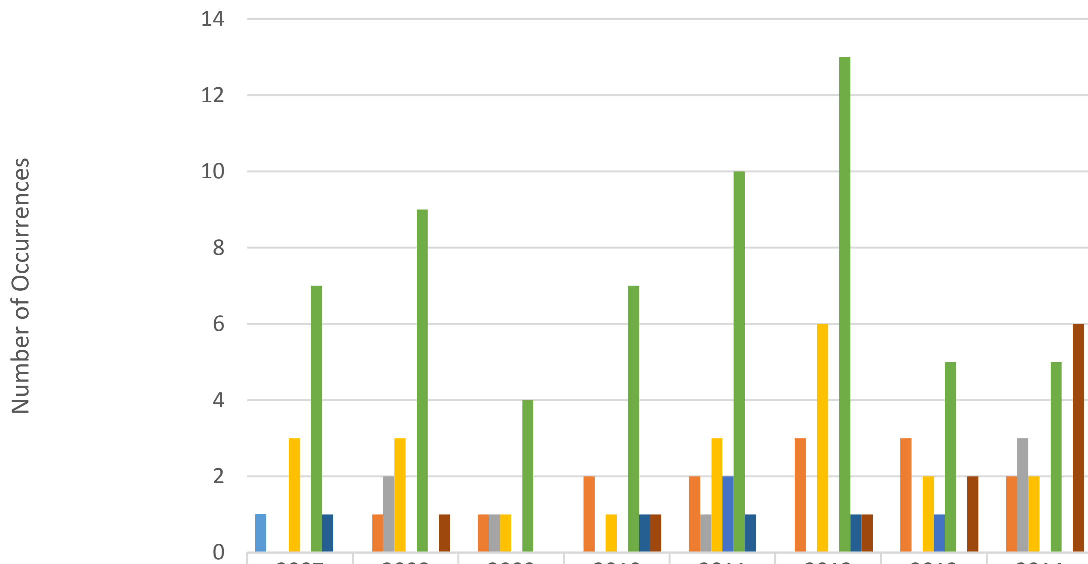
To assist the planning team, historical storm-event data from the past eight years (since the last plan) were compiled from the National Climatic Data Center (NCDC). NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

The NCDC Storm Events Database includes the following hazard related events:

- Tornadoes
- Severe thunderstorms (wind/lightning/hail)
- Drought
- Extreme temperatures (cold and hot)
- Winter storms
- Floods (riverine and flash floods)

The NCDC data included 78 days with a reported event (total of 121 events) in Brown County between January 1, 2007 and December 31, 2014. There were no recorded events for drought. Figure 5-1 shows number of occurrences of each hazard within that timeframe.

Figure 5-1: NCDC Reported Hazard Events 2007-2014



	2007	2008	2009	2010	2011	2012	2013	2014
Excessive Heat	1							
Flash Flood		1	1	2	2	3	3	2
Flood		2	1		1			3
Hail	3	3	1	1	3	6	2	2
Heavy Rain					2		1	
Thunderstorm Wind	7	9	4	7	10	13	5	5
Tornado	1			1	1	1		
Winter Storm		1		1		1	2	6

5.1.3 Hazard Ranking Methodology

During meeting #1, held on January 21, 2015, the planning team reviewed historical hazards information and the previous mitigation plans ranked hazards, and participated in a risk analysis exercise to rank hazards by community and according to severity of risk.

The team reviewed and calculated a risk priority index, this task is completed through a series of tasks. First, for each hazard, a score between 0-5 is assigned to the following five factors: history, area affected, predictability, preparedness, human impact and economic impact. The questions that each of these factors ask is seen in Table 5-1. A score of '0' represents zero effect on a community and high predictability and preparedness; whereas a score of '5'indicates a catastrophic effect on a community with a low predictability and low preparedness for the given disaster. Second, add each score per hazard to allow for hazard comparison. The scoring benchmarks are listed in Table 5-2. These total scores are weighted by history (35%), area affected (5%), predictability

(5%), preparedness (5%), human impact (25%) and economic impact (25%). The higher the score, the greater the hazard risk.

The planning team identified 11 hazards affecting Brown County. Table 5-3 shows how each hazard ranked by factor for the County.

Table 5-1: Hazard Factor Questions

Factor	Questions asked
History	When and how often has the event happened? (Based on historical data)
Area Affected	How much of the county would be directly impacted by the event? (Impacted as to potential threat to life, property and business interruption)
Predictability	Based on historical records, is the given event highly probable on occurring again?
Preparedness	Can preparation for the event reduce human and economic impact?
Human Impact	Does the event require shelter, evacuation or other protective measures for the population in the area directly affected by the event?
Economic Impact	What is the amount of damage to private and public property, and how much business would be interrupted?

Table 5-2: Hazard Ranking Benchmarks – Scoring System

FACTORS		BENCHMARK SCORES 0	1	2	3	4	5
History		Has never happened	>100 years	1 in 100	1 in 50	1 in 10	1+/year
Area Affected		One neighborhood	One jurisdiction	Multi-jurisdictional	50% of county	75% of county	Entire county
Predictability		Can accurately determine a time and location days before event occurs	Can determine days ahead, not accurate as to specific time and location	Can calculate hours ahead, location can be estimated	Can calculate hours ahead, cannot accurately determine location	Detectable only moments before event, cannot accurately determine location	Highly unlikely, difficult to estmate time and location
Preparedness		Can be fully prepared	Can prepare with available resources for reduction in human and economic impact	Can prepare with additional resources to reduce human and economic impact	Preparation difficult, many resources needed to reduce human and economic impact.	Can only prepare to reduce human impact, cannot reduce economic impact	Cannot prepare
Human Impact		No effect on the population	Minimal, in-place protective measures required	Shelter and/or evacuation or other protective measures required for less than 50% of the population involved.	Shelter and/or evacuation or other protective measures required for 50% of the population involved	Shelter and/or evacuation or other protective measures required for 75% of the population involved	Total population in the area affected: shelter and/or evacuation or other protective measures required
Economic Impact *The three categories to right are averaged to create economic impact score*	*Residential Property*	No damage	10% damage and/or destroyed	25% damage and/or destroyed	50% damage and/or destroyed	75% damage and/or destroyed	Total destruction
	Public Property	No damage	10% damage and/or destroyed	25% damage and/or destroyed	50% damage and/or destroyed	75% damage and/or destroyed	Total destruction
	Business Interruption	Business not affected	10% business interruption	25% business interruption	50% business interruption	75% business interruption	All Business Stopped

Table 5-3: Hazard Ranking for Brown County

Rank	Hazard	History	Area	Prediction	Preparation	Human Impact	Economic Impact	Total Score	Weighted Score
1	Flooding	5	2	2	2	4	4	19	4.05
2	Tornado	4	2	4	4	5	4	23	4.15
3	Drought	1	3	1	4	1	1	11	1.25
4	Winter Storms	5	5	1	2	1	2	16	2.9
5	Thunderstorms	5	5	3	4	1	2	20	3.1
6	Landslides	4	2	3	3	4	2	18	3.3
7	Extreme Temperatures	1	3	1	4	1	1	11	1.25
8	Hazmat	4	2	5	3	1	1	16	2.4
9	Fire	5	2	5	2	1	1	16	2.7
10	Dam/Levee Failure	1	2	5	4	4	2	18	2.4
11	Earthquake	1	5	5	4	1	1	17	1.55

5.1.4 GIS and Hazus-MH Modeling

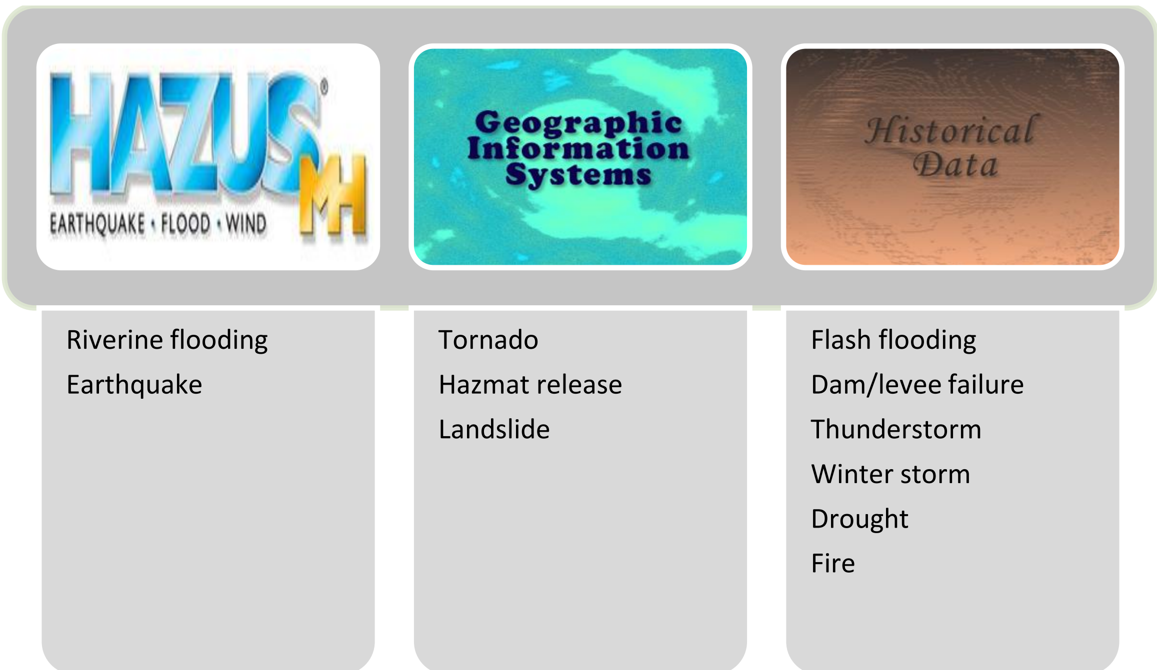
FEMA's Pre-Disaster Mitigation (PDM) program is designed to provide assistance to local communities to develop and implement their hazard mitigation plan, thereby reducing risk to property and lives. The initial multi-hazard mitigation plan (MHMP) for Brown County, Ohio was submitted to FEMA and approved in 2007. The previous plan did not complete a detailed Hazus-MH and GIS-based analyses. These software packages, coupled with the implementation of new technology and locally available parcel datasets, a current detailed analysis may be completed. Multi-hazard mitigation plan updates may document significant variances from the original MHMP.

The risk assessment is based on a Level 2 Hazus analysis. Hazus-MH generated a combination of site-specific (flood) and aggregated loss (earthquake) estimates. Aggregate inventory loss estimates, which include building stock analysis, are based upon the assumption that building stock is evenly distributed across census blocks/tracts. With this in mind, total losses tend to be more reliable over larger geographic areas than for individual census blocks/tracts. Site-specific analysis is based upon loss estimations for individual structures. For flooding, analysis of site-specific structures takes into account the depth of water in relation to the structure. Hazus-MH also takes into account the actual dollar exposure to the structure for the costs of building reconstruction, content, and inventory. Damages, however, are based upon the assumption that each structure will fall into a structural class, and structures in each class will respond in a similar fashion to a specific depth of flooding. Site-specific analysis also is based upon a point location rather than a polygon; therefore the model does not account for the percentage of a building that is inundated. A summation of the type of analyses completed is seen in Figure 5-2.

It is important to note that Hazus-MH is not intended to be a substitute for detailed engineering studies. Rather, it is intended to serve as a planning aid for communities interested in assessing their risk to flood, earthquake, and hurricane-related hazards. This documentation does not provide full details on the processes and procedures completed in the development of this project. It is only intended to highlight the major steps that were followed during the project.

We analyzed 11 hazard events using Hazus-MH, GIS, and historical information to predict which communities would be at risk.

Figure 5-2: Summation of hazard analysis tools utilized in MHMP



5.2 Assess Vulnerability

The planning team members were provided with a plot and report of essential and critical facilities, as well as a list of potential community assets. The planning team took GIS data provided by The Polis Center and MU; verified the datasets, using local knowledge, and allowed The Polis Center to use its local GIS data for additional verification. Polis and MU GIS analysts made these updates and corrections to the Hazus-MH data tables prior to performing the risk assessment. Secondly, Brown County provided Polis and MU with parcel and assessment records to generate an accurate picture of countywide building inventory and associated potential replacement costs. These changes to the Hazus-MH inventory reflect an enhanced level 1 analysis. This update process improved the accuracy of the model predictions.

The default Hazus-MH data have been updated as follows:

- The Hazus-MH defaults, critical facilities, and essential facilities are updated based on the most recent available data sources. Local subject matter experts verified, revised, and approved ccritical and essential point facilities.
- Updated essential facility data (schools, medical care facilities, fire stations, police stations, and EOCs) are reflected in the Hazus-MH analysis results.

5.2.1 Identify Facilities

For the purpose of this plan, ***essential facilities*** are defined as those that are vital to the county in the event of a hazard. These include emergency operations centers (EOCs), police departments, fire stations, schools, and care facilities. Table 5-4 identifies the updated essential facilities utilized in analysis. Essential facilities are a subset of critical facilities. ***Critical facilities*** are additional entities that are deemed economically or socially viable to the county, including communication facilities, utilities, transportation facilities, infrastructure, and hazardous materials sites. Names and locations of all essential and critical facilities are documented in Appendix E.

> ***Essential facilities*** are defined as those that are vital to the county in the event of a hazard and are a subset of critical facilities… ***Critical facilities*** are additional entities that are deemed economically or socially viable to the

Table 5-4: Essential Facilities in Brown County

Facility	Number of Facilities
Care Facilities	5
Emergency Operations Centers	1
Fire Stations	20
Police Stations	10
Schools	35

5.2.2 Facility Replacement Costs

Facility replacement costs and total building exposure are identified in Table 5-5[4]. The replacement costs have been updated by local data. Table 5-5 also includes the estimated number of buildings within each occupancy class.

Table 5-5: Building Exposure

General Occupancy	Estimated Total Buildings	Total Building Exposure
Agricultural	2,432	$208,321,000
Commercial	399	$58,626,000
Education	13	$21,598,000
Government	139	$40,547,000
Industrial	9	$718,000

[4] The Assessor records do not contain values for non-taxable properties, including government, non-profit, and education facilities. Therefore, building losses may be under represented.

General Occupancy	Estimated Total Buildings	Total Building Exposure
Religious/Non-Profit	100	$22,679,000
Residential	18,142	$1,220,974,000
Total	**21,234**	**$1,573,463,000**

5.3 Profiling Hazards

5.3.1 Tornado Hazard

Tornadoes pose a great risk to the state of Ohio and its citizens. Tornadoes can occur at any time during the day or night and during any month of the year. The unpredictability of tornadoes makes them one of Ohio's most dangerous hazards. Their extreme winds are violently destructive when they touch down in the region's developed and populated areas. Current estimates place the maximum velocity at about 300 miles per hour, but higher and lower values can occur. A wind velocity of 200 miles per hour will result in a wind pressure of 102.4 pounds per square foot of surface area—a load that exceeds the tolerance limits of most buildings.

Tornadoes are defined as violently-rotating columns of air extending from thunderstorms to the ground. Funnel clouds are rotating columns of air not in contact with the ground; however, the violently-rotating column of air can reach the ground very quickly and become a tornado. If the funnel cloud picks up and blows debris, it has reached the ground and is a tornado.

Tornadoes are classified according to the Fujita tornado intensity scale. Originally introduced in 1971, the scale was modified in 2006 to better define the damage and estimated wind scale. The Enhanced Fujita Scale ranges from low intensity EF0 with effective wind speeds of 65 to 85 miles per hour, to EF5 tornadoes with effective wind speeds of over 200 miles per hour. The Enhanced Fujita intensity scale is included in Table 5-6.

Table 5-6: Enhanced Fujita Tornado Rating

Fujita Number	Estimated Wind Speed	Path Width	Path Length	Description of Destruction
EF0 Gale	65-85 mph	6-17 yards	0.3-0.9 miles	Light damage, some damage to chimneys, branches broken, sign boards damaged, shallow-rooted trees blown over.
EF1 Moderate	86-110 mph	18-55 yards	1.0-3.1 miles	Moderate damage, roof surfaces peeled off, mobile homes pushed off foundations, attached garages damaged.
EF2 Significant	111-135 mph	56-175 yards	3.2-9.9 miles	Considerable damage, entire roofs torn from frame houses, mobile homes demolished, boxcars pushed over, large trees snapped or uprooted.

Fujita Number	Estimated Wind Speed	Path Width	Path Length	Description of Destruction
EF3 Severe	136-165 mph	176-566 yards	10-31 miles	Severe damage, walls torn from well-constructed houses, trains overturned, most trees in forests uprooted, heavy cars thrown about.
EF4 Devastating	166-200 mph	0.3-0.9 miles	32-99 miles	Complete damage, well-constructed houses leveled, structures with weak foundations blown off for some distance, large missiles generated.
EF5 Incredible	> 200 mph	1.0-3.1 miles	100-315 miles	Foundations swept clean, automobiles become missiles and thrown for 100 yards or more, steel-reinforced concrete structures badly damaged.

Source: http://www.srh.noaa.gov

Summary Vulnerability Assessment

Brown County ranked tornadoes as the number two hazard of concern. Tables 5-7 provides a summary of the estimated damages from the tornado model. To complete the analyses, The Polis Center and MU used a GIS overlay model to estimate damages for the hypothetical scenario. The results are presented in the following tables.

Table 5-7: Hypothetical EF4 Path through Brown County

Building Type	Number of Buildings	Estimated Losses
Residential	640	$8,992,000
Non-Residential	81	$1,633,000
Critical Facilities[5]	1	-
Totals	**722**	**$10,625,000**

Previous Occurrences for Tornado Hazard- 8 Years

The NCDC data included four days with a reported tornado event in Brown County between January 1, 2007 and December 31, 2014. Three tornadoes were EF1 and one tornado measured at EF0. Estimated property damage for the three events is $650,000. Table 5-8 lists the specifics of each tornado hazard event.

Table 5-8: Tornado Hazard Events – past 8 years[6]

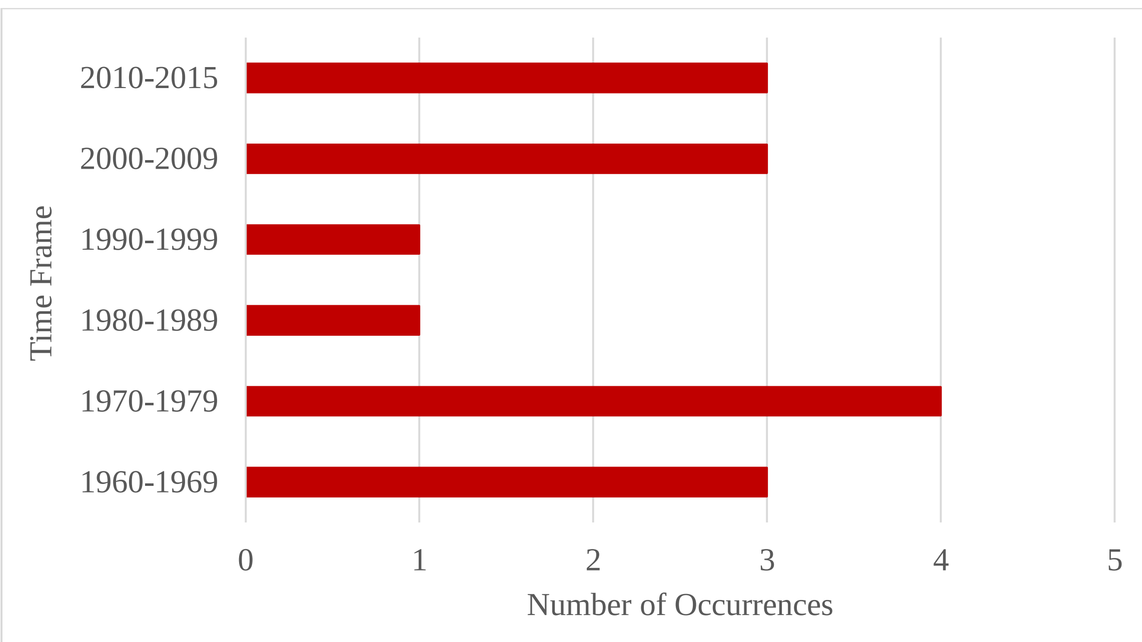
[5] Assessment records do not include values for critical facilities, therefore building losses are not calculated for these facilities.
[6] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

Date	Location	Enhanced Fujita Number	Estimated Losses ($)
4/26/2007	Macon	EF0	$50,000
6/27/2011	Georgetown/Brown Co. ARP	EF1	$90,000
3/2/2012	Maple	EF1	$500,000
5/21/2014	White Oak	EF1	$10,000
		Total	**$650,000**

Previous Occurrences for Tornado Hazard- 50 Year

There have been several occurrences of tornados within Brown County during the past few decades. The NCDC database reported 16 tornados/funnel clouds in Brown County since 1955. Figure 5-3 shows the number of tornado occurrences by decade. The most damaging tornado occurred on April 23, 1968 with an estimated $2.5 million in damages. A list of some of the most damaging tornadoes are detailed below.

Figure 5-3: Brown County Tornado Occurrences-50 Year



Lake Lorelei to Cowan Lake
F-4, April 23, 1968 1:20 pm
Fatalities: 1 Injuries: 5

This tornado first touched ground in the vicinity of Glen Este and then moved southeast at 40-45 miles per hour crossing US Route 50 east of Newtonsville and lifted about 3 miles east of Westboro. The tornado left a path of destruction that demolished five house and one house-trailer. The heaviest damage occurred across a mile or more of terrain paralleling State Route 131 east of Newtonsville. In this immediate area, 30 homes and 50 barns were totally destroyed. A 13-year old boy was killed when his home was completely demolished. More than 100 persons were left homeless. Injuries ranged from bruises to broken bones. The width of the funnel was 50-100yards in the Glen Este area, but the path width increased to nearly ¾ mile near Newtonsville. The Storm lifted after passing through the woods east of Westboro. Many people reported hail and a deafening "roar." This event resulted in $2.5 million in property damage.

Falmouth, Kentucky to Lucasville, Ohio
F-4, April 23, 1968 2:15 pm
Fatalities: 1 Injuries: 4

About 2:15 pm, a Dover, Kentucky resident reported he saw 3 funnel clouds. The main funnel apparently moved across the Ohio River between Levanna and Ripley, and moved up Chicken Hollow Road, three miles north of Ripley on US Route 42. However, inspection of the damage in Ripley itself revealed that a tornado also skipped through the town. A woman was killed and her son injured when the main twister disintegrated their trailer home on Chicken Hollow Road. The main tornado moved in an east northeast direction at about 50 miles per hour into Adams and Scioto Counties causing more destruction in its path. This event resulted in $2.5 million in property damage.

Ripley to Neel, Ohio
F-2, March 10, 1986 4:54 pm
Fatalities: 0 Injuries: 0

A tornado struck the east side of Ripley. The storm traveled northeast 6 miles and lifted off near Neel. Most damage was in Ripley, where 2 warehouses were destroyed. Also in Ripley, another warehouse, a restaurant and a high school were severely damaged. This event resulted in $2.5 million in property damage.

3 miles west of Mt. Orab
F-1, November 22, 1992 6:15 pm
Fatalities: 0 Injuries: 0

A tornado destroyed or heavily damaged three mobile homes and 10 outbuildings. This event also resulted in $2.5 million in property damage.

5 miles northwest of Mt. Orab
F-1, May 27, 2004 7:20 pm
Fatalities: 0 Injuries: 0

A tornado touched down along Five Mile Road. Several mobile homes and a well-built house sustained major damage. Numerous trees were uprooted and downed. This event also resulted in $100,000 in property damage.

Brown County Airport, 2 miles southeast of Georgetown
EF-1, June 27, 2011 5:44 pm
Fatalities: 0 Injuries: 0

A warm front lifting northward across the Ohio Valley combined with a moderate low-level shear during the afternoon and evening hours. This helped to produce scattered thunderstorms across south central Ohio. Some of these storms produced funnel clouds and tornadoes.

The tornado touched down north of the intersection of US Highway 68 and State Route 125. It moved east through several wooded areas where it snapped and uprooted numerous trees. The tornado then crossed State Route 125 near Township Highway 15 where it demolished four small barns. The tornado then lifted just before crossing County Highway 77. The maximum estimated wind speed based on damage was 90 miles per hour. This event also resulted in $90,000 in property damage.

Maple, Ohio
EF-1, March 2, 2012 4:58 pm
Fatalities: 0 Injuries: 0

Thunderstorms developed during the afternoon in a high-wind shear environment ahead of a strengthening low pressure system. Many of these storms became severe, with large hail, damaging thunderstorm winds, and tornadoes all being the main threats.

The tornado initially touched down in south central Campbell County, Kentucky at 4:39 northwest of Peach Grove. The tornado then crossed into Pendleton County at 4:41 pm after producing high-end EF3 damage near the Campbell and Pendleton County line. The tornado then moved across Mays Road producing significant and widespread EF2 to low-end EF3 damage. The tornado then crossed AA highway and eventually the Ohio River, after crossing Kentucky Highway 8. Based on the damage surveyed, the maximum wind speed of the tornado was estimated to be 160 miles per hour in Campbell County and 140 miles per hour in Pendleton County. The tornado then moved into Clermont County Ohio at 4:46 pm, where it hit the village of Moscow, causing EF3 damage, three fatalities and 13 injuries. The tornado continued on the ground across Clermont County, crossing into Brown County at 4:58 pm. The tornado then lifted south of Hamersville in western Brown County at 5:02 pm. This tornado caused extensive damage to structures and trees along its entire path on both sides of the Ohio River. Numerous homes were very heavily damaged or destroyed. Many homes lost their roofs, having complete exterior wall failure. Some modular homes were completely removed from their foundations, lifted, and thrown in excess of 100 yards where they were destroyed. The damage in Ohio from this tornado was consistent with maximum winds estimated at 160 miles per hour in Clermont

County, and 100 miles per hour in Brown County. The tornado traveled a total of 11.04 miles in Clermont County, and 2.69 miles in Brown County. This event also resulted in $500,000 in property damage in Brown County and $5,660,000 in property damage in Clermont County.

Geographic Location for Tornado Hazard

The entire county has the same risk for occurrence of tornadoes. They can occur at any location within the county.

Hazard Extent for Tornado Hazard

The historical tornadoes generally moved from southwest to northeast across the county. The extent of the hazard varies in terms of the extent of the path and the wind speed. Tornadoes can occur at any location within the county.

Risk Identification for Tornado Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
2	Tornado	1 in 10	Multi-jurisdictional	Predictable only moments before event, cannot predict location	Can only prepare to reduce human impact, cannot reduce economic impact	Total population in the area affected: shelter and/or evacuation or other protective measures required	75% damage and/or destroyed and business interruption

Brown County ranked tornado hazard as the number two priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 27% (16 tornadoes/59 years of record). This assumes same spatial and temporal patterns across all of Brown County.

Vulnerability Analysis for Tornado Hazard

Tornadoes can occur within any area in the county; therefore the entire county population and all buildings are vulnerable to tornadoes. To accommodate this risk, this plan will consider all buildings within the county as vulnerable.

Essential Facilities

All essential facilities are vulnerable to tornadoes. An essential facility will encounter many of the same impacts as any other building within the jurisdiction. These impacts will vary, based on the magnitude of the tornado, but can include structural failure, damaging debris (trees or limbs), roofs blown off or windows broken by hail or high winds, and loss of facility functionality (e.g., a damaged police station will no longer be able to serve the community).

Building Inventory

The same impacts to buildings within the county can be expected. The impacts are similar to those discussed for critical facilities and include structural failure, damaging debris (trees or limbs), roofs blown off or windows broken by hail or high winds, and loss of building function (e.g., damaged home will no longer be habitable causing residents to seek shelter).

Infrastructure

During a tornado, the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, bridges, and ports. Because the county's entire infrastructure is equally vulnerable, it is important to emphasize that any number of these structures could become damaged during a tornado. The impacts to these structures include broken, failed, or impassable roadways, broken or failed utility lines (e.g., loss of power or gas to community), and railway failure from broken or impassable railways. Bridges could fail or become impassable, causing risk to traffic. Ports could be closed causing delays to commerce.

GIS Tornado Analysis

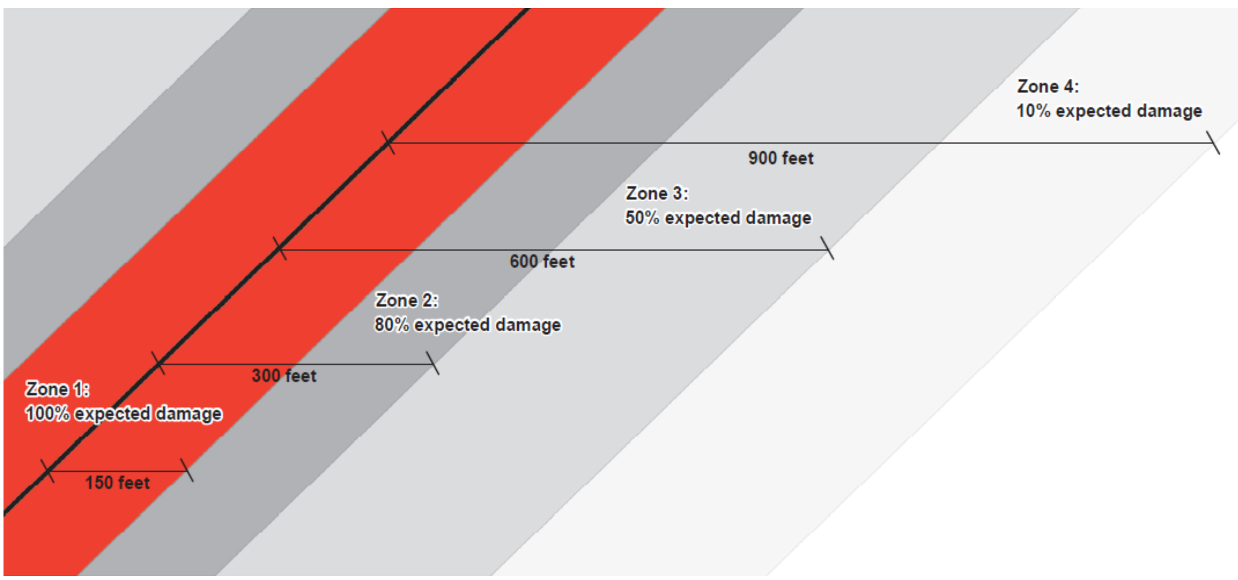
Analysts used GIS overlay analysis to estimated potential losses from an EF4 tornado with a northwest trajectory running 28.55 miles through Brown County. The selected widths were modeled after a recreation of the Fujita-Scale guidelines, based on conceptual wind speeds, path widths, and path lengths. There is no guarantee that every tornado will fit exactly into one of these six categories. Table 5-9 depicts tornado damage curves as well as path widths.

Table 5-9: Tornado Path Widths and Damage Curves

Enhanced Fujita Scale	Path Width (feet)	Maximum Expected Damage
EF5	2,400	100%
EF4	1,800	100%
EF3	1,200	80%
EF2	600	50%
EF1	300	10%
EF0	150	0%

Within any given tornado path there are degrees of damage. The most intense damage occurs within the center of the damage path with decreasing amounts of damage away from the center. After the hypothetical path is digitized on a map the process is modeled in GIS by adding buffers (damage zones) around the tornado path. Figure 5-4 and Table 5-9 describe the zone analysis. The selected historical tornado path is depicted in Figure 5-5, and the damage curve buffers are shown in Figure 5-4.

Figure 5-4: GIS Analysis Using Tornado Buffers



An F4 tornado has four damage zones. Total devastation is estimated within 150 feet of the tornado path (the darker-colored Zone 1). The outer buffer is 900 feet from the tornado path (the lightest colored Zone 4), within which 10% of the buildings will be damaged. The damage related to buffer zones is listed in Table 5-10.

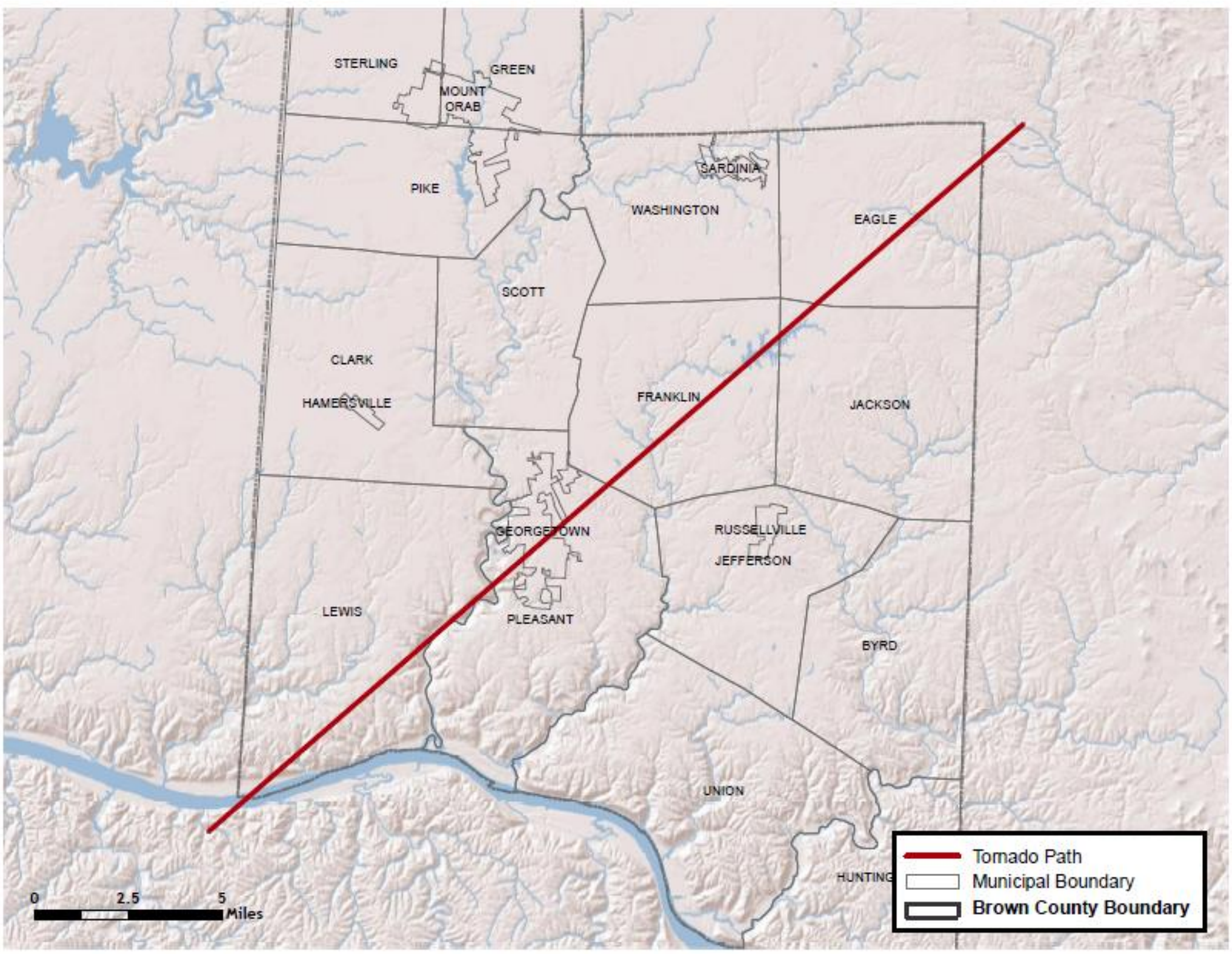
Table 5-10: Tornado Zones and Damage Curves

Fujita Scale	Zone	Buffer (feet)	Damage Curve
F-4	4	600-900	10%
F-4	3	300-600	50%
F-4	2	150-300	80%
F-4	1	0-150	100%

Fujita Scale	Zone	Buffer (feet)	Damage Curve

The selected tornado path is depicted in Figure 5-5, and the damage curve buffers are shown in Figure 5-5.

Figure 5-5: Hypothetical EF-4 Tornado Path in Brown County



The GIS analysis estimates that 722 buildings could be damaged. The estimated building losses are $10.6 million. The building losses are an estimate of building replacement costs multiplied by the percentages of damage. The overlay was performed against parcels that were joined with

Assessor records showing property replacement value. The losses and building counts are listed by Zone in Table 5-11 and Table 5-12, shown in Figure 5-6[7].

Table 5-11: Estimated Numbers of Buildings Damaged by Occupancy Type

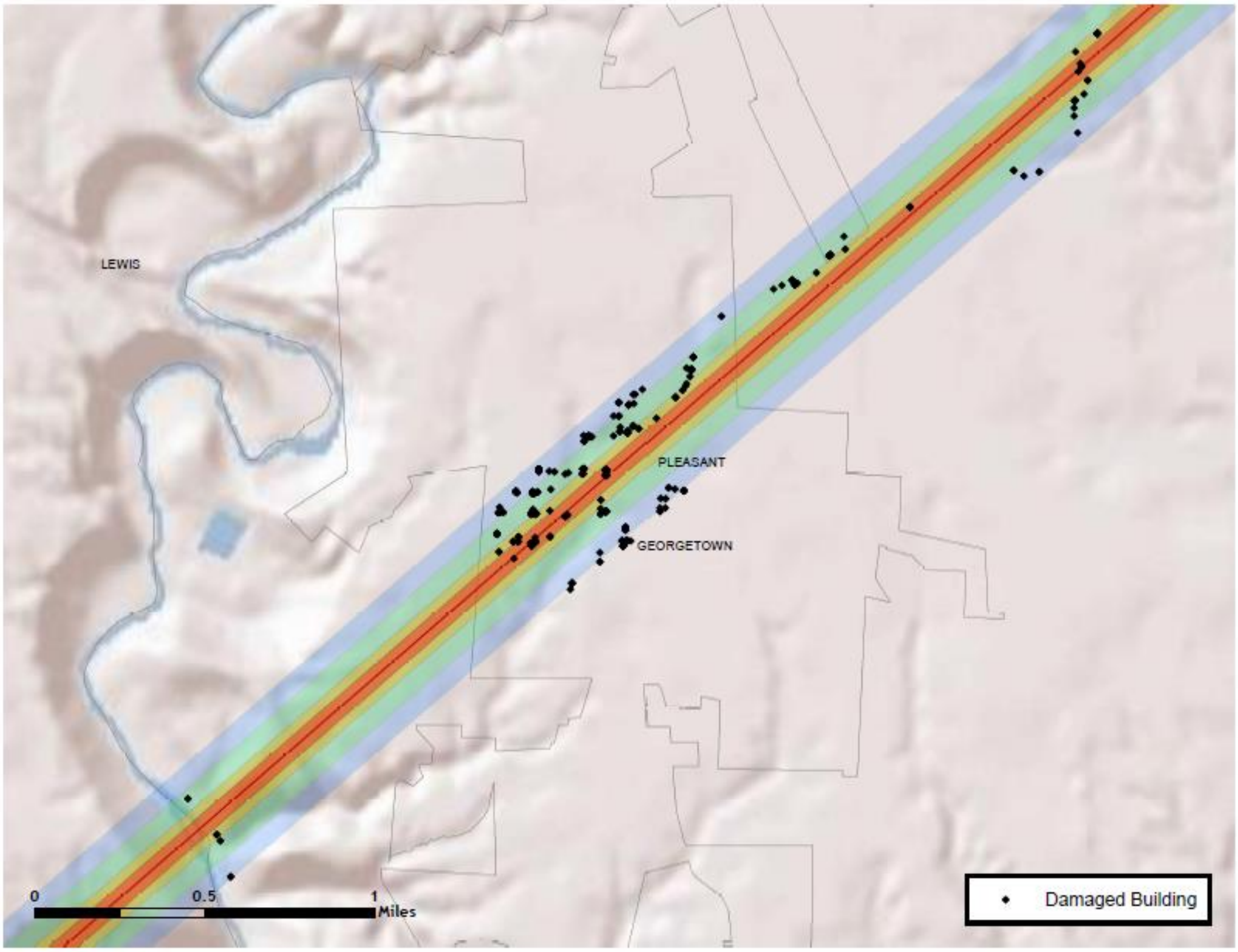
Occupancy	Zone 1	Zone 2	Zone 3	Zone 4
Residential	71	125	233	211
Commercial	1	1	3	7
Industrial	0	0	0	0
Agriculture	4	9	20	13
Religious	0	0	0	10
Government	0	0	0	11
Education	0	0	0	2
Total	**76**	**135**	**256**	**254**

Table 5-12: Estimated Building Losses by Occupancy Type

Occupancy	Zone 1	Zone 2	Zone 3	Zone 4
Residential	$1,187,000	$1,667,000	$3,171,000	$2,967,000
Commercial	$12,000	$41,000	$114,000	$61,000
Industrial	$0	$0	$0	$0
Agriculture	$44,000	$243,000	$384,000	$526,000
Religious	$0	$0	$0	$19,000
Government	$0	$0	$0	$180,000
Education	$0	$0	$0	$9,000
Total	**$1,243,000**	**$1,951,000**	**$3,669,000**	**$3,762,000**

[7] The Assessor records do not contain values for non-taxable properties, including government, non-profit, and education facilities. Therefore, building losses may be under represented.

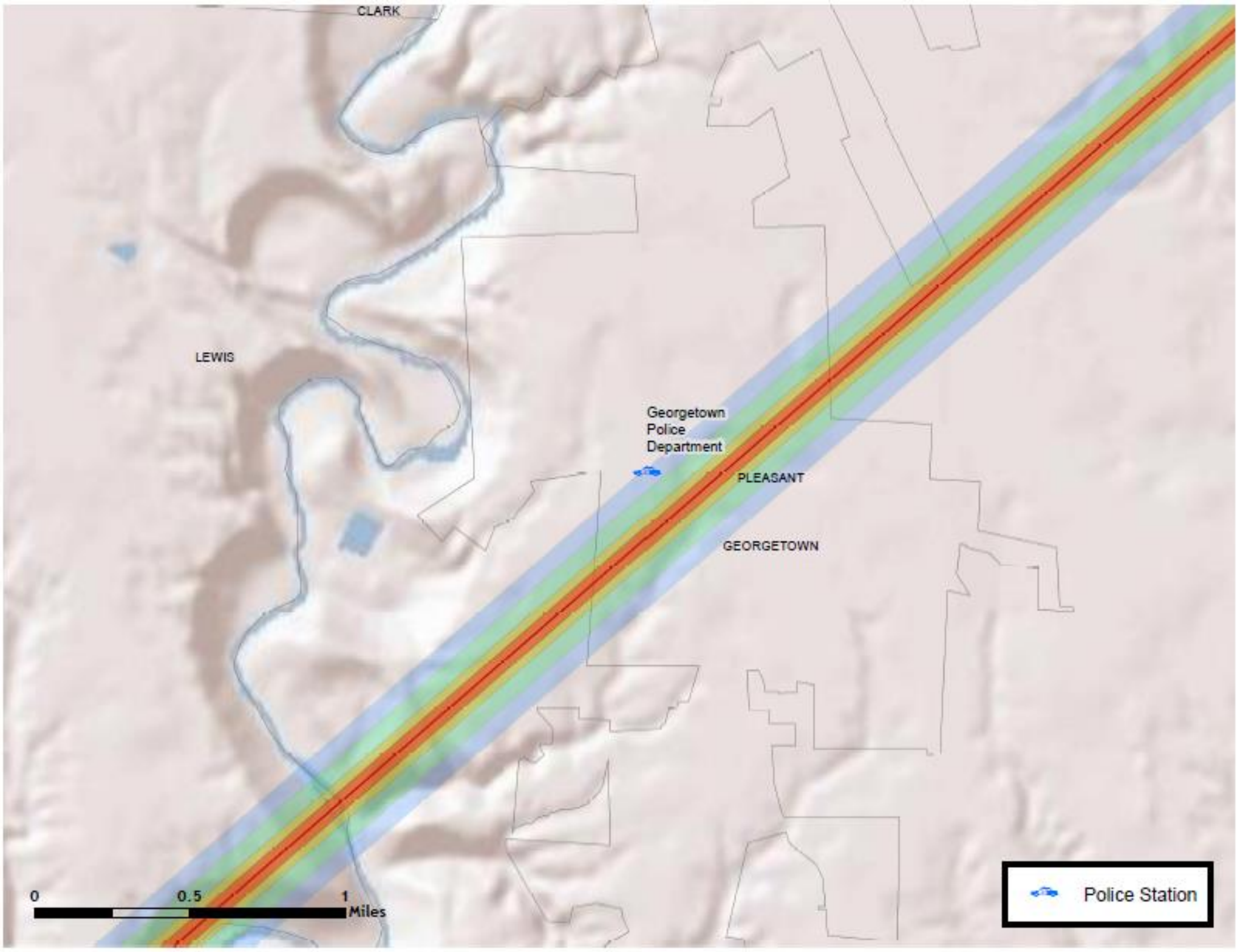
Figure 5-6: Vulnerable Facilities within EF4 Tornado Path in Georgetown



Essential and Critical Facilities Damage

The Georgetown Police Department is the only essential and/or critical facilities located within 900 feet of the hypothetical tornado path, see Figure 5-7.

Figure 5-7: Damaged Critical Facility Locations - Georgetown



5.3.2 Flood Hazard

Flooding is a significant natural hazard throughout the United States. The type, magnitude, and severity of flooding are functions of the amount and distribution of precipitation over a given area, the rate at which precipitation infiltrates the ground, the geometry of the catchment, and flow dynamics and conditions in and along the river channel. Floods can be classified as one of two types: upstream floods or downstream floods. Both types of floods are common in Ohio.

Upstream floods, also called flash floods, generally occur in the upper parts of drainage basins and are generally characterized by periods of intense rainfall over a short duration. These floods arise with very little warning and often result in locally intense damage, and sometimes loss of life, due to the high energy of the flowing water. Flood waters can snap trees, topple buildings, and easily move large boulders or other structures. Six inches of rushing water can upend a person; another 18 inches might carry off a car. Generally, upstream floods cause damage over relatively localized areas, but they can be quite severe in the areas in which they occur. Urban flooding is a type of upstream flood. Urban flooding involves the overflow of storm drain systems and can be the result of inadequate drainage combined with heavy rainfall or rapid snowmelt. Upstream or flash floods can occur at any time of the year in Ohio, but they are most common in the spring and summer months.

Downstream floods, sometimes called riverine floods, refer to floods on large rivers at locations with large upstream catchments. Downstream floods are typically associated with precipitation events that are of relatively long duration and occur over large areas. Flooding on small tributary streams may be limited, but the contribution of increased runoff may result in a large flood downstream. The lag time between precipitation and time of the flood peak is much longer for downstream floods than for upstream floods, generally providing ample warning for people to move to safe locations and, to some extent, secure some property against damage. Riverine flooding on the large rivers of Ohio generally occurs during either the spring or summer.

The National Weather Service (NWS) will define stages of downstream flooding for the purpose of warning the public of different flood stages. These stages include minor flooding, moderate flooding, major flooding, and record flooding. Table 5-13 lists the types of flooding and their descriptions.

Table 5-13: National Weather Service (NWS) flooding definitions

Minor Flooding	Moderate Flooding	Major Flooding	Record Flooding
Minimal or no property damage, but possibly some public threat.	Some inundation of structures and roads near stream. Some evacuations of people and/or transfer of property to higher elevations.	Extensive inundation of structures and roads. Significant evacuations of people and/or transfer of property to higher elevations.	Flooding which equals or exceeds the highest stage or discharge at a given site during the period of record keeping.

Summary Vulnerability Assessment

Brown County ranked flooding as the number one hazard of concern. Tables 5-13 provides a summary of the estimated damages from the Hazus-MH flood model. The results are presented in Table 5-14.

Table 5-14: Hazus-MH Flood Analysis

Building Type	Number of Buildings	Estimated Losses
Residential	370	$8,437,000
Non-Residential	71	$4,360,000
Critical Facilities[8]	8	-
Totals	**449**	**$12,797,000**

Previous Occurrences for Flooding- 8 Years

The NCDC data included 18 recorded occurrences of flooding (not flash floods) in Brown County since 1996 with over $2.5 million in damages. NCDC detailed records on flooding were not kept prior to 1993. The worst flood recorded was in March 1997 with estimated property damage over $2 million. The 1997 flood in southern Ohio affected eighteen counties with damages approaching $180 million. In southern Ohio, nearly 20,000 persons were evacuated with five casualties[9]. One of the most recent damaging events occurred in May 2012 when flash flooding from heavy rain affected Georgetown and Ripley totaling $20,000. Table 5-15 lists the specifics of each flood hazard event and a summary illustrated in Figure 5-8.

Table 5-15: Brown County Floods & Flash Floods[10]

Date	Type	Location	Property Damage
1/17/1996	Flood		$10,000
1/23/1996	Flood		$500,000
5/4/1996	Flash Flood	Brown Co.	$4,000
5/15/1996	Flash Flood	Brown Co.	$5,000
3/1/1997	Flash Flood	Brown Co.	$2,000,000
3/2/1997	Flood		$2,000,000
5/31/1997	Flash Flood	Brown Co.	$10,000

[8] Assessment records do not include values for critical facilities, therefore building losses are not calculated for these facilities.

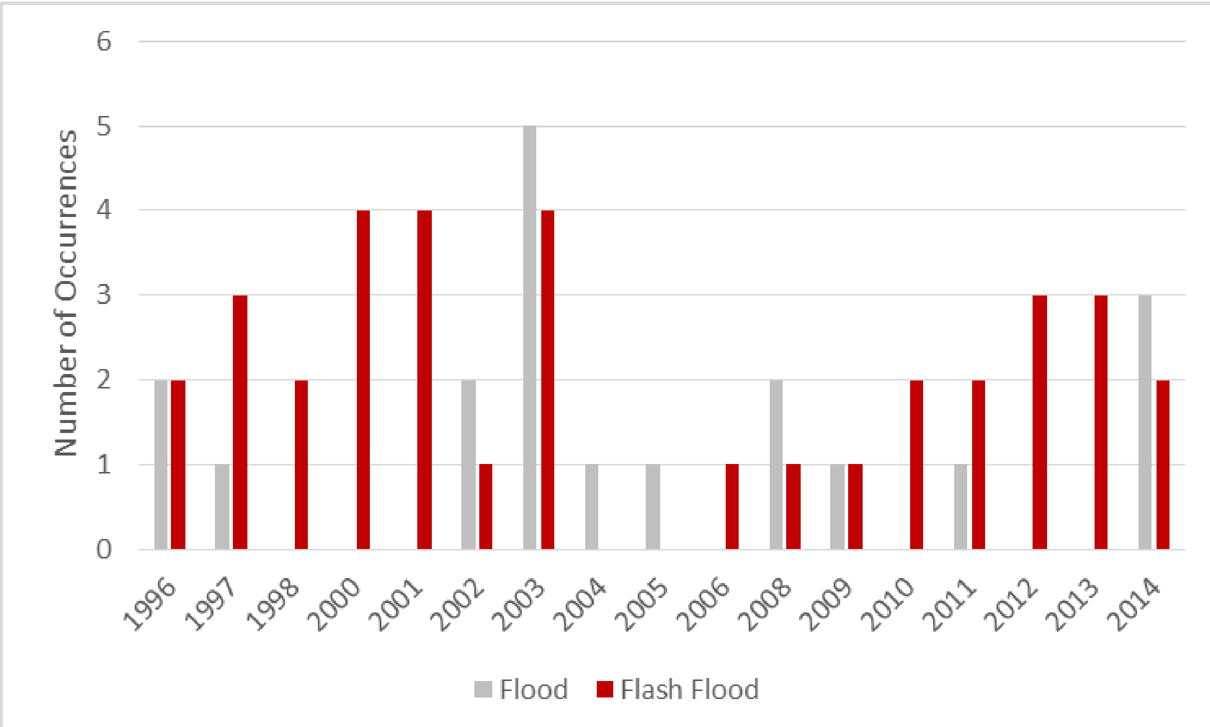
[9] Jackson, K.S. and S.A. Vivian. (1997) Flood of March 1997 in Southern Ohio. US. Geological Survey, Water-Resources Investigations Report 97-4149.

[10] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

Date	Type	Location	Property Damage
6/1/1997	Flash Flood	Brown Co.	$5,000
6/10/1998	Flash Flood	HAMERSVILLE	$5,000
6/11/1998	Flash Flood	Brown Co.	$5,000
1/3/2000	Flash Flood	Brown Co.	$5,000
2/18/2000	Flash Flood	Brown Co.	$25,000
8/9/2000	Flash Flood	Brown Co.	$5,000
12/16/2000	Flash Flood	Brown Co.	$100,000
5/18/2001	Flash Flood	Brown Co.	$5,000
7/17/2001	Flash Flood	Brown Co.	$586,000
7/22/2001	Flash Flood	MT ORAB	0
7/25/2001	Flash Flood	Fayetteville	0
1/24/2002	Flash Flood	Ripley	0
4/19/2002	Flood		0
4/28/2002	Flood		0
5/10/2003	Flood		0
5/10/2003	Flash Flood	Brown Co.	0
5/10/2003	Flash Flood	North Portion	0
5/10/2003	Flash Flood	Brown Co.	0
6/14/2003	Flash Flood	Fayetteville	0
7/10/2003	Flood		0
7/31/2003	Flood		0
8/4/2003	Flood		0
8/9/2003	Flood		0
7/31/2004	Flood		0
7/16/2005	Flood		0
7/13/2006	Flash Flood	Feesburg	0
3/4/2008	Flood	Aberdeen	$5,000
3/19/2008	Flood	Hamersville	$10,000
6/4/2008	Flash Flood	Ripley	$10,000
9/21/2009	Flash Flood	Georgetown/Brown Co.	$2,000
9/21/2009	Flood	Ripley	$1,000
5/2/2010	Flash Flood	Georgetown	$5,000
6/2/2010	Flash Flood	Mt Orab	$2,000
4/23/2011	Flash Flood	Sardinia	$2,000
6/21/2011	Flash Flood	Hamersville	$1,000
12/5/2011	Flood	Neel	$1,000
5/21/2012	Flash Flood	Georgetown	$10,000
5/21/2012	Flash Flood	Ripley	$10,000
7/23/2013	Flash Flood	North Stringtown	$1,000
7/23/2013	Flash Flood	Crosstown	$1,000
7/23/2013	Flash Flood	Centerville	$1,000
4/4/2014	Flash Flood	Neel	$1,000
4/29/2014	Flood	Georgetown	0

Date	Type	Location	Property Damage
6/19/2014	Flood	Brownstown	$1,000
6/20/2014	Flash Flood	Five pts	$1,000
		Total	**$75,000**

Figure 5-8: Brown County Floods since 2007



Repetitive Loss Properties

FEMA defines a repetitive loss structure as a structure covered by a contract of flood insurance issued under the NFIP, which has suffered flood loss damage on two occasions during a 10-year period that ends on the date of the second loss, in which the cost to repair the flood damage is 25% of the market Value of the structure at the time of each flood loss.

Table 5-16 lists repetitive loss data in detail. There are no severe repetitive loss (SRL) in Brown County.

In summary:

Total residential repetitive loss payments: $80,144

Total non-residential repetitive loss payments: $9,197

Table 5-16: Brown County Repetitive Losses

Community	Structure Type	Properties	Losses	Building Pmts	Contents Pmts	Total Pmts

Community	Structure Type	Properties	Losses	Building Pmts	Contents Pmts	Total Pmts
Brown County	Residential	2	6	$61,511.16	-	$61,511.16
	Non-Residential	0	0	-	-	-
Aberdeen	Residential	1	2	$16,468.56	$2,164.00	$18,632.56
	Non-Residential	0	0	-	-	-
Georgetown	Residential	0	0	$8,484.94	$712.40	$9,197.34
	Non-Residential	1	2	-	-	-

Geographic Location for Flooding

Most river flooding occurs in the spring and is the result of excessive rainfall and/or the combination of rainfall and snowmelt. Severe thunderstorms may cause flooding during the summer or fall, but tend to be localized.

Flash floods, brief heavy flows in small streams or normally dry creek beds, also occur within the county. Flash flooding is typically characterized by high-velocity water, often carrying large amounts of debris. Urban flooding involves the overflow of storm drain systems and is typically the result of inadequate drainage following heavy rainfall or rapid snowmelt.

Hazard Extent for Flooding

The Hazus-MH flood model is designed to generate a flood depth grid and flood boundary polygon by deriving hydrologic and hydraulic information based on user-provided elevation data or by incorporating selected output from other flood models. Hazus-MH also has the ability to clip a Digital Elevation Model (DEM) with a user-provided flood boundary, thus creating a flood depth grid. For Brown County, Hazus-MH was used to extract flood depth by clipping the DEM with the Digital Flood Insurance Rate Map (DFIRM) Base Flood Elevation (BFE) boundary. The BFE is defined as the area that has a 1% chance of flooding in any given year.

Risk Identification for Flood Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
1	Flooding	1+/year	Multi-jurisdictional	Can predict hours ahead, location can be predicted	Can prepare with additional resources to reduce human and economic impact	Shelter and/or evacuation or other protective measures required for 75% of the population involved	75% damage and/or destroyed and business interruption

Brown County ranked flood hazard as the number one priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 86% (18 floods/21 years of record) and 100% (34 flash floods/21 years of record). This assumes same spatial and temporal patterns across all of Brown County, which we know for flooding, is concentrated on floodplains or low-lying lands across the County.

Hazus-MH Analysis: 100-Year Flood Boundary and County Parcels

Hazus-MH estimates the 1% (100-year) flood across the entire county would damage 441 buildings at a replacement cost of $12.8 million. The total estimated numbers of damaged buildings are given in Table 5-27. Ripley community sustained the most damage with 212 buildings damaged at a replacement cost of $7.4 million. The total buildings damaged in Aberdeen community were 105 with a replacement cost shy of $1.2 million. The total estimated numbers and cost of damaged buildings by community are given in Tables 5-17 and 5-18[11]. Figure 5-9 depicts the Brown County parcel points that fall within the 1%-annual-chance flood risk area (i.e. 100-year floodplain). Figures 5-10 through 5-12 highlight damaged buildings within the floodplain areas in each flood-prone jurisdiction.

Table 5-17: Number of buildings incurring damage

Building Type	Aberdeen	Higginsport	Ripley	Unincorp	Total
Agriculture	2	0	7	19	28
Commercial	9	1	19	2	31
Education	0	0	2	0	2
Government	0	0	10	0	10
Industrial	0	0	0	0	0
Religious	0	0	0	0	0
Residential	94	16	174	86	370
Total	**105**	**17**	**212**	**107**	**441**

[11] The Assessor records do not contain values for non-taxable properties, including government, non-profit, and education facilities. Therefore, building losses may be under represented.

Table 5-18: Potential flood-related losses

Building Type	Aberdeen	Higginsport	Ripley	Unincorp	Total
Agriculture	$17,000	$0	$308,000	$571,000	$896,000
Commercial	$184,000	$89,000	$1,201,000	$157,000	$1,631,000
Education	$0	$0	$1,168,000	$0	$1,168,000
Government	$0	$0	$665,000	$0	$665,000
Industrial	$0	$0	$0	$0	$0
Religious	$0	$0	$0	$0	$0
Residential	$1,164,000	$406,000	$4,090,000	$2,327,000	$8,437,000
Total	**$1,185,000**	**$495,000**	**$7,432,000**	**$3,055,000**	**$12,797,000**

Figure 5-9: Brown County Buildings in 100-Year Floodplain

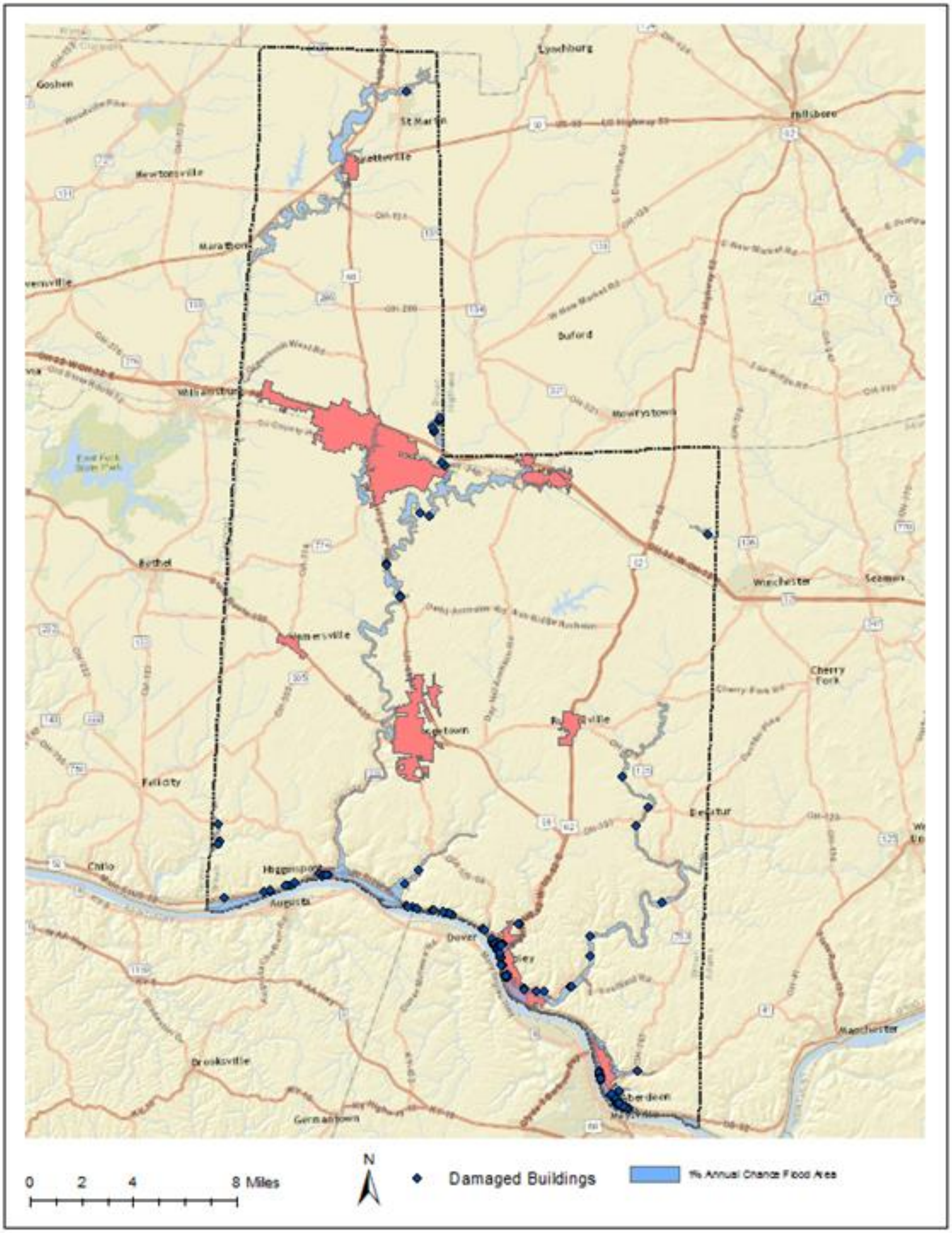


Figure 5-10: Aberdeen Buildings in 100-Year Floodplain

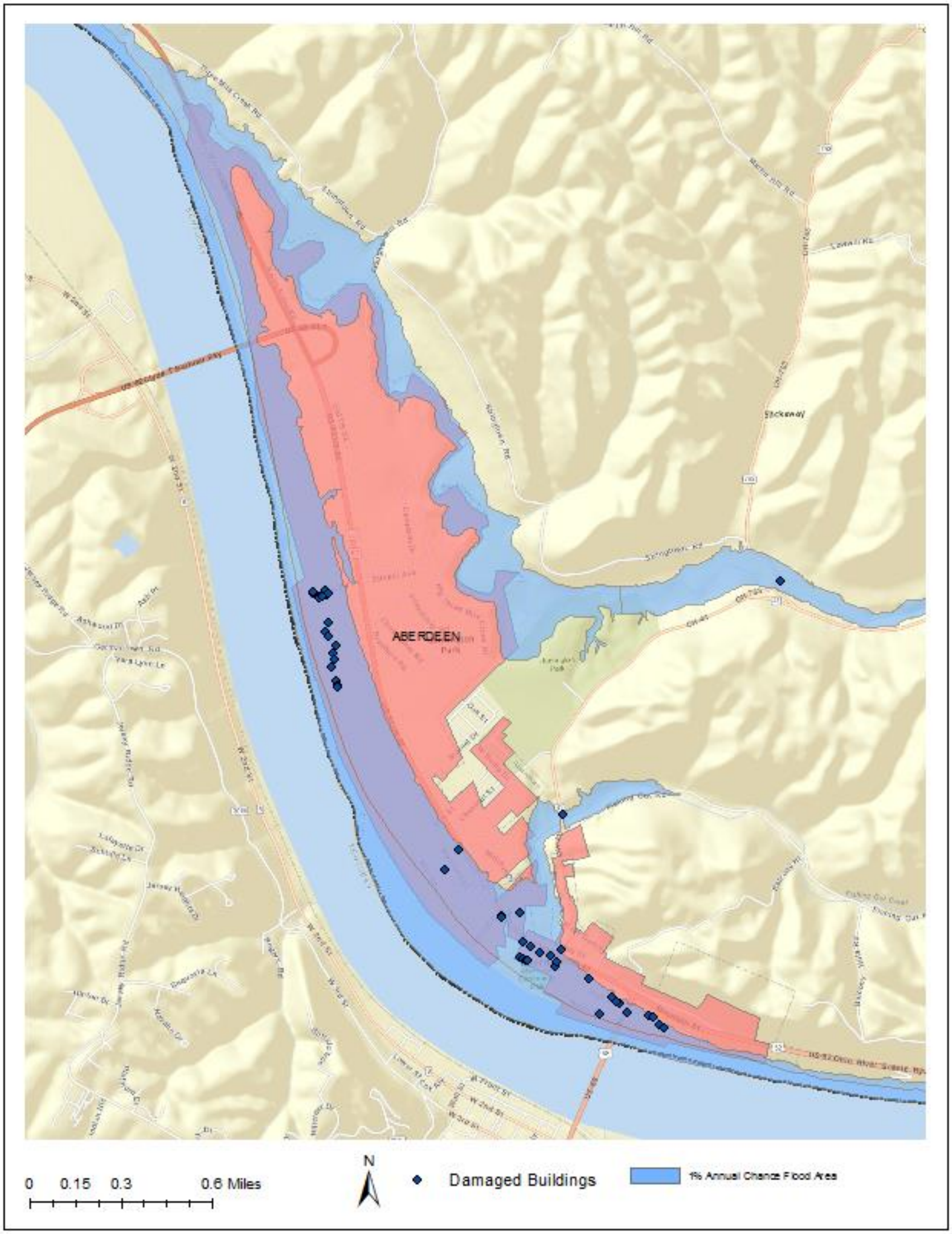


Figure 5-11: Higginsport Buildings in 100-Year Floodplain

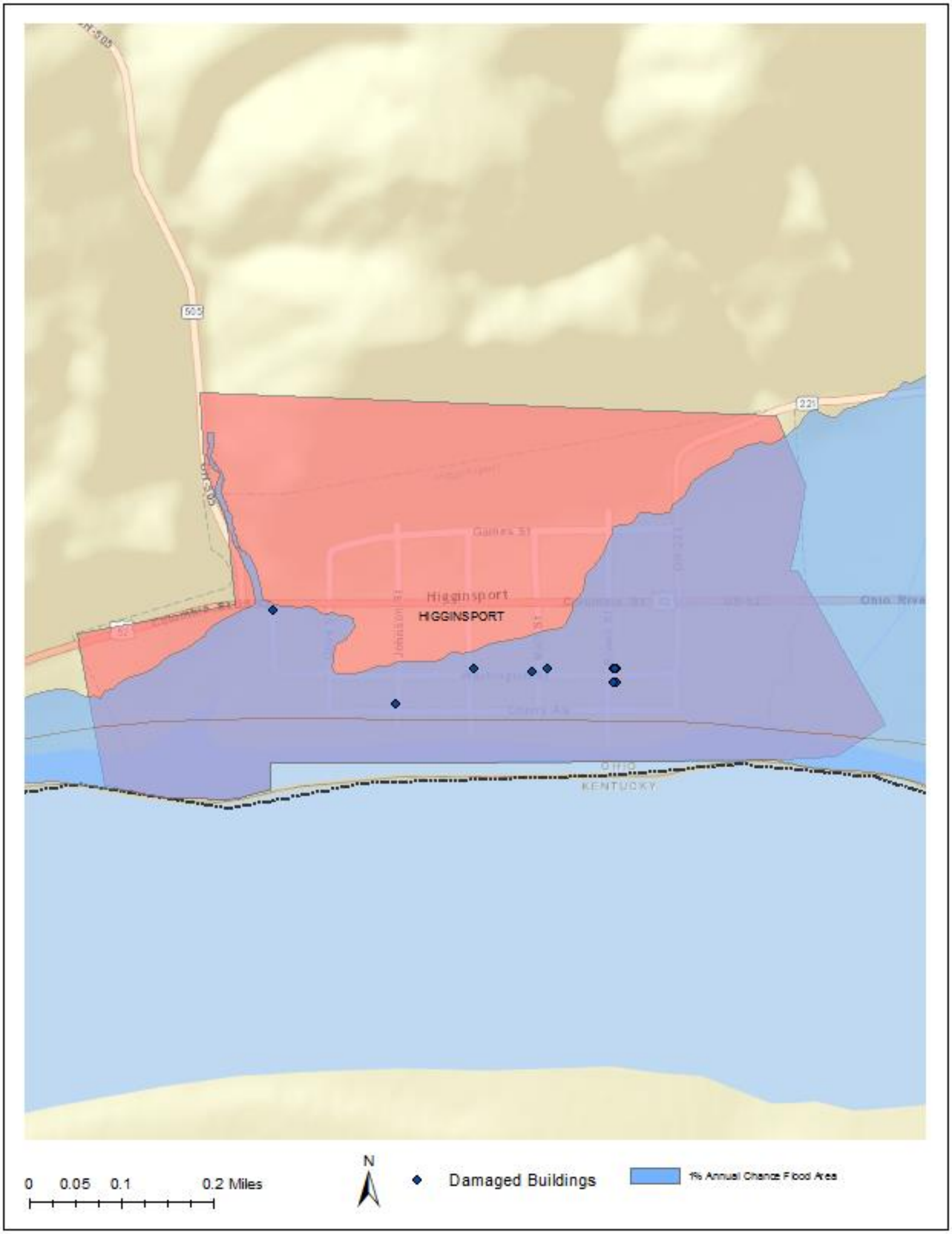
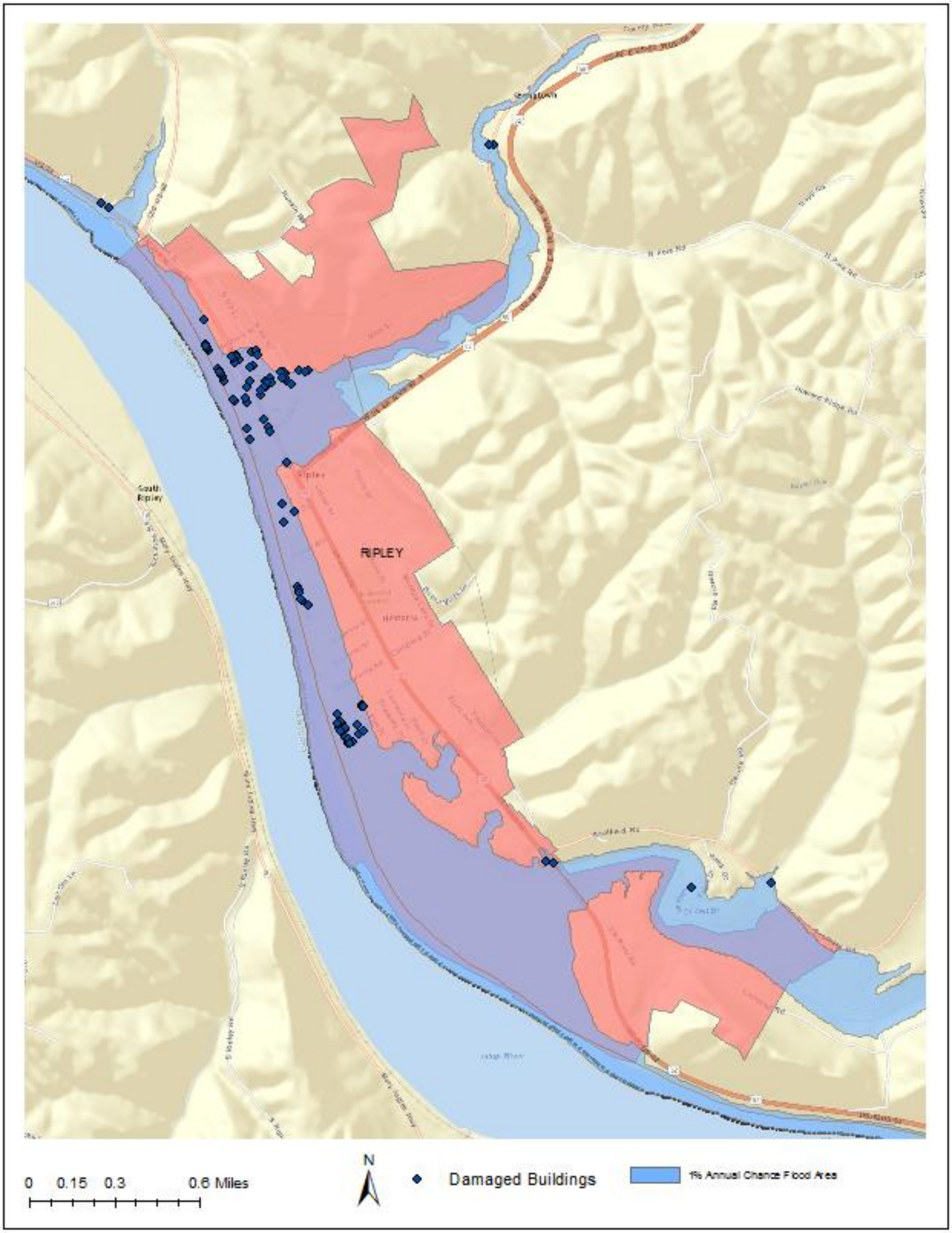


Figure 5-12: Ripley Buildings in 100-Year Floodplain



Essential and Critical Facility Losses

An essential facility will encounter many of the same impacts as other buildings within the flood boundary. These impacts can include structural failure, extensive water damage to the facility and loss of facility functionality (e.g. a damaged police station will no longer be able to serve the community).

The results of the overlay analysis indicate that six essential and critical facilities in Brown County could sustain damage. Table 5-19 lists these facilities.

Table 5-19: Essential and Critical Facilities in the 1%-annual chance flood zone

Facility Type	Facility Name
Fire Station	Higginsport Voluntary Fire Department
Police Station	Aberdeen Police Department
Schools	Ripley-Union-Lewis-Huntington High School
Waste Water Facilities	Village of Aberdeen
	Ripley STP
	Village of Mt. Orab

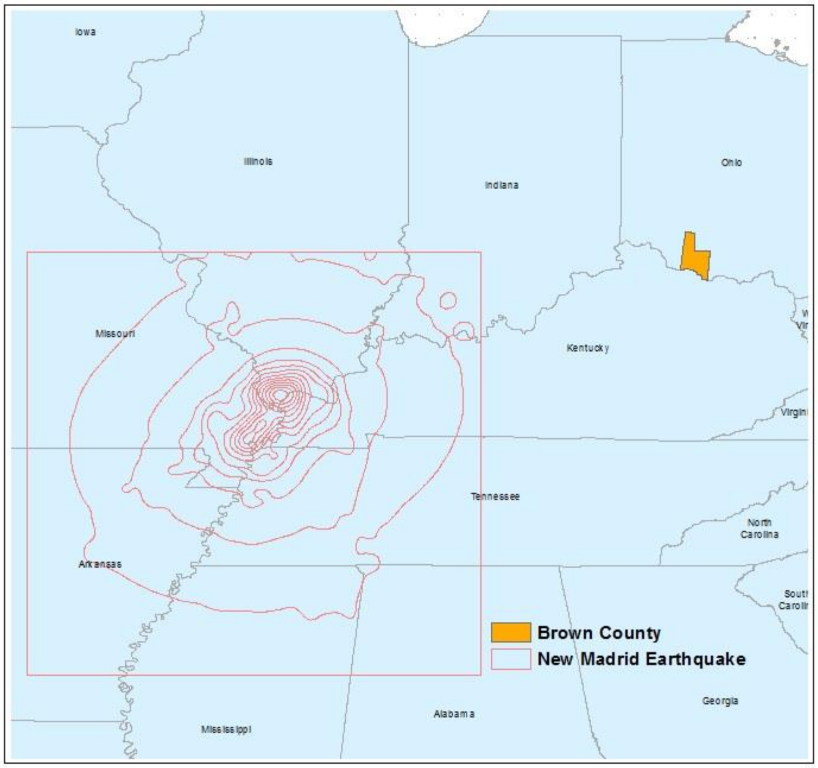
5.3.3 Earthquake Hazard

An earthquake is a sudden, rapid shaking of the earth caused by the breaking and shifting of rock beneath the earth's surface. For hundreds of millions of years, the forces of plate tectonics have shaped Earth as the huge plates that form the Earth's surface move slowly over, under, and past each other. Sometimes the movement is gradual. At other times, the plates are locked together, unable to release the accumulating energy. When the accumulated energy grows strong enough, the plates break free, causing the ground to shake.

Most earthquakes occur at the boundaries where the plates meet; however, some earthquakes occur in the middle of plates, as is the case for seismic zones in the Midwestern United States. The most

In 1811-1812 the NMSZ experienced a series of earthquakes ranging from 7-over 8 magnitude. The immediate area experienced the greatest amount of damage, but records indicate that the spires at Churchill Downs in Louisville, Kentucky were damaged and the Liberty Bell in Philadelphia rang when the earthquakes struck. However, it is difficult for science to estimate damages beyond the known seismic zone seismically active area in the Midwest is referred to as the New Madrid Seismic Zone (NMSZ). However, this zone is not of particular concern to Ohio (see Figure 5-13). However, in 1811-1812 the NMSZ experienced a series of earthquakes ranging from 7- over 8 magnitude. The immediate area experienced the greatest amount of damage, but records indicate that the spires at Churchill Downs in Louisville, Kentucky were damaged and the Liberty Bell in Philadelphia rang when the earthquakes struck. However, it is difficult for science to estimate damages beyond the known seismic zone seen in Figure 5-13.

Figure 5-13: New Madrid Zone



Ground shaking from strong earthquakes can collapse buildings and bridges; disrupt gas, electric, and phone service; and sometimes trigger landslides, avalanches, flash floods, fires, and huge destructive ocean waves (tsunamis). Buildings with foundations resting on unconsolidated landfill and other unstable soil, and trailers or homes not tied to their foundations are at risk because they can be shaken off their mountings during an earthquake. When an earthquake occurs in a populated area, it may cause deaths, injuries, and extensive property damage.

The possibility of the occurrence of a catastrophic earthquake in the central and eastern United States is real, as evidenced by history and described throughout this section. The impacts of significant earthquakes affect large areas, terminating public services and systems needed to aid the suffering and displaced. These impaired systems are interrelated in the hardest struck zones. Power lines, water and sanitary lines, and public communication may be lost; and highways, railways, rivers, and ports may not allow transportation to the affected region. Furthermore, essential facilities, such as fire and police departments and hospitals, may be disrupted if not previously improved to resist earthquakes.

As with hurricanes, mass relocation may be necessary, but the residents who are suffering from the earthquake can neither leave the heavily impacted areas nor receive aid or even communication in the aftermath of a significant event.

Magnitude, which is determined from measurements on seismographs, measures the energy released at the source of the earthquake. Intensity measures the strength of shaking produced by the earthquake at a certain location and is determined from effects on people, human structures, and the natural environment. Tables 5-20 and 5-21 define earthquake magnitudes and their corresponding intensities.

http://earthquake.usgs.gov/learning/topics/mag_vs_int.php

Table 5-20: Abbreviated Modified Mercalli Intensity Scale

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

Table 5-21: Earthquake Magnitude vs. Modified Mercalli Intensity Scale

Earthquake Magnitude	Typical Maximum Modified Mercalli Intensity
1.0-3.0	I
3.0-3.9	II-III
4.0-4.9	IV-V
5.0-5.9	VI-VII
6.0-6.9	VII-IX

Summary Vulnerability Assessment

Brown County ranked earthquakes as the number eleven hazard of concern. Tables 5-22 provides a summary of the estimated damages from the Hazus-MH earthquake model. The results are presented in the following table.

Table 5-22: Hazus-MH Earthquake Analysis for 500-Year Probabilistic

Building Type	Building Loss ($)	Total Economic Loss ($)
Residential	$237,000	$312,000
Non-Residential	$80,000	$177,000
Totals	**$317,000**	**$489,000**

Previous Occurrences for Earthquake Hazards

At least 200 earthquakes, 2.0M and greater, have occurred in Ohio for which reasonably accurate records exist. The last earthquake in Ohio causing physical impact—as of the date of this report—was on December 31, 2011, centered on Youngstown and measured 4.0 in magnitude. Approximately 4,700 individuals submitted felt reports to the United States Geological Survey (USGS) and minor damage occurred in the form of cracked plaster on buildings and glassware falling off shelves. This was the eleventh earthquake in a sequence that began at Youngstown on March 17, 2011. According to the Ohio Department of Natural Resources (DNR), the series of quakes resulted from hydraulic injection of gas-drilling wastewater into the earth.

The most recent naturally occurring earthquake in Ohio took in northwest Ohio on April 12, 2015 measuring 2.3 in magnitude. USGS received four felt reports, but there was no physical damage.

The most damaging earthquake in Ohio occurred on March 8, 1937 in western Ohio near the town of Anna and measured 5.4 in magnitude. This occurred in the same location as an earthquake on March 2, 1937, and was the stronger of the two. In Anna—where most of the damage occurred—chimneys toppled, foundations and plaster cracked, water wells were disturbed, and cemetery monuments were rotated. The earthquake caused building damage as far away as Fort Wayne, Indiana and was reportedly felt in Indiana, Illinois, Kentucky, Michigan, Missouri, West Virginia, Pennsylvania, and Southern Canada.

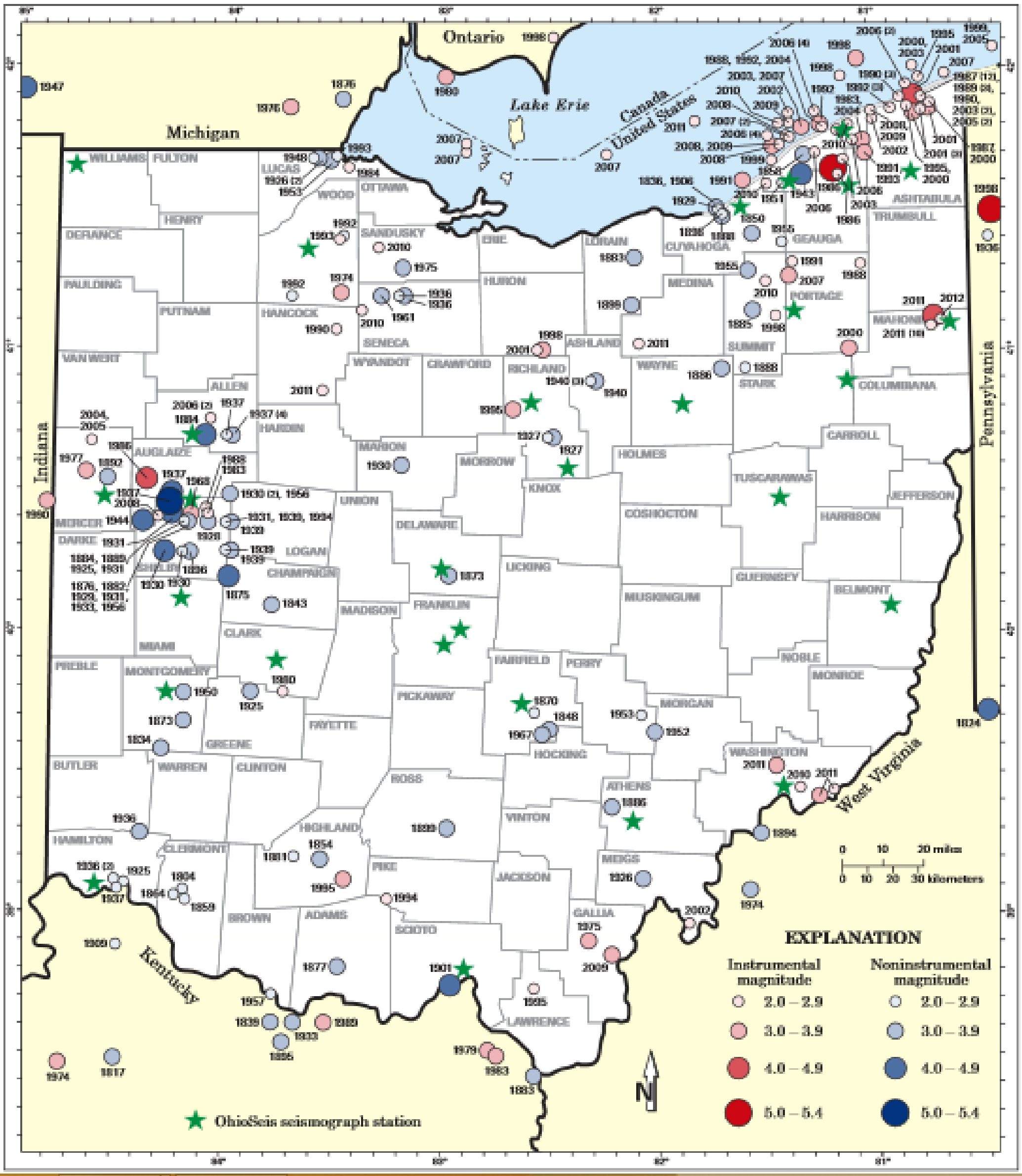
The most recent earthquake which impacted the state from outside the boundary region occurred on August 23, 2011 when a magnitude 5.8 earthquake in Virginia was felt across most of Ohio. There was reported damages in the epicenter region; however, none were identified in Ohio. Additionally, a set of 4.5 magnitude twin shocks occurring 12 seconds apart on December 9, 2003 in central Virginia were felt as far away as Marietta, though little physical damage was reported.

The most recent earthquake felt by Brown County was through a series of quakes, the last one on July 23, 2013. The epicenter was in northern Kentucky but was felt in Ripley, Ohio and other Kentucky communities. Residents reported a sharp, brief shaking and a loud booming sound.

Check out Ohio earthquake histories Ohio Division of Geological Survey website: http://geosurvey.ohiodnr.gov/.

According to the Ohio Department of Natural Resources, there are no earthquakes with an epicenter in Brown County. However, there is a history of earthquakes in the surrounding region around the county. The most recent earthquake felt by Brown County was through a series of quakes, the last one on July 23, 2013. The epicenter was in northern Kentucky but was felt in Ripley, Ohio and other Kentucky communities. Residents reported a sharp, brief shaking and a loud booming sound. Earthquake histories for this area exist in 1834, 1895, 1933, and 1957. See Figure 5-14, this map is updated as of 2012 showing all earthquakes felt with a magnitude 2.0 or greater.

Figure 5-14: Earthquake History in Ohio



(The above history was abridged from Earthquakes in Ohio, Educational Leaflet No. 9, Revised Edition 2012 and from http://www.dnr.state.oh.us/geosurvey/html/eqcat03/tabid/8298/Default.aspx)

Geographic Location for Earthquake Hazard

Ohio earthquakes are shallow-focus events, occurring in the upper portion of the crust at depths of about 3 to 6 miles, in crystalline rocks of Precambrian age. According the Ohio Division of Geological Survey, three areas of Ohio appear to be particularly susceptible to earthquake activity: Shelby County and surrounding counties in the west; Lake County and offshore in Lake Erie in the northeast, and; Meigs and Portsmouth Counties in the south.

Hazard Extent for Earthquake Hazard

The extent of an earthquake is countywide. One of the most critical sources of information that is required for accurate assessment of earthquake risk is soils data. Soils along rivers and other bodies of water have higher water tables and higher sand content. As a result, these areas are more susceptible to liquefaction and land shaking. Liquefaction is a phenomenon in which the strength and stiffness of a soil is reduced by earthquake shaking as a result of water filling the space between individual soil particles. This can cause buildings to tilt or sink into the ground, slope failures, lateral spreading, surface subsidence, ground cracking, and sand blows.

Risk Identification for Earthquake Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
11	Earthquake	>100 years	Entire county	Cannot predict	Can only prepare to reduce human impact, cannot reduce economic impact	Minimal, in-place protective measures required	10% damage and/or destroyed and business interruption

Brown County ranked earthquake hazard as the number eleven priority hazard based on the infrequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring is extremely low (mathematically would be 0 as there is no history of earthquakes). However, Brown County needs to be prepared to the uncertainty that surrounds the nature of earthquakes.

Vulnerability Analysis for Earthquake Hazard

This hazard may impact the entire jurisdiction; therefore the entire county's population and all buildings are vulnerable to an earthquake and can expect the same impacts within the affected area. To accommodate this risk, this plan will consider all buildings within the county as vulnerable.

Facilities

All critical facilities are vulnerable to earthquakes. A critical facility would encounter many of the same impacts as any other building within the county. These impacts include structural failure and loss of facility functionality (e.g., a damaged police station will no longer be able to serve the community). Names and locations of essential and critical facilities, as well as community assets, are in Appendix E.

Building Inventory

Impacts similar to those discussed for critical facilities can be expected for the buildings within the county. These impacts include structural failure and loss of building function that could result in indirect impacts (e.g., damaged homes will no longer be habitable, causing residents to seek shelter).

Infrastructure

During an earthquake, the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, and bridges. Because an extensive inventory of the infrastructure is not available to this plan, it is important to emphasize that any number of these structures could become damaged in the event of an earthquake. The impacts to these structures include broken, failed, or impassable roadways; broken or failed utility lines (e.g., loss of power or gas to community); and railway failure from broken or impassable railways. Bridges also could fail or become impassable, causing traffic risks. Typical scenarios are described to gauge the anticipated impacts of earthquakes in the county in terms of numbers and types of buildings and infrastructure.

Hazus-MH Earthquake Analysis

The Polis team reviewed existing geological information and recommendations for earthquake scenarios and ran one probabilistic scenario with a 500-year return period. This type of scenario is based on ground-shaking parameters derived from USGS's probabilistic seismic hazard curves. The analysis evaluates the average impacts of a multitude of possible earthquake epicenters with a magnitude that would be typical of that expected for a 500-year return period (0.2% probability).

500-Year Probabilistic Scenario

Building Damages

The results of the 500-year probabilistic analysis are depicted in Tables 5-23 and 5-24[12] and Figure 5-15. Hazus-MH estimates that approximately 33 buildings will be at least moderately damaged. This does not even amount to 1% of total buildings in Brown County. Analysis indicates that no buildings will be damaged beyond repair.

The total building-related losses totaled $0.49 million; 22% of the estimated losses were related to the business interruption of the region. By far, the largest loss was sustained by the residential occupancies, which made up more than 64% of the total loss.

Table 5-23: Brown County 500 Year Probabilistic Scenario- Damage % by Occupancy

Occupancy Type	None	Slight	Moderate	Extensive	Complete
Agricultural	2,418	13	1	0	0
Commercial	396	2	1	0	0
Education	13	0	0	0	0
Government	138	1	0	0	0

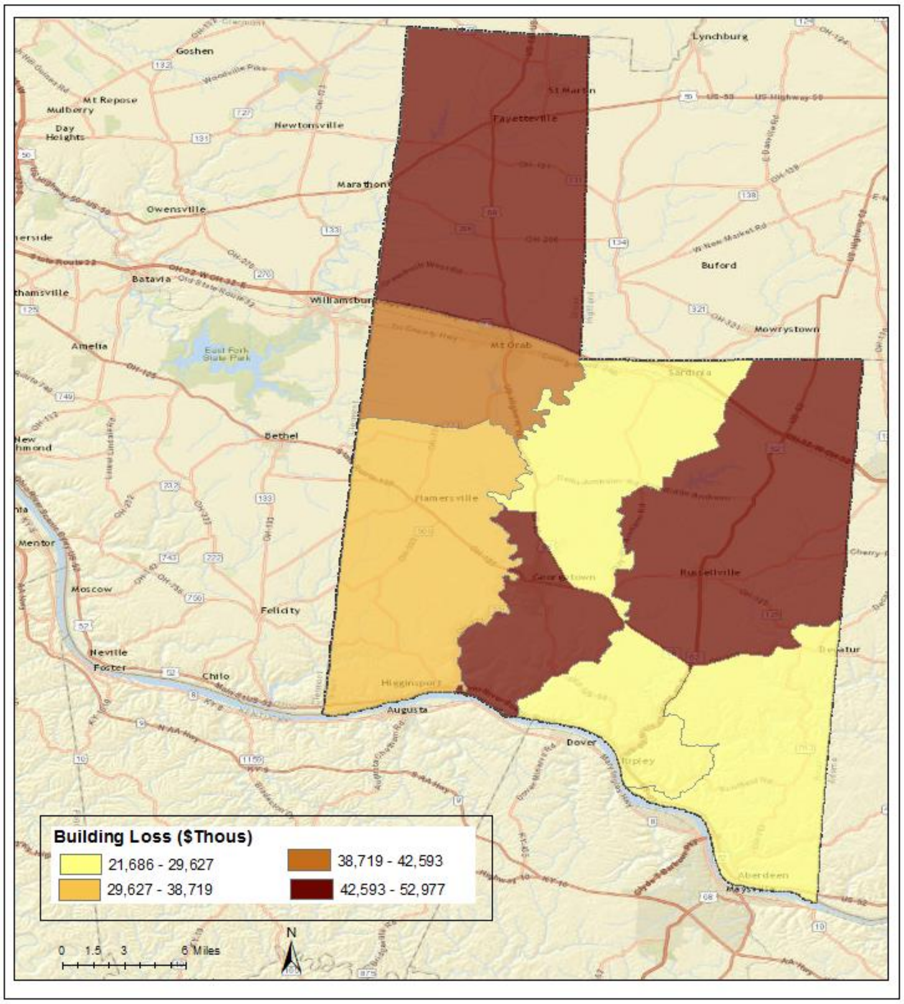
[12] The Assessor records do not contain values for non-taxable properties, including government, non-profit, and education facilities. Therefore, building losses may be under represented.

Industrial	9	0	0	0	0
Other Residential	2,893	82	25	3	0
Religion	99	1	0	0	0
Single Family	15,065	70	3	0	0
Total	**21,301**	**169**	**30**	**3**	**0**

Table 5-24: Brown County 500 Year Probabilistic Scenario- Building Economic Losses

Occupancy Type	Building Loss	Total Economic Loss
Residential	$237,000	$312,000
Agricultural	$28,000	$47,000
Commercial	$21,000	$62,000
Industrial	$500	$500
Others	$32,000	$68,000
Total	**$318,500**	**$489,500**

Figure 5-15: Brown County 500 Probabilistic Scenario- Building Economic Losses



5.3.4 Severe Thunderstorms

Severe thunderstorms are defined as thunderstorms with one or more of the following characteristics: strong winds, large damaging hail, or frequent lightning. Severe thunderstorms most frequently occur in Ohio during the spring and summer but can occur any month of the year at any time of day. A severe thunderstorm's impacts can be localized or can be widespread in nature. A thunderstorm is classified as severe when it meets one or more of the following criteria:

- Hail of diameter 0.75 inches or higher
- Frequent and dangerous lightning
- Wind speeds equal to or greater than 58 miles an hour

Hail

Hail is a product of a strong thunderstorm. Hail usually falls near the center of a storm; however, strong winds occurring at high altitudes in the thunderstorm can blow the hailstones away from the storm center, resulting in damage in other areas near the storm. Hailstones range from pea-sized to baseball-sized, but hailstones larger than softballs have been reported on rare occasions.

Lightning

Lightning is a discharge of atmospheric electricity from a thunderstorm. It can travel at speed up to 140,000 mph and reach temperatures approaching 54,000 degrees. Lightning is often perceived as a minor hazard; in reality, lightning causes damage to many structures and kills, or severely injures, numerous people in the United States. It is estimated that there are 16 million lightning storms worldwide every year.

Severe Winds (Straight-Line Winds)

Straight-line winds from thunderstorms are a fairly common occurrence across Ohio. Straight-line winds can cause damage to homes, businesses, power lines, and agricultural areas, and may require temporary sheltering of individuals who are without power for extended periods of time.

Summary Vulnerability Assessment

Because thunderstorm hazards are wide-spread events, it was not possible to complete a GIS-modeled scenario.

From 2007 to 2014, NCDC reported 81 thunderstorm (hail, winds) events in Cincinnati with total property damage of $555,000, which indicates an average annual risk of $69,375 in building losses. There were no accurate, available records that detailed how many or what types of structures were damaged; therefore building counts and building occupancy types are not available.

Previous Occurrences for Thunderstorm Hazards – 8 Years

The NCDC database reported 21 hailstorms in Brown County since January 1, 2007. Hailstorms occur nearly every year in the late spring and early summer. All recorded events have had minimal impact, with hail 2.0 inches diameter or less. There have been no injuries or fatalities reported for events in the past eight years, however, the September 7, 2010 storm induced $35,000 in property and crop damage.

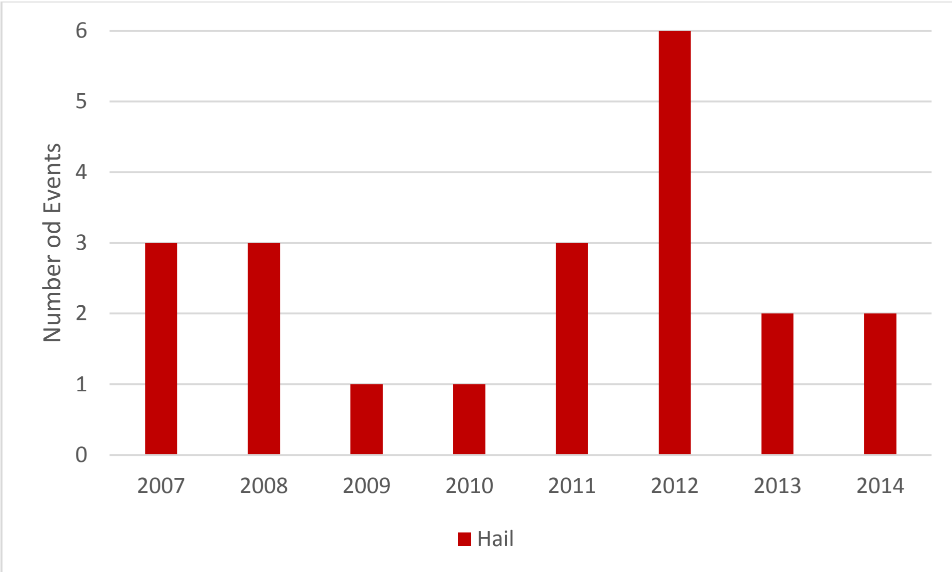
The Brown County hailstorms are identified in Table 5-25 and frequency shown in Figure 5-16.

Table 5-25: Brown County Hail Occurrences- 8 years

Date	Location	Type	Size	Property Damage[13]
4/11/2007	Sardinia	Hail	.75	$2,000
4/11/2007	Sardinia	Hail	.75	$2,000
11/5/2007	New Hope	Hail	.75	$1,000
7/22/2008	Hamersville	Hail	.88	$3,000
7/22/2008	Russellville	Hail	.75	$1,000
7/22/2008	Slickaway	Hail	.75	$1,000
8/4/2009	Bardwell	Hail	0.88	$0
9/7/2010	Mt Orab	Hail	1.00	$20,000
3/21/2011	Sardinia	Hail	1.00	$0
4/1/2011	Russellville	Hail	0.88	$0
6/21/2011	Georgetown	Hail	0.88	$0
3/2/2012	Mt Orab	Hail	0.75	$0
3/2/2012	Locust Ridge	Hail	1.00	$0
3/2/2012	Sardinia	Hail	0.75	$0
6/29/2012	Slickaway	Hail	0.88	$0
7/26/2012	Mt Orab	Hail	1.00	$0
9/26/2012	Shiloh	Hail	0.88	$0
4/16/2013	Georgetown	Hail	0.75	$0
8/31/2013	Macon	Hail	0.88	$0
5/28/2014	Locust Ridge	Hail	0.75	$0
6/20/2014	Macon	Hail	1.00	$0

Table 5-16: Brown County Hail Occurrences- 8 year

[13] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.



Lightning occurs every year in Brown County; however, NCDC did not report any significant lightning strikes in Brown County in the last eight years.

The NCDC database identified 60 thunderstorm winds reported since 2007. The February 6, 2008 storm caused significant damage in the communities of Ripley, Five Mile, and Mt. Orab. This storm was part of a larger system that produced 87 verified tornadoes across the southern United States and the lower Ohio River Valley. No tornadoes touched down near Brown County. As shown in Table 5-26, wind storms historically have occurred year-round, with the greatest frequency and damage between May and July. Annual frequency illustrated in Figure 5-17.

Table 5-26: Brown County Thunderstorm Wind Occurrence- 8 Years

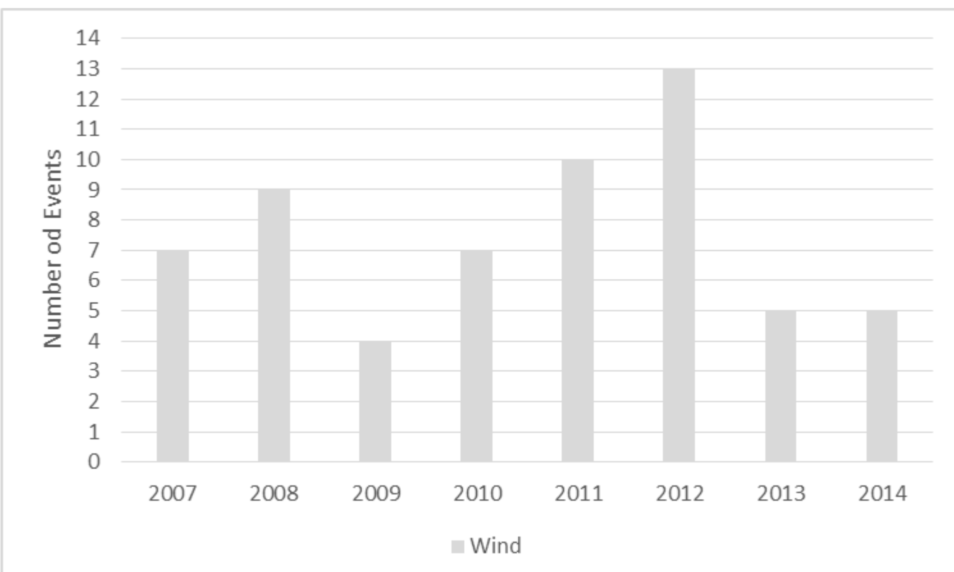
Location	Date	Top Wind Speed	Property Damage[14]
Ripley	4/11/2007	50	$ 2,000
Fayetteville	6/8/2007	50	$ 2,000
Aberdeen	7/10/2007	50	$ 2,000
Mt Orab	7/10/2007	50	$ 2,000
Ripley	8/16/2007	50	$ 5,000
Red Oak	8/16/2007	50	$ 3,000
Georgetown	9/26/2007	50	$ 3,000

[14] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

Location	Date	Top Wind Speed	Property Damage[14]
Hamersville	1/29/2008	50	$ 20,000
Mt Orab	2/6/2008	60	$ 30,000
Ripley	2/6/2008	70	$ 80,000
Five Mile	2/6/2008	78	$ 60,000
Centerville	5/11/2008	50	$ 10,000
Fayetteville	6/4/2008	61	$ 30,000
Georgetown/Brown Co	6/26/2008	50	$ 3,000
Mt Orab	7/20/2008	50	$ 12,000
Red Oak	7/20/2008	50	$ 3,000
Mt Orab	2/11/2009	50	$ 3,000
Fayetteville	2/11/2009	50	$ 3,000
Mt Orab	6/14/2009	56	$ 9,000
Mt Orab	8/10/2009	50	$ 1,000
Mt Orab	6/2/2010	50	$ 1,000
Mt Orab	6/12/2010	50	$ 1,000
Aberdeen	6/15/2010	61	$ 15,000
Red Oak	6/27/2010	50	$ 2,000
Fayetteville	8/4/2010	50	$ 1,000
Mt Orab	9/7/2010	70	$ 2,000
Ripley	10/26/2010	60	$ 20,000
Hamersville	2/28/2011	50	$ 2,000
Fayetteville	2/28/2011	50	$ 4,000
Russellville	3/23/2011	52	$ -
Aberdeen	3/23/2011	52	$ -
Five Mile	4/20/2011	87	$ 15,000
Fayetteville	4/20/2011	60	$ 15,000
Fayetteville	4/27/2011	50	$ 7,000
Georgetown	5/23/2011	60	$ 30,000
Mt Orab	6/21/2011	50	$ 2,000
Georgetown	6/21/2011	50	$ 3,000
Sardinia	3/2/2012	60	$ 10,000
Macon	3/2/2012	65	$ 20,000
Fayetteville	6/29/2012	50	$ 3,000
Georgetown	6/29/2012	50	$ 1,000
Mt Orab	7/1/2012	56	$ -
Mt Orab	7/1/2012	50	$ 5,000
Fayetteville	7/24/2012	50	$ 1,000
Feesburg	7/24/2012	50	$ 3,000

Location	Date	Top Wind Speed	Property Damage[14]
Sardinia	7/26/2012	50	$ 2,000
Mt Orab	7/27/2012	50	$ 10,000
Hamersville	8/9/2012	50	$ 5,000
Georgetown	8/9/2012	50	$ 1,000
Slickaway	9/8/2012	50	$ 1,000
Fayetteville	7/10/2013	50	$ 2,000
Mt Orab	8/31/2013	50	$ 1,000
Macon	8/31/2013	50	$ 3,000
Brown County	11/17/2013	50	$ 10,000
Russellville	12/22/2013	50	$ 10,000
Mt Orab	4/29/2014	50	$ 15,000
Ripley	5/14/2014	50	$ 1,000
Aberdeen	5/14/2014	50	$ 15,000
Fincastle	6/10/2014	50	$ 1,000
Mt Orab	8/20/2014	50	$ 2,000

Figure 5-17: Brown County Thunderstorm Wind Occurrence- 8 Years

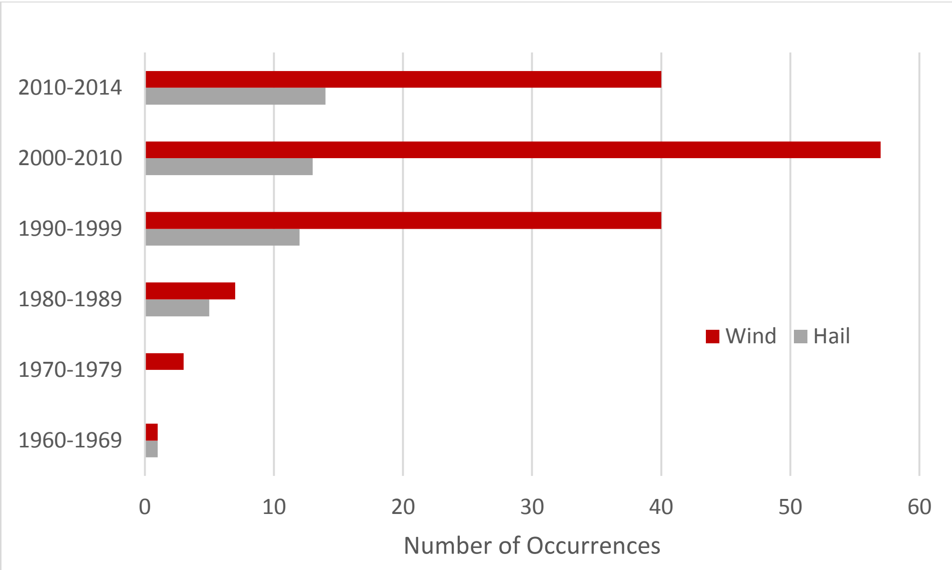


Previous Occurrences for Thunderstorm Hazards – 50 Years

There have been many occurrences of thunderstorm/wind events in Brown County during the past few decades. The NCDC database reported 147 with thunderstorm hazard event, inclusive of hail, lightning and wind events in Brown County since 1961. Although common, this type of storm can cause significant property damage.

NCDC recorded thunderstorm wind and hail events for Brown County are identified in Figure 5-18.

Figure 5-18: Thunderstorm Wind and Hail Occurrences- 50 year[15]



Geographic Location for Thunderstorm Hazard

This hazard is a countywide hazard and affects all jurisdictions and areas of the county.

Hazard Extent for Thunderstorm Hazard

The extent of the historical thunderstorms varies in terms of the extent of the storm, the wind speed, and the size of hail stones. Thunderstorms can occur at any location within the county.

Risk Identification for Thunderstorm Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
5	Thunderstorms	1+/year	Entire county	Can predict hours ahead, cannot predict location	Can only prepare to reduce human impact, cannot reduce economic impact	Minimal, in-place protective measures required	25% damage and/or destroyed and business interruption

Brown County ranked thunderstorm (hail/wind/lightning) hazard as the number five priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The

[15] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

probability of this disaster occurring, based on known recorded history, is over 100% (147 thunderstorm events/53 years of record). This assumes same spatial and temporal patterns across all of Brown County.

Vulnerability Analysis for Thunderstorm Hazard

Severe thunderstorms are an equally distributed threat across the entire jurisdiction; therefore the entire county's population and all buildings are vulnerable to a severe thunderstorm, and the same impacts can be expected within the affected area. This plan will therefore consider all buildings within the county as vulnerable.

Facilities

All facilities are vulnerable to severe thunderstorms. An essential or critical facility will encounter many of the same impacts as any other building within the jurisdiction. These impacts include structural failure, damaging debris (trees or limbs), roofs blown off or windows broken by hail or high winds, fires caused by lightning, and loss of building functionality (e.g., a damaged police station will no longer be able to serve the community). Names and locations of critical and essential facilities, as well as community assets, are in Appendix E.

Building Inventory

Impacts similar to those discussed for critical facilities can be expected for the buildings within the county. These impacts include structural failure, damaging debris (trees or limbs), roofs blown off or windows broken by hail or high winds, fires caused by lightning, and loss of building functionality (e.g., a damaged home will no longer be habitable, causing residents to seek shelter).

Infrastructure

During a severe thunderstorm, the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, and bridges. Because the county's entire infrastructure is equally vulnerable, it is important to emphasize that any number of these structures could become damaged during a severe thunderstorm. The impacts to these structures include broken, failed, or impassable roadways; broken or failed utility lines (e.g., loss of power or gas to community); or railway failure from broken or impassable railways. Bridges could fail or become impassable, causing risk to traffic.

Potential Dollar Losses for Thunderstorm Hazard

A GIS analysis was not completed for thunderstorms because the widespread extent of such a hazard makes it difficult to accurately model outcomes. To determine dollar losses for a thunderstorm hazard, the available NCDC hazard information was condensed to include only thunderstorm hazards that occurred within the past 10 years. It was determined that since 2005, Brown County has incurred an average of $60,500 annually in damages relating to thunderstorms (including hail and wind damages, there were not damages related to lightning). Table 5-27 provides data regarding damages related to thunderstorm events.

Table 5-27: Brown County Thunderstorm Hazard Damages[16]

Year	Tstm Wind Damages	Hail Damages
2005	$23,000	0
2006	$15,000	0
2007	$25,000	$4,000
2008	$251,000	$1,000
2009	$6,000	$5,000
2010	$32,000	0
2011	$59,000	$20,000
2012	$87,000	0
2013	$27,000	0
2014	$50,000	0
Total	**$575,000**	**$30,000**

Vulnerability to Future Assets/Infrastructure for Thunderstorm Hazard

All future development within the county and all communities will remain vulnerable to these events.

Analysis of Community Development Trends

Preparing for severe storms will be enhanced if officials sponsor a wide range of programs and initiatives to address the overall safety of county residents. New structures need to be built with more-sturdy construction, and those structures already in place need to be hardened to lessen the potential impacts of severe weather. Community warning sirens to provide warning of approaching storms are also vital to preventing the loss of property and ensuring the safety of Brown County residents.

[16] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

5.3.5 Winter Storm Hazard

Severe winter weather consists of various forms of precipitation and strong weather conditions. This may include one or more of the following: freezing rain, sleet, heavy snow, blizzards, icy roadways, extreme low temperatures, and strong winds. These conditions can cause human health risks such as frostbite, hypothermia, and death.

Ice (Glazing) and Sleet Storms

Ice or sleet, even in the smallest quantities, can result in hazardous driving conditions and can be a significant cause of property damage. Sleet can be easily identified as frozen raindrops. Sleet does not stick to trees and wires. The most damaging winter storms in Ohio have been ice storms. Ice storms are the result of cold rain that freezes on contact with objects having a temperature below freezing. Ice storms occur when moisture-laden gulf air converges with the northern jet stream causing strong winds and heavy precipitation. This precipitation takes the form of freezing rain coating power lines, communication lines, and trees with heavy ice. The winds will then cause the overburdened limbs and cables to snap; leaving large sectors of the population without power, heat, or communication. Falling trees and limbs can also cause building damage during an ice storm. In the past few decades numerous ice storm events have occurred in Ohio.

Snowstorms

Significant snowstorms are characterized by the rapid accumulation of snow, often accompanied by high winds, cold temperatures, and low visibility. A blizzard is categorized as a snowstorm with winds of 35 miles per hour or greater and/or visibility of less than one-quarter mile for three or more hours. The strong winds during a blizzard blow about falling and already existing snow, creating poor visibility and impassable roadways. Blizzards have the potential to result in property damage.

Blizzard conditions not only cause power outages and loss of communication, but also make transportation difficult. The blowing of snow can reduce visibility to less than one-quarter mile, and the resulting disorientation makes even travel by foot dangerous if not deadly.

Summary Vulnerability Assessment

Winter storms affect mostly humans, particularly special needs populations, and animals due to lack of mobility or isolation from supplies. Winter storms are also often accompanied by power loss. For this planning effort, it was not possible to analyze the number of lives or amount of property exposed to the impacts of winter storms.

Previous Occurrences for Winter Storm Hazard

The NCDC database identified eleven winter weather events for Brown County since January 1, 2009. The most recent winter storm event, which is not yet logged in the NCDC, occurred in

February 2015. A series of strong systems deposited over a foot of snow on majority of Brown County restricting access to roads and declaring a Level 3 snow emergency.

The NCDC winter weather events occurring in Brown County since 2007 are listed in Table 5-28. There is no recorded loss of life or recorded damages.

Table 5-28: Winter Storm Hazard Occurrences- 8 Years[17]

Start Date	Type
3/7/2008	Winter Storm
12/16/2010	Winter Storm
12/28/2012	Winter Storm
3/5/2013	Winter Storm
12/6/2013	Winter Storm
1/20/2014	Winter Storm
2/2/2014	Winter Storm
2/4/2014	Winter Storm
2/14/2014	Winter Storm
3/2/2014	Winter Storm
11/16/2014	Winter Storm

Geographic Location for Winter Storm Hazard

This hazard is a countywide hazard and affects all jurisdictions and areas of the county.

Hazard Extent for Winter Storm Hazard

The extent of the historical winter storms varies in terms of storm location, temperature, and ice or snowfall. A severe winter storm can occur anywhere in Brown County.

Risk Identification for Winter Storm Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
4	Winter Storms	1+/year	Entire county	Can predict days ahead, not accurate as to specific time and location	Can prepare with additional resources to reduce human and economic impact	Minimal, in-place protective measures required	25% damage and/or destroyed and business interruption

Brown County ranked winter storm hazard as the number four priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this

[17] NCDC records are estimates of damage reported to the National Weather Service from various local, state and federal sources. These estimates are often preliminary in nature and may not match the final assessment of economic and property losses associated with any given weather event.

disaster occurring, based on known recorded history, is over 100% (11 winter storms/8 years of record). This assumes same spatial and temporal patterns across all of Brown County.

Vulnerability Analysis for Winter Storm Hazard

Winter storm impacts are equally distributed across the entire jurisdiction; therefore, the entire county is vulnerable to a winter storm and can expect the same impacts within the affected area.

Critical Facilities

All critical facilities are vulnerable to a winter storm. A critical facility will encounter many of the same impacts as other buildings within the jurisdiction. These impacts include loss of gas or electricity from broken or damaged utility lines, damaged or impassable roads and railways, broken water pipes, and roof collapse from heavy snow. A complete list of critical facilities, replacement cost, and a map of locations is included as Appendices D.

Building Inventory

The impacts to the general buildings within the county are similar to the damages expected to the critical facilities. These include loss of gas or electricity from broken or damaged utility lines, damaged or impassable roads and railways, broken water pipes, and roof collapse from heavy snow.

Infrastructure

During a winter storm, the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, bridges, and ports. Since the county's entire infrastructure is equally vulnerable, it is important to emphasize that any number of these structures could become damaged during a winter storm. Potential impacts include broken gas and/or electricity lines or damaged utility lines, damaged or impassable roads and railways, and broken water pipes.

Potential Dollar Losses for Winter Storm Hazard

A Hazus-MH analysis was not completed for winter storms because the widespread extent of such a hazard makes it difficult to accurately model outcomes. To determine dollar losses for a winter storm hazard, the available NCDC hazard information was condensed to include only winter storm hazards that occurred within the past ten years. However, the NCDC database reports no damages for winter storm hazards over the past ten years.

Vulnerability for Future Assets/Infrastructure for Winter Storm Hazard

Any new development within the county will remain vulnerable to these events.

Analysis of Community Development Trends

Because the winter storm events are regional in nature, future development will be impacted equally across the county.

5.3.6 Extreme Temperatures

Extreme temperatures—both hot and cold—can have significant impact on human health and safety, commercial businesses, agricultures, and primary and secondary effects on infrastructure (e.g. burst pipes, power failures, etc.) Weather conditions described as extreme heat or cold vary across different areas of the country, based on the range of average temperatures within the region.

Extreme Heat Hazard Definition

Temperatures that hover 10 degrees Fahrenheit or more above the average high temperature for a region, and last for several weeks, constitute an extreme heat event (EHE). An extended period of extreme heat of three or more consecutive days is typically referred to as a heat wave. Most summers see EHEs in one or more parts of the U.S. East of the Rocky Mountains, they tend to combine both high temperatures and high humidity; although some of the worst heat waves have been catastrophically dry.

> Extreme heat is the number one cause of weather-related fatalities in the US, with hundreds occurring each year. On average, extreme heat claims more than 1,500 lives annually—more than floods, lightning, tornados, and hurricanes combined.

Prolonged exposure to extreme heat may lead to serious health problems, including heat stroke, heat exhaustion, or sunburn. Certain populations—such as seniors age 65 or older, infants and young children under five years of age, pregnant women, the homeless or poor, the overweight, and people with mental illnesses, disabilities, and chronic diseases are at greater risk to the effects of extreme heat. Depending on severity, duration, and location, EHEs can also trigger secondary hazards, including dust storms, droughts, wildfires, water shortages, and power outages.

Criteria for EHE typically shift by location and time of year, and are dependent on the interaction of multiple meteorological variables (i.e. temperature, humidity, cloud cover.) While this makes it difficult to define EHEs using absolute, specific measures, there are ways to identify conditions. Some locations evaluate current and forecast weather to identify conditions with specific, weather-based mortality algorithms. Others identify and forecast conditions based on statistical comparison to historical meteorological baselines, e.g. the criterion for EHE conditions could be an actual or forecast temperature that is equal to or exceeds the 95th percentile value from a historical distribution for a defined time period.18

[18] Office of Atmospheric Programs. (2006). *Excessive Heat Events Guidebook.* Unites States Environmental Protection Agency. Washington, D.C.

Heat alert procedures are based primarily on Heat Index Values. The Heat Index—given in degrees Fahrenheit—is often referred to as the apparent temperature and is a measure of how hot it really feels when the relative humidity is factored with the actual air temperature. The National Weather Service Heat Index Chart can be seen in Figure 5-19.

Figure 5-19: National Weather Service Heat Index

NOAA's National Weather Service

Heat Index

Temperature (°F)

Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution / Extreme Caution / Danger / Extreme Danger

Source: http://www.nws.noaa.gov/os/heat/index.shtml#heat_hazards

Each National Weather Service Forecast Office may issue the following heat-related products as conditions warrant:

- **Excessive Heat Outlooks**- issued when the potential exists for an EHE in the next 3-7 days. An Outlook provides information to those who need considerable lead time to prepare for the event, such as public utility staff, emergency managers, and public health officials.

- **Excessive Heat Watches**- issued when conditions are favorable for an EHE in the next 24 to 72 hours. A Watch is used when the risk of a heat wave has increased but its occurrence and timing is still uncertain. A Watch provides enough lead time so that those who need to prepare can do so, such as city officials who have excessive heat mitigation plans.

- **Excessive Heat Warnings/Advisories**- issued when an EHE is expected in the next 36 hours. These products are issued when an excessive heat event is occurring, is imminent, or has a very high probability of occurring. The warning is used for conditions posing a threat to life or property. An advisory is for less serious conditions that cause significant discomfort or inconvenience and, if caution is not taken, could lead to a threat to life and/or property.

Summary Vulnerability Assessment

Excessive heat affects mostly humans, particularly special needs populations, and animals. These events may be exacerbated by power loss. For this planning effort, it was not possible to analyze the number of lives or amount of property exposed to the impacts of extreme heat.

Previous Occurrences for Excessive Heat

Although the NCDC database does not include any reported past occurrences of excessive heat, residents of Brown County should be prepared for such an event in any given year.

Geographic Location for Excessive Heat Hazard

This hazard is a countywide hazard and affects all jurisdictions and areas of the county.

Hazard Extent for Excessive Heat Hazard

Excessive heat events typically occur in the summer months. The extent of EHEs varies in terms of the Heat Index and duration of the event.

Risk Identification for Excessive Heat Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
7	Extreme Temperatures	>100 years	50% of county	Can predict days ahead, not accurate as to specific time and location	Can only prepare to reduce human impact, cannot reduce economic impact	Minimal, in-place protective measures required	10% damage and/or destroyed and business interruption

Brown County ranked extreme temperatures (hot and cold) hazard as the number seven priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 0%. However, we know that high heat can occur and is something Brown County must be prepared to tackle when heat does strike.

Vulnerability Analysis for Excessive Heat Hazard

Unlike other natural hazard events, extreme heat events leave little to no physical damage to communities; however, they can lead to severe short and long-term health conditions, or even death. Extreme heat events can also impact environmental and economic vulnerabilities as a result of water shortages and drought.

Extreme Cold Hazard Definition

What constitutes an extreme cold event, and its effects, varies across different regions across the United States. In areas unaccustomed to winter weather, near freezing temperatures are considered "extreme cold." Extreme cold temperatures are typically characterized by the ambient air temperature dropping to approximately 0 degrees Fahrenheit or below.

Exposure to cold temperatures—indoors or outdoors—can lead to serious or life-threatening health problems, including hypothermia, cold stress, frostbite or freezing of the exposed extremities, such as fingers, toes, nose, and earlobes. Certain populations—such as seniors age 65 or older, infants and young children under five years of age, individuals who are homeless or stranded, or those who live in a home that is poorly insulated or without heat (such as mobile homes)—are at greater risk to the effects of extreme cold.

Extremely cold temperatures often accompany a winter storm, so individuals may also have to cope with power failures and icy roads. Although staying indoors can help reduce the risk of vehicle accidents and falls on the ice, individuals are susceptible to indoor hazards. Homes may become too cold due to power failures or inadequate heating systems. The use of space heaters and fireplaces to keep warm increases the risk of household fires, as well as carbon monoxide poisoning.

The magnitude of extreme cold temperatures is generally measured through the Wind Chill Temperature (WCT) Index. Wind Chill Temperature is the temperature that is felt when outside and is based on the rate of heat loss from exposed skin by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin's temperature to drop.

In 2001, the NWS implemented a new WCT Index, designed to more accurately calculate how cold air feels on human skin. The index, shown in Figure 5-20, includes a frostbite indicator, showing points where temperature, wind speed, and exposure time will produce frostbite in humans.

Figure 5-20: NWS Wind Chill Temperature Index

NWS Windchill Chart

Temperature (°F)

Wind (mph)	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes / 10 minutes / 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Each National Weather Service Forecast Office may issue the following wind chill-related products as conditions warrant:

- **Wind Chill Watch**: Issued when there is a chance that wind chill temperatures will decrease to at least 24° F below zero in the next 24-48 hours
- **Wind Chill Advisory**: Issued when the wind chill could be life threatening if action is not taken. The criteria for this advisory are expected wind chill readings of 15° F to 24° F below zero
- **Wind Chill Warning**: Issued when wind chill readings are life threatening. Wind chill readings of 25° F below zero or lower are expected.

Summary Vulnerability Assessment

Excessive cold affects mostly humans, particularly special needs populations, and animals. These events may be exacerbated by power loss. For this planning effort, it was not possible to analyze the number of lives or amount of property exposed to the impacts of extreme cold.

Previous Occurrences for Extreme Cold

Although the NCDC database does not include any reported past occurrences of extreme cold, residents of Brown County should be prepared for such an event in any given year.

Geographic Location for Extreme Cold Hazard

This hazard is a countywide hazard and affects all jurisdictions and areas of the county.

Hazard Extent for Extreme Cold Hazard

Extreme cold events typically occur in the winter months. The extent of extreme cold varies in terms of the Wind Chill Temperature and duration of the event.

Risk Identification for Extreme Cold Hazard

FACTORS	BENCHMARK SCORES					
	History	Area Affected	Predictability	Preparedness	Human Impact	Economic Impact
Extreme Temperatures	>100 years	50% of county	Can accurately predict as to time and location days before event occurs	Can only prepare to reduce human impact, cannot reduce economic impact	Minimal, in-place protective measures required	10% damage and/or destroyed

Brown County ranked extreme temperatures (hot and cold) hazard as the number seven priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 0%. However, we know that excessive cold can occur and is something Brown County must be prepared to tackle when cold does strike.

Vulnerability Analysis for Extreme Cold Hazard

Extreme cold can result in damages to buildings, utilities, and infrastructure, due to the strong winds that often accompany these events. Additionally, extreme cold events often lead to severe short and long term health conditions, or even death. Extreme cold events can occur within any area in the county; therefore, the entire county population and all buildings are vulnerable to extreme cold hazards.

5.3.7 Drought Hazard

The meteorological condition that creates a drought is below normal rainfall. However, excessive heat can lead to increased evaporation, which will enhance drought conditions. Droughts can occur in any month. Drought differs from normal arid conditions found in low rainfall areas. Drought is the consequence of a reduction in the amount of precipitation over an undetermined length of time (usually a growing season or more).

There are several common types of droughts including meteorological, hydrological, agricultural, and socioeconomic. Figure 5-21 describes the sequence of drought occurrence and impacts of drought types.

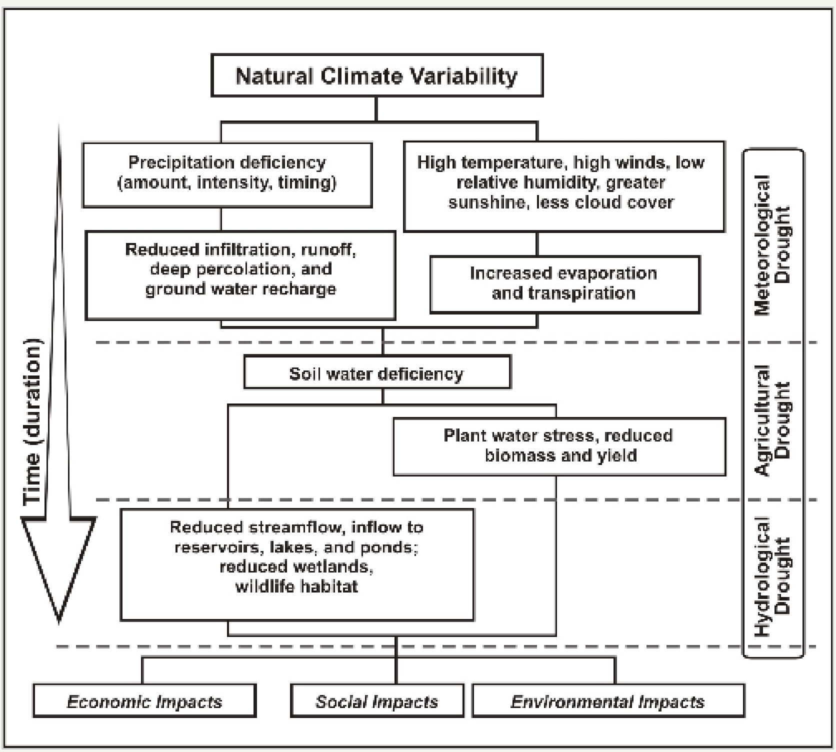
- **Meteorological:** Defined by the degree of dryness (as compared to an average) and the duration of the dry period. These are region-specific and only appropriate for regions characterized by year-round precipitation.
- **Hydrological:** Associated with the effects of periods of precipitation shortfalls (including snow) on surface or subsurface water supply, e.g. stream flow, reservoir and lake levels,

and groundwater. Impacts of hydrological droughts do not emerge as quickly as meteorological and agricultural droughts. For example, deficiency on reservoir levels may not affect hydroelectric power production or recreational uses for many months.

- **Agricultural:** Links characteristics of meteorological or hydrological drought to agricultural impacts. An agricultural drought accounts for the variable susceptibility of crops during different stages of crop development from emergence to maturity.

- **Socioeconomic:** Links the supply and demand of some economic good, e.g. water, forage, food grains, and fish, with elements of meteorological, hydrological, or agricultural droughts. This type of drought occurs when demand for an economic good exceeds supply as a result of weather-related shortfall in water supply.

Figure 5-21: Sequence of Drought Occurrence and Impacts



Sequence of drought occurrence and impacts for commonly accepted drought types. All droughts originate from a deficiency of precipitation or meteorological drought but other types of drought and impacts cascade from this deficiency. (Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.)

The severity of a drought depends on location, duration, and geographical extent. Additionally, drought severity depends on the water supply, usage demands made by human activities, vegetation, and agricultural operations. Drought brings several different problems that must be addressed. The quality and quantity of crops, livestock, and other agricultural assets will be affected during a drought. Drought can adversely impact forested areas leading to an increased potential for extremely destructive forest and woodland fires that could threaten residential, commercial, and recreational structures.

Drought conditions are often accompanied by extreme heat, which is defined as temperatures that hover 10°F or more above the average high for the area and last for several weeks. Extreme heat can occur in humid conditions when high atmospheric pressure traps the damp air near the ground or in dry conditions, which often provoke dust storms.

The Palmer Drought Severity Index (PDSI), developed by W.C. Palmer in 1965, is a soil moisture algorithm utilized by most federal and state government agencies to trigger drought relief programs and responses. The PDSI—shown in Table 29—is based on the supply-and-demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the PDSI is to provide standardized measurements of moisture, so that comparisons can be made between locations and periods of time—usually months. The PDSI is designed so that a -4.0 in South Carolina has the same meaning in terms of the moisture departure from a climatological normal as a -4.0 does in Ohio.

Table 5-29: Palmer Drought Severity Classifications

Classification Rating	Classification Description
4.0 or greater	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

Summary Vulnerability Assessment

Droughts affect mostly humans, particularly special needs populations, and animals. These events may be exacerbated by power loss. For this planning effort, it was not possible to analyze the number of lives or amount of property exposed to the impacts of drought.

Previous Occurrences for Drought Hazard

The NCDC database reported 15 drought events that affected Ohio since 1990[19]. In 2005, the National Drought Mitigation Center (NDMC) began development of a comprehensive drought impact database, the Drought Impact Reporter (DIR)[20]. This database allows anyone to report an impact they've seen in their respective community as a result of a drought. The impact can fall into any of ten categories: 1) agriculture, 2) business & industry, 3) energy, 4) fire, 5) general awareness, 6) plants and wildlife, 7) relief, response & restrictions, 8) society & public health, 9) tourism & recreation, and 10) water supply & quality. A new version of DIR was released in 2011 allowing for increased reports and collaboration between other agencies, including: National Oceanic and Atmospheric Administration and the USDA Risk Management Agency. Since the new release, the DIR saw an increase in the number of submitted drought impact reports. Table 5-30 depicts the categories and number of reported impacts in Brown County since 2007. Details of some previous drought occurrences are detailed below.

Table 5-30: Brown County Drought Impact Reports- 8 Year[21]

Type of Impact	2007	2008	2009	2010	2011	2012	2013	2014
Agriculture	1	1	0	1	7	65	36	18
Business and Industry	0	0	0	0	0	19	5	3
Fire	2	0	0	0	0	2	0	0
Plants and Wildlife	0	0	0	0	0	7	6	3
Relief, Response, and Restrictions	4	2	0	0	2	18	5	4
Society and Public Health	0	0	0	0	3	16	12	14
Tourism and Recreation	0	0	0	0	1	3	1	0
Water Supply and Quality	0	0	0	0	0	8	6	0
Total	**7**	**3**	**4**	**1**	**13**	**138**	**71**	**42**

[19] NCDC records are estimates of damage compiled by the National Weather Service from various local, state, and federal sources. However, these estimates are often preliminary in nature and may not match the final assessment of economic and property losses related to a given weather event.

[20] Web Source: http://droughtreporter.unl.edu/

[21] In 2011, The National Drought Mitigation Center released an updated version of the DIR. The new version allowed for increased reporting from various parties. The ability to increase reporting skews the numbers pre- and post- 2011. Looking post-2011, 2012 would indicate a particularly dry year compared to 2013 and 2014. To understand the type of impacts, a deeper look at the reports on the DIR website is necessary.

2012 North American Drought

The 2012-2013 North American Drought began in the spring of 2012, when the lack of snow in the United States caused very little melt water to absorb into the soil. The drought includes most of the US and included Ohio. Brown County, and several other Ohio counties, were designated with moderate drought conditions by mid-June. It had similar effects as droughts in the 1930s and 1950s but it was not as long. However, the drought has inflicted catastrophic economic ramifications. In most measures, the drought exceeded the 1988-1989 North American Drought, which is the most recent comparable drought.

On July 30, 2012, the Governor of Ohio sent a memorandum to the USDA Oho State Executive Director requesting primary county natural disaster designations for eligible counties due to agricultural losses caused by drought and additional disasters during the 2012 crop year. The USDA reviewed the Loss Assessment Reports and determined that there was sufficient production losses in 85 counties to warrant a Secretarial disaster designation. On September 5, 2012, Brown County was one of those designated counties.

The map below illustrates the drought affects across the United States (see Figure 5-22). Figure 5-23 illustrates the commodity loss statistics for Brown County between a non-drought year (2011) and a drought year (2012).

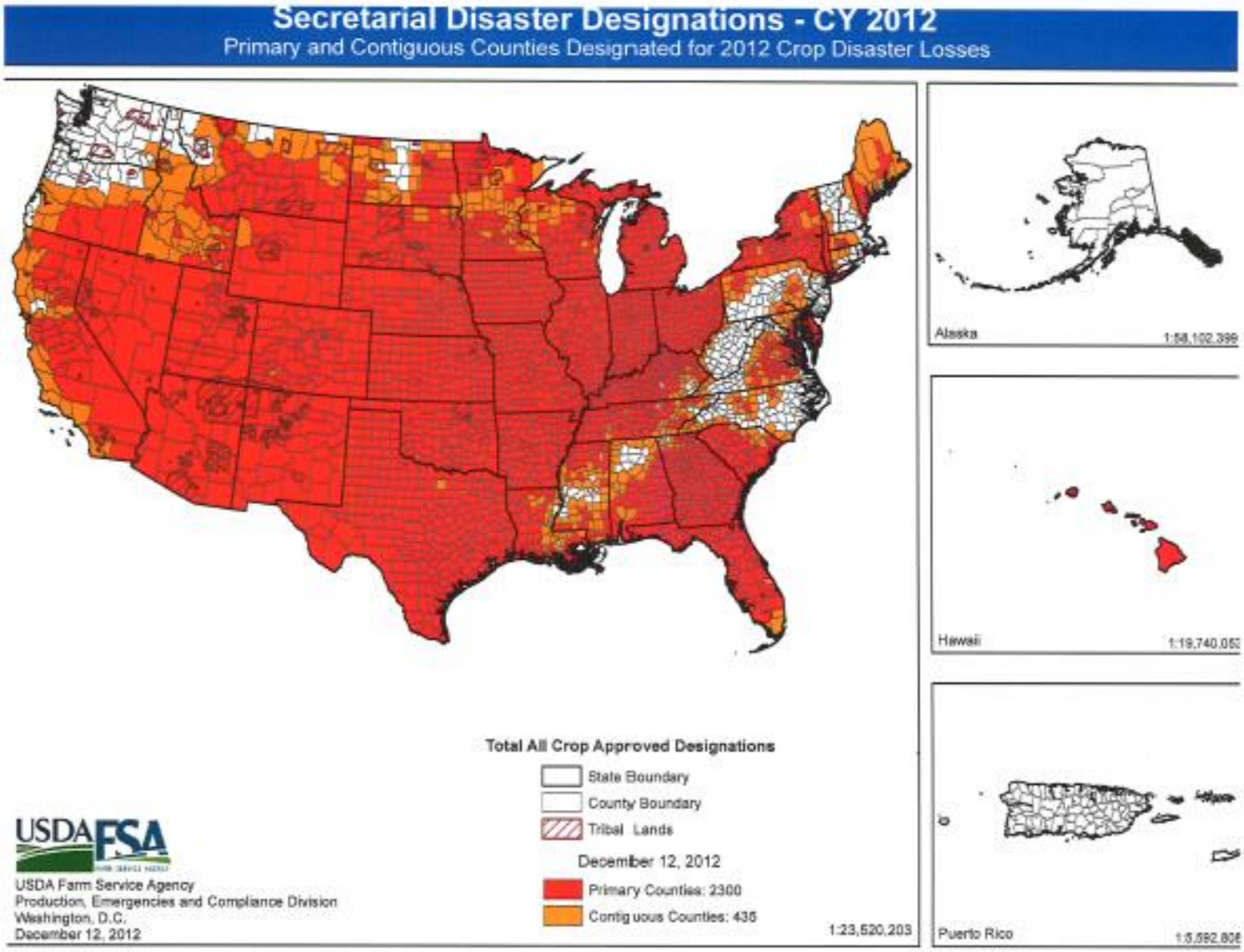


Figure 5-22: Counties declared in the secretarial disaster designation for droughts in 2012

Figure 5-23: Commodity Loss Statistics for Brown County between 2011 and 2012

COMMODITY LOSS STATISTICS
2012 DROUGHT

COUNTY: **Brown**

COMMODITY		Non-Drought Year-2011	Drought Year 2012	UNITS	CHANGE	AMOUNT
Corn - planted		18,200	28,500	acres	up	10,300
Corn, grain - harvested		17,900	27,500	acres	up	9,600
	Yield	98.35%	96.49%		down	1.86%
Corn, grain - production		2,680,000	3,404,000	bushels	up	724,000
Corn, grain - yield		149.7	123.8	bushels/acre	down	25.9
Hay - harvested		17,500	17,500	acres	unchanged	0
Hay - production		29,500	28,900	tons	down	600
Hay - yield		1.70	1.65	tons/acre	down	0.05
Soybeans - planted		87,300	81,400	acres	down	5,900
Soybeans - harvested		87,200	81,300	acres	down	5,900
	Yield	99.89%	99.88%		down	0.01%
Soybeans - production		3,831,000	3,951,000	bushels	up	120,000
Soybeans - yield		43.9	48.6	bushels/acre	up	4.70

Source: U.S. Dept. of Agriculture, National Agricultural Statistics Service

Geographic Location for Drought Hazard

This hazard is a countywide hazard and affects all jurisdictions and areas of the county.

Hazard Extent for Drought

Droughts can be widespread or localized events. The extent of droughts varies both in terms of the extent of the heat and range of precipitation.

Risk Identification for Drought Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
3	Drought	>100 years	50% of county	Can predict days ahead, not accurate as to specific time and location	Can only prepare to reduce human impact, cannot reduce economic impact	Minimal, in-place protective measures required	10% damage and/or destroyed and business interruption

Brown County ranked drought hazard as the number three priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 62% (15 drought events/24 years of record).

Vulnerability Analysis for Drought Hazard

Drought impacts can be an equally distributed threat across the entire jurisdiction; therefore, the county is vulnerable to this hazard and can expect similar impacts within the affected area. Due to the nature of drought, the entire population and the businesses that rely on ideal weather conditions (i.e. agriculture) are the most vulnerable to drought.

Critical Facilities

All critical facilities are vulnerable to drought. A critical facility will encounter many of the same impacts as any other building within the jurisdiction, which should involve only minor damage. These impacts include water shortages, fires as a result of drought conditions, and residents in need of medical care from the heat and dry weather. A complete list of critical facilities, replacement cost, and a map of locations is included as Appendix E

Building Inventory

The buildings within the county can all expect the same impacts similar to those discussed for critical facilities. These impacts include water shortages, fires as a result of drought conditions, and residents in need of medical care from the heat and dry weather.

Infrastructure

During a drought the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, and bridges. The risk to these structures is primarily associated with a fire that could result from the hot, dry conditions. Since the county's entire infrastructure is equally vulnerable, it is important to emphasize that any number of these items could be impacted during a drought.

Vulnerability to Future Assets/Infrastructure for Drought Hazard

Future development will remain vulnerable to these events. Typically, some urban and rural areas are more susceptible than others. For example, urban areas are subject to water shortages during periods of drought. Excessive demands of the populated area place a limit on water resources. In rural areas, crops and livestock may suffer from extended periods of heat and drought. Dry conditions can lead to the ignition of wildfires that could threaten residential, commercial, and recreational areas.

Analysis of Community Development Trends

Because droughts are regional in nature, future development will be impacted across the county. Agriculture impacts will continue to be most impacted with related heat impacts in the urban areas.

5.3.8 Hazardous Materials Hazard

The State of Ohio has numerous active transportation lines that run through many of its counties. Active railways transport harmful and volatile substances between our borders every day. The transportation of chemicals and substances along interstate routes and railroads is commonplace in Ohio. The rural areas of Ohio have considerable agricultural commerce, creating a demand for fertilizers, herbicides, and pesticides to be transported along rural roads. Ohio is bordered by the Ohio River to the south and Lake Erie to the north. Barges transport chemicals and substances along these waterways daily. These factors increase the chance of hazardous material releases and spills throughout the State of Ohio.

The release or spill of certain substances can cause an explosion. Explosions result from the ignition of volatile products such as petroleum products, natural and other flammable gases, hazardous materials/chemicals, dust, and bombs. An explosion potentially can cause death, injury, and property damage. In addition, a fire routinely follows an explosion, which may cause further damage and inhibit emergency response. Emergency response may require fire, safety/law enforcement, search and rescue, and hazardous materials units.

Summary Vulnerability Assessment

Brown County ranked Hazmat-related spills as the number eight hazard. The Polis Center and MU used the E.P.A.'s ALOHA model to complete two plume analyses in Brown County. The summarized results are included in Table 5-31 and Table 5-32.

Table 5-31: Scenario #1 - Aberdeen

Building Type	Population Exposure	Number of Buildings	Estimated Losses/Exposure
Residential	1,308	523	$36,260,000
Non-Residential	281	112	$11,446,000
Critical Facilities[22]	0	2	-
Totals	**1,589**	**635**	**$47,706,000**

Table 5-32: Scenario #2 – Mt. Orab

Building Type	Population Exposure	Number of Buildings	Estimated Losses/Exposure
Residential	2,701	1,080	$68,618,000
Non-Residential	431	172	$18,544,000

[22] Assessment records do not include values for critical facilities, therefore building losses are not calculated for these facilities.

Critical Facilities	0	4	-
Totals	**4,940**	**2,211**	**$87,162,000**

Previous Occurrences for Hazardous Materials Hazards

Brown County has not experienced a significantly large-scale hazardous material incident at a fixed site or during transport that resulted in multiple deaths or serious injuries, although there have been many minor releases that have put local firefighters, hazardous materials teams, emergency management, and local law enforcement into action to try to stabilize these incidents and prevent or lessen harm to Brown County residents.

Geographic Location for Hazardous Materials Hazard

The hazardous material hazards are countywide and primarily are associated with the transport of materials by highway, railroad, and/or river barge. The Rumpke landfill is of particular concern to the residents of Brown County due to the smell and particularly the gas, and potential chemical-related runoff coming from the landfill.

Hazard Extent for Hazardous Materials

The extent of the hazardous material (referred to as hazmat) hazard varies in terms of the quantity of material being transported as well as the specific content of the container.

Risk Identification for Hazardous Materials Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
8	Hazmat	1 in 10	Multi-jurisdictional	Cannot predict	Preparation difficult, many resources needed to reduce human and economic impact.	Minimal, in-place protective measures required	10% damage and/or destroyed and business interruption

Brown County ranked chemical-release (HAZMAT) hazard as the number eight priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 0%. However, Brown County recognizes that due to the human and economical impact it could have on the region, mitigation measures must be taken.

Vulnerability Analysis for Hazardous Materials

Hazardous material hazard event may occur at any time and place, therefore the entire county is vulnerable to a hazardous material release and can expect the same impacts within the affected area. The main concern during a release or spill is the population affected. This plan will therefore consider all buildings located within the county as vulnerable.

Facilities

All facilities and communities within the county are at risk. A critical facility will encounter many of the same impacts as any other building within the jurisdiction. These impacts include structural failure due to fire or explosion and loss of function of the facility (e.g., a damaged police station will no longer be able to serve the community). Names and locations of critical and essential facilities, as well as community assets, are in Appendix E.

Building Inventory

During a hazardous material release, the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, bridges, and ports. The impacts to these structures include broken, failed, or impassable roadways; broken or failed utility lines (e.g., loss of power or gas to community); and railway failure from broken or impassable railways. Bridges could fail or become impassable, causing risk to traffic.

In terms of numbers and types of buildings and infrastructure, typical scenarios are described to gauge the anticipated impacts of hazardous material release events in the county.

GIS Hazardous Materials Analysis

The U.S. EPA's ALOHA (Areal Locations of Hazardous Atmospheres) was used to develop models for this risk assessment. ALOHA is a computer program designed especially by use for people responding to chemical accidents, as well as for emergency planning and training. The ALOHA models assess the area of impact for three potential scenarios involving Chlorine at railroads in Aberdeen and Mt. Orab. Chlorine is a greenish yellow gas with a pungent to suffocating odor. The gas liquefies above-35°C at ambient pressure and will liquefy from pressure applied at room temperature. Contact with unconfined liquid chlorine can cause frostbite from evaporative cooling. Chlorine does not burn but, like oxygen, supports combustion. The toxic gas can have adverse health effects from either long-term inhalation of low concentrations of vapors or short-term inhalation of high concentrations. Chlorine vapors are much heavier than air and tend to settle in low areas. Chlorine is commonly used to purify water, bleach, wood pulp, and make other chemicals (NOAA Reactivity 2007).

Source: http://cameochemicals.noaa.gov/chemical/2862

Hazardous Materials Scenario 1: Aberdeen

For this scenario, moderate atmospheric and climatic conditions with a slight breeze from the southwest were assumed. The target area was chosen due to its proximity to the residential and commercial locations.

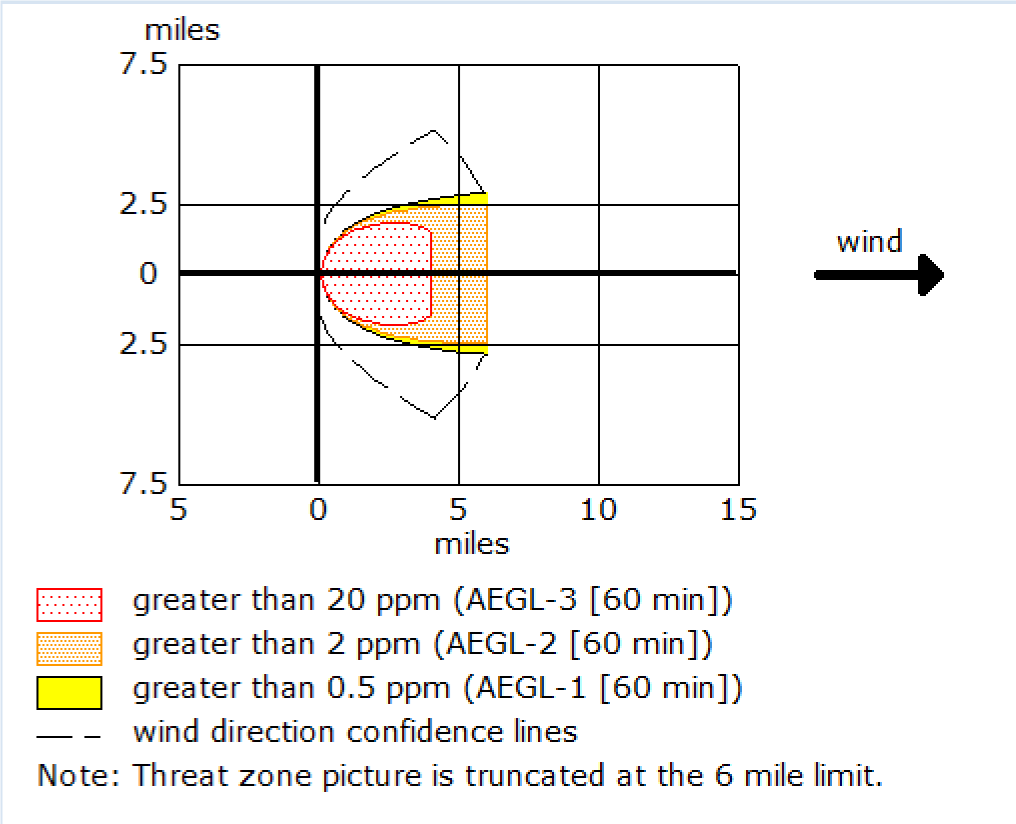
The ALOHA atmospheric modeling parameters, depicted in Figure 5-24, were based upon a southwest wind speed of 4 MPH. The temperature was 75°F with 75% humidity and cloudy skies.

The source of the chemical spill is a cylindrical-shaped tank. The diameter of the tank was set to 8 feet and the length set to 33 feet (12,408 gallons). At the time of its release, it was estimated that the tank was 95% full. The chlorine in this tank is in its liquid state. This release was based on a leak from a 1 foot diameter hole, 12 inches above the bottom of the tank. According to the ALOHA parameters, approximately 2,230 pounds of material would be released per second (maximum average sustained release rate). The image in Figure 5-25 depicts the plume footprint generated by ALOHA.

Figure 5-24: ALOHA Plume Modeling Parameters

```
SITE DATA:
  Location: ABERDEEN, OHIO
  Building Air Exchanges Per Hour: .53 (user specified)
  Time: July 7, 2015  2034 hours EDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLORINE                Molecular Weight: 70.91 g/mol
  AEGL-1 (60 min): 0.5 ppm   AEGL-2 (60 min): 2 ppm   AEGL-3 (60 min): 20 ppm
  IDLH: 10 ppm
  Ambient Boiling Point: -29.9° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 miles/hour from SW at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 75° F                 Stability Class: E
  No Inversion Height                    Relative Humidity: 75%

SOURCE STRENGTH:
  Leak from hole in horizontal cylindrical tank
  Non-flammable chemical is escaping from tank
  Tank Diameter: 8 feet                  Tank Length: 33 feet
  Tank Volume: 12,408 gallons
  Tank contains liquid                   Internal Temperature: 75° F
  Chemical Mass in Tank: 68.8 tons       Tank is 95% full
  Circular Opening Diameter: 1 feet
  Opening is 12 inches from tank bottom
  Note: RAILCAR predicts a stationary cloud or 'mist pool' will form.
  Model Run: traditional ALOHA tank
  Release Duration: 1 minute
  Max Average Sustained Release Rate: 2,230 pounds/sec
     (averaged over a minute or more)
  Total Amount Released: 133,931 pounds
  Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 4.0 miles --- (20 ppm = AEGL-3 [60 min])
  Orange: greater than 6 miles --- (2 ppm = AEGL-2 [60 min])
```

Figure 5-25: Plume Footprint Generated by ALOHA



Acute Exposure Guideline Levels (AEGLs) are intended to describe the health effects on humans due to once-in-a-lifetime or rare exposure to airborne chemicals. The National Advisory Committee for AEGLs is developing these guidelines to help both national and local authorities, as well as private companies, deal with emergencies involving spills or other catastrophic exposures. As the substance moves away from the source, the level of substance concentration decreases. Each color-coded area depicts a level of concentration measured in parts per million (ppm).

- **AEGL 3:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death. The red buffer (>=1100 ppm) extends no more than 4.8 miles from the point of release after one hour.

- **AEGL 2:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. The orange buffer (>=160 ppm) extends no more than six miles from the point of release after one hour.

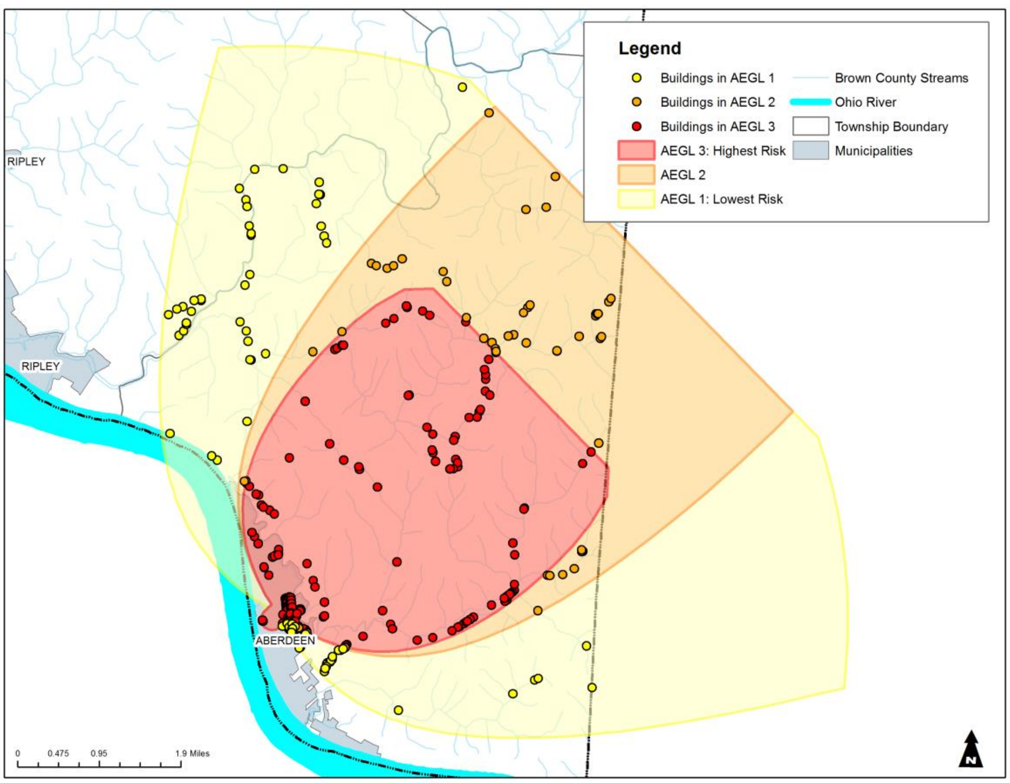
- **AEGL 1:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. The yellow buffer (>=30 ppm) extends more than six miles from the point of release after one hour.

- **Confidence Lines:** The confidence lines depict the level of confidence in which the exposure zones will be contained. The ALOHA model is 95% confident that the release will stay within this boundary.

Results

By summing the building inventory within all AEGL exposure levels (Level 3: > =1100 ppm, Level 2: > = 160 ppm and Level 1: > = 30 ppm.), the GIS overlay analysis predicts that as many as 635[23] buildings and as many as 1,589 people could be exposed[24]. The overlay was performed against parcels provided by Brown County that were joined with Assessor records showing property improvement. The location of buildings affected by the plume footprint is depicted in Figure 5-26.

Figure 5-26: Brown County Building Inventory Classified By Plume Footprint



[24] Population estimated based on 2.5 persons per resident.

Building Inventory Exposure

The potential losses related to the chlorine spill are listed in Tables 5-33 through 5-36.

Table 5-33: Estimated Exposure for all AEGL Levels (all ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	1308	523	$36,260,000
Commercial	53	21	$3,237,000
Industrial	0	0	0
Agriculture	223	89	$7,626,000
Religious	0	0	0
Government	5	2	$583,000
Education	0	0	0
Total	**1589**	**635**	**$47,706,000**

Table 5-34: Estimated Exposure for AEGL Level 3 (>=1100 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	735	294	$20,163,000
Commercial	30	12	$1,949,000
Industrial	0	0	0
Agriculture	98	39	$3,341,000
Religious	0	0	0
Government	5	2	$583,000
Education	0	0	0
Total	**868**	**347**	**$26,036,000**

Table 5-35: Estimated Exposure for AEGL Level 2 (>=160 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	135	54	$3,559,000
Commercial	3	1	$142,000
Industrial	0	0	0
Agriculture	60	26	$2,227,000
Religious	0	0	0
Government	0	0	0
Education	0	0	0
Total	**203**	**81**	**$5,928,000**

Table 5-36: Estimated Exposure for AEGL Level 1 (>=30 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	438	175	$12,538,000
Commercial	20	8	$1,146,000
Industrial	0	0	0
Agriculture	60	24	$2,058,000
Religious	0	0	0
Government	0	0	0
Education	0	0	0
Total	**518**	**207**	**$15,742,000**

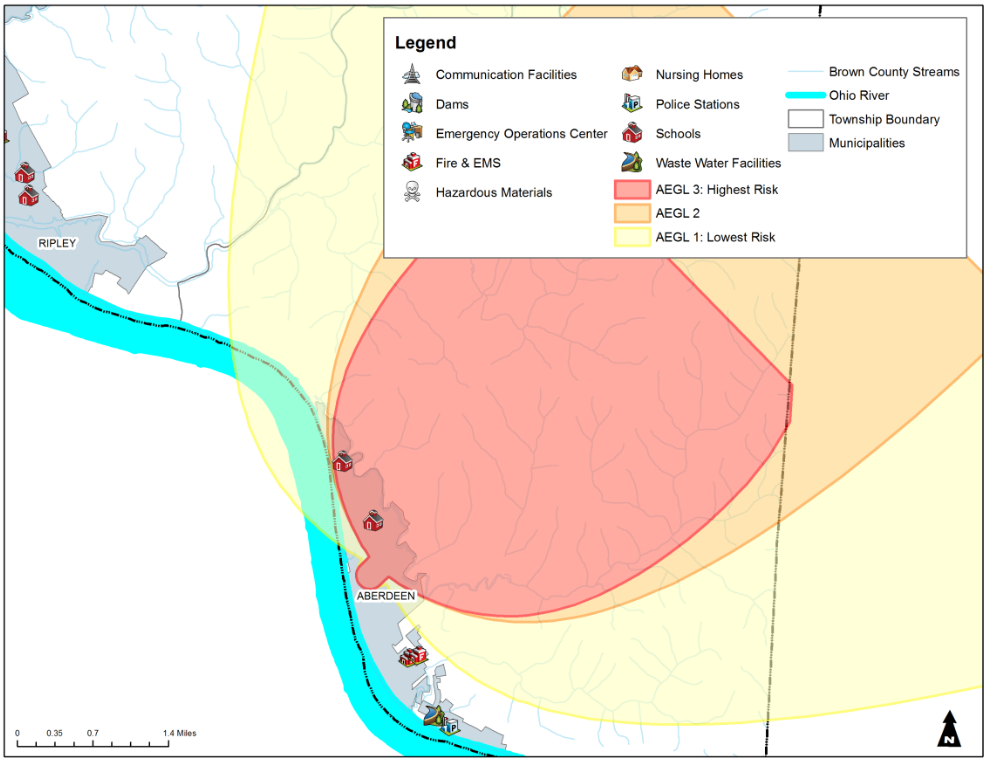
Essential Facilities Exposure

There are three essential and critical facilities located within the limits of the chemical spill plume. The affected facilities are identified in Table 5-37. Figure 5-27 shows the geographic location of some essential and critical facilities.

Table 5-37: Exposed Critical and Essential Facilities

Exposed Facilities
Ripley Union Lewis Huntington Middle School
Ripley Union Lewis Huntington Local

Figure 5-27: Vulnerable Facilities within Plume Footprint



Hazmat Scenario 2: Mt. Orab

For this scenario, moderate atmospheric and climatic conditions with a slight breeze from the northeast were assumed.

The ALOHA atmospheric modeling parameters, depicted in Figure 5-28, were based upon a southwest wind speed of 4 mph. The temperature was 75°F with 75% humidity and cloud covered skies.

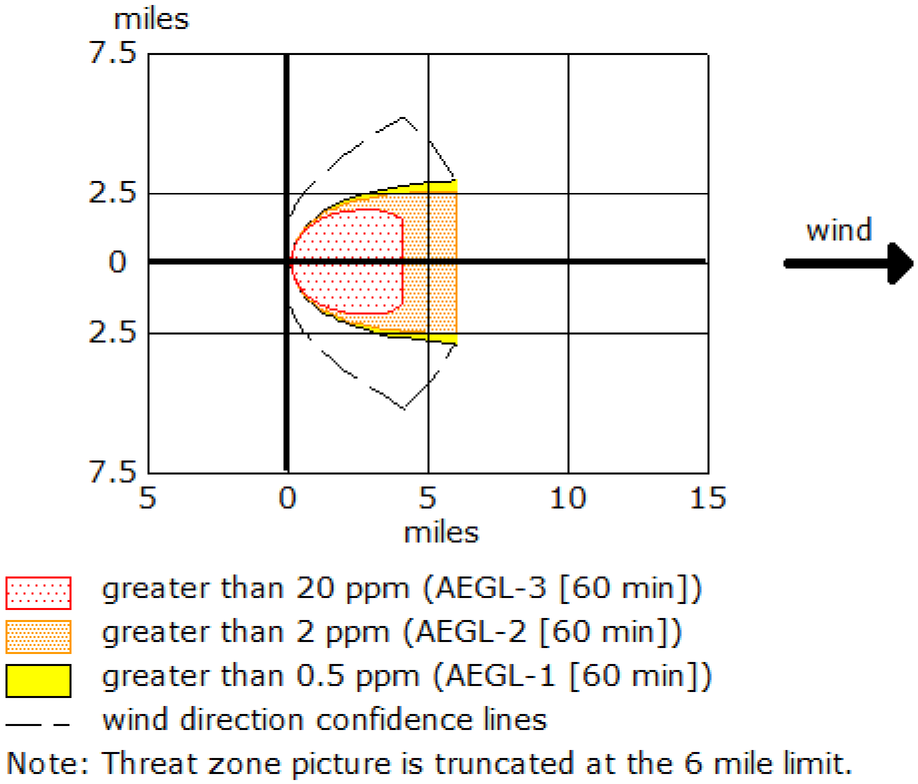
The source of the chemical spill is a horizontal, cylindrical-shaped tank. The diameter of the tank was set to 8 feet and the length set to 33 feet (12,408 gallons). At the time of its release, it was estimated that the tank was 95% full. The chlorine in this tank is in its liquid state.

This release was based on a leak from a 2.5 foot-diameter hole, 12 inches above the bottom of the tank. According to the ALOHA parameters, the maximum average sustained release rate is 137,000 pounds per minute (averaged over a minute or more). The image in Figure 5-29 depicts the plume footprint generated by ALOHA.

Figure 5-28: ALOHA Plume Modeling Parameters

```
SITE DATA:
  Location: MT. ORAB, OHIO
  Building Air Exchanges Per Hour: .53 (user specified)
  Time: July 7, 2015  2050 hours EDT (using computer's clock)

CHEMICAL DATA:
  Chemical Name: CHLORINE                Molecular Weight: 70.91 g/mol
  AEGL-1 (60 min): 0.5 ppm   AEGL-2 (60 min): 2 ppm   AEGL-3 (60 min): 20 ppm
  IDLH: 10 ppm
  Ambient Boiling Point: -30.6° F
  Vapor Pressure at Ambient Temperature: greater than 1 atm
  Ambient Saturation Concentration: 1,000,000 ppm or 100.0%

ATMOSPHERIC DATA: (MANUAL INPUT OF DATA)
  Wind: 4 miles/hour from sw at 3 meters
  Ground Roughness: urban or forest      Cloud Cover: 5 tenths
  Air Temperature: 75° F                 Stability Class: E
  No Inversion Height                    Relative Humidity: 75%

SOURCE STRENGTH:
  Leak from hole in horizontal cylindrical tank
  Non-flammable chemical is escaping from tank
  Tank Diameter: 8 feet                  Tank Length: 33 feet
  Tank Volume: 12,408 gallons
  Tank contains liquid                   Internal Temperature: 75° F
  Chemical Mass in Tank: 68.8 tons       Tank is 95% full
  Circular Opening Diameter: 2.5 feet
  Opening is 1 feet from tank bottom
  Release Duration: 9 minutes
  Max Average Sustained Release Rate: 137,000 pounds/min
     (averaged over a minute or more)
  Total Amount Released: 137,600 pounds
  Note: The chemical escaped as a mixture of gas and aerosol (two phase flow).

THREAT ZONE:
  Model Run: Heavy Gas
  Red   : 4.1 miles --- (20 ppm = AEGL-3 [60 min])
  Orange: greater than 6 miles --- (2 ppm = AEGL-2 [60 min])
  Yellow: greater than 6 miles --- (0.5 ppm = AEGL-1 [60 min])
```

Figure 5-29: Plume Footprint Generated by ALOHA



Acute Exposure Guideline Levels (AEGLs) are intended to describe the health effects on humans due to once-in-a-lifetime or rare exposure to airborne chemicals. The National Advisory Committee for AEGLs is developing these guidelines to help both national and local authorities, as well as private companies, deal with emergencies involving spills or other catastrophic exposures. As the substance moves away from the source, the level of substance concentration decreases. Each color-coded area depicts a level of concentration measured in parts per million (ppm).

- **AEGL 3:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death. The red buffer (>=1100 ppm) extends no more than 4.8 miles from the point of release after one hour.

- **AEGL 2:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape. The orange buffer (>=160 ppm) extends no more than six miles from the point of release after one hour.

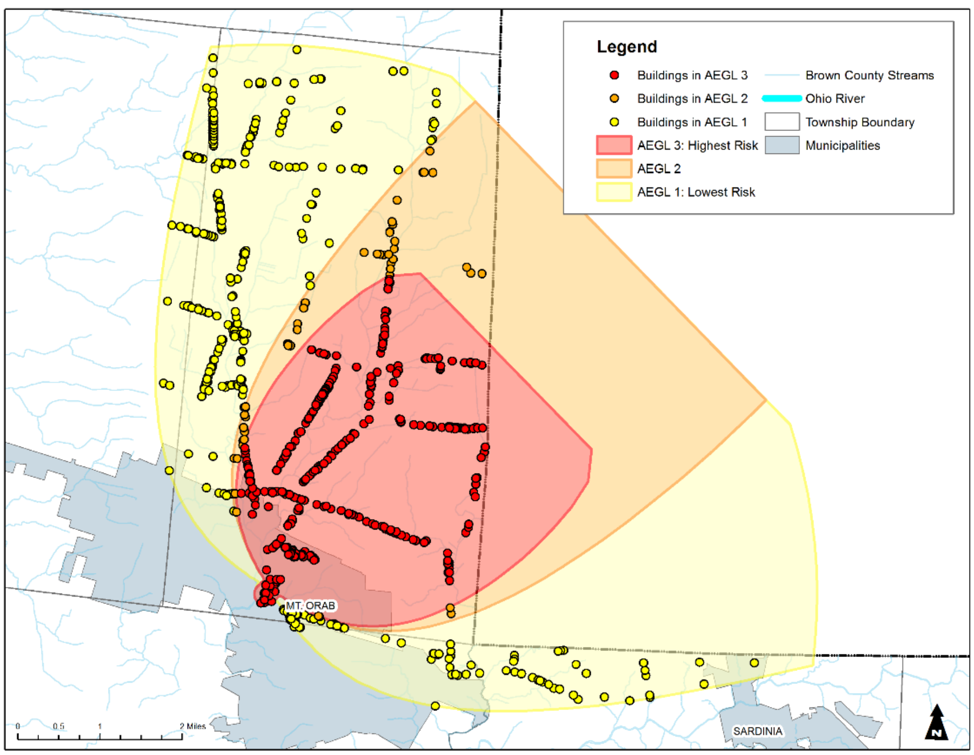
- **AEGL 1:** Above this airborne concentration of a substance, it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure. The yellow buffer (>=30 ppm) extends more than six miles from the point of release after one hour.

- **Confidence Lines:** The confidence lines depict the level of confidence in which the exposure zones will be contained. The ALOHA model is 95% confident that the release will stay within this boundary.

Results

By summing the building inventory within all AEGL exposure levels (Level 3: > =1100 ppm, Level 2: > = 160 ppm and Level 1: > = 30 ppm.), the GIS overlay analysis predicts that as many as 2,208[25] buildings could be exposed, including approximately 5,516 people[26]. The overlay was performed against parcels provided by Brown County that were joined with Assessor records showing property improvement. The location of buildings affected by the plume footprint is depicted in Figure 5-30.

Figure 5-30: Brown County Building Inventory Classified By Plume Footprint



25

26 Population estimated based on 2.5 persons per resident.

Building Inventory Exposure

The potential losses related to the chlorine chemical spill are listed in Tables 5-38 through 5-41.

Table 5-38: Estimated Exposure for all AEGL Levels (all ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	2701	1080	$68,618,000
Commercial	50	20	$3,006,000
Industrial	10	4	$319,000
Agriculture	355	142	$12,164,000
Religious	3	1	$227,000
Government	10	4	$1,167,000
Education	3	1	$1,1661,000
Total	**3132**	**1252**	**$87,162,000**

Table 5-39: Estimated Exposure for AEGL Level 3 (>=1100 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	1268	507	$31,490,000
Commercial	25	10	$1,579,000
Industrial	10	4	$319,000
Agriculture	155	62	$5,311,000
Religious	0	0	0
Government	0	0	0
Education	0	0	0
Total	**1458**	**583**	**$38,699,000**

Table 5-40: Estimated Exposure for AEGL Level 2 (>=160 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	173	69	4,733,000
Commercial	5	2	284,000
Industrial	0	0	0
Agriculture	45	18	1,542,000
Religious	0	0	0
Government	0	0	0
Education	0	0	0
Total	**223**	**89**	

Table 5-41: Estimated Exposure for AEGL Level 1 (>=30 ppm)

Occupancy	Population	Building Counts	Building Exposure
Residential	1260	504	$32,395,000
Commercial	20	8	$1,143,000
Industrial	0	0	0
Agriculture	155	62	$5,311,000
Religious	3	1	$227,000
Government	10	4	$1,167,000
Education	3	1	$1,661,000
Total	**1451**	**580**	**$41,904,000**

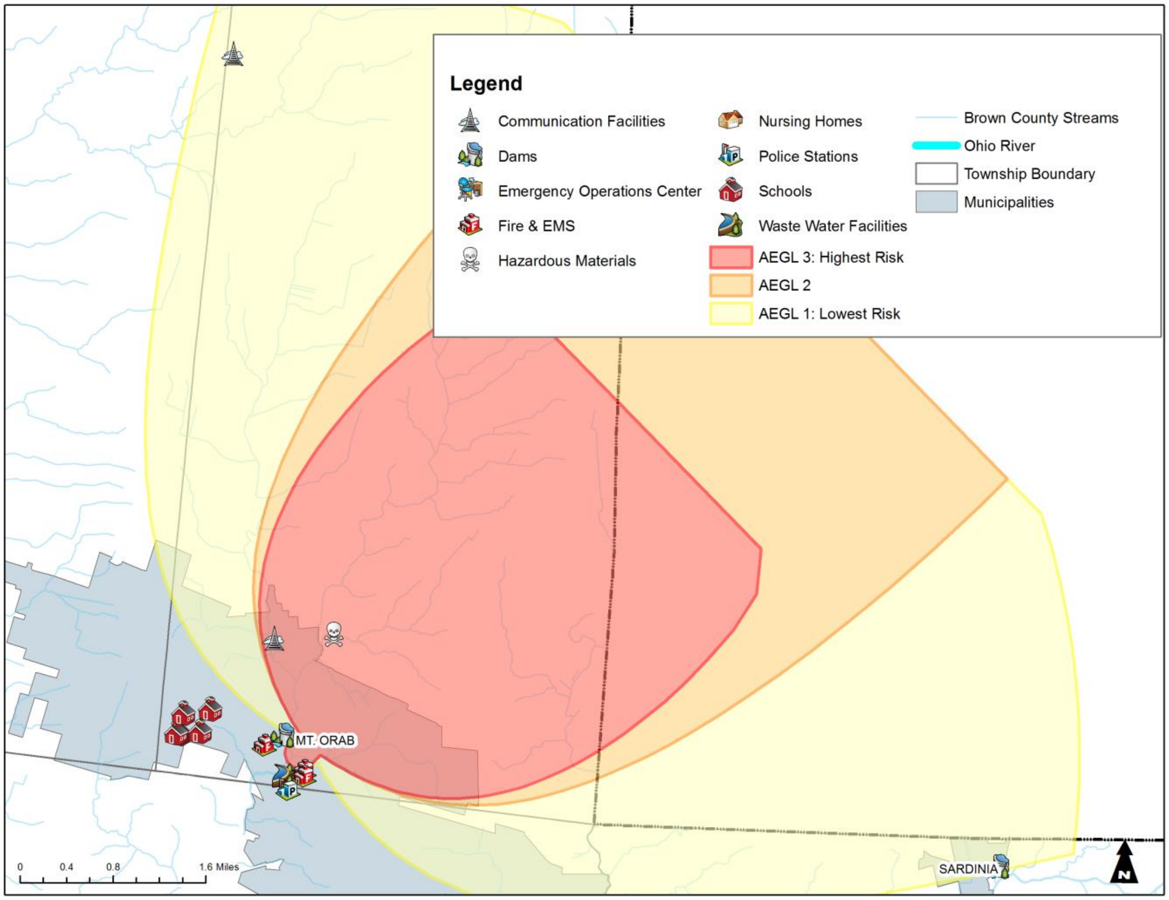
Essential and Critical Facilities Exposure

There are three vulnerable facilities within the limits of the chemical spill plume. The affected facilities are identified in Table 5-42. Their geographic locations are depicted in Figures 5-31.

Table 5-42: Exposed Critical and Essential Facilities

Exposed Facilities
Communication Facility: T-Mobile Central LLC
Communication Facility: Cincinnati Bell Tower
Hazardous Materials: Milacron, Inc (Methanol & Ammonia)
Dam: Sardinia Reservoir Dam

Figure 5-31: Exposed Critical and Essential Facilities



5.3.9 Fire Hazard

Fires constitute a much larger problem than is generally known. Deaths and injuries from all natural disasters combined—floods, hurricanes, tornados, earthquakes, etc.—are just a fraction of the annual casualties from fire. For example, deaths from natural disasters average just under 200 per year, versus approximately 4,000 deaths from fires.[27]

This plan will identify four major categories of fires within the county: tire/scrap fires, structural fires, wildfires, and arson.

Tire Fires

The State of Ohio generates more than 12 million scrap tires annually. Many of those scrap tires end up in approved storage sites that are carefully regulated and controlled by federal and state officials. Scrap tires, however, sometimes are dumped intentionally in unapproved locations throughout the State. According to Ohio EPA, there is a scrap tire collection facility within Brown County[28]. The number of unlicensed locations cannot be readily determined. These illegal sites are owned by private residents who continually have been dumping waste and refuse, including scrap tires, at those locations for many years.

Tire disposal sites can be fire hazards, in large part, because of the enormous number of scrap tires typically present at one site. This large amount of fuel renders standard firefighting practices nearly useless. Flowing and burning oil released by the scrap tires can spread the fire to adjacent areas. Tire fires differ from conventional fires in the following ways:

- Relatively small tire fires can require significant fire resources to control and extinguish.
- Those resources often cost much more than Brown County government can absorb, compared to standard fire responses.
- There may be significant environmental consequences of a major tire fire. Extreme heat can convert a standard vehicle tire into approximately 2 gallons of oily residue that may leak into the soil or migrate to streams and waterways.

Structural Fires

Lightning strikes, poor building construction, and building condition are the main causes for most structural fires in Ohio. Brown County has structural fires each year countywide.

[27] U.S. Fire Administration/National Fire Data Center. (2009) *Fire in the United States 2003-2007.* 15th ed. FEMA. FA-325

[28] Scrap Tire Facilities by County in Ohio: http://www.epa.ohio.gov/dmwm/Home/ScrapTires.aspx

Wildfires

Each year in Ohio, an average of 1,000 wildfires burn 4,000 to 6,000 acres of forest and grassland within Ohio's forest fire protection district. The fire protection district includes all 185,000 acres of Ohio's 20 State Forests, as well as privately owned lands within the district boundaries, and corresponds mostly to the state's unglaciated hill country. Ohio's wildfire seasons occur primarily in the spring—March, April, and May—before vegetation has "greened-up", and in the fall—October and November—when leaf drop occurs. During these times, especially when weather conditions are warm, windy, and with low humidity, cured vegetation is particularly susceptible to burning. When combined, fuel, weather, and topography, present an unpredictable danger to unwary civilians and firefighters in the path of a wildfire.

Arson

It is important to note that arson is a contributing factor to fire-related incidents within the county. According the United States Fire Administration, an estimated average of 316,000 intentional fires are reported to fire departments in the United States each year, causing injuries to 7,825 firefighters and civilians. In addition to needless injury and death, an estimated $1.1 billion in direct property loss occurs annually.[29]

Summary Vulnerability Assessment

Brown County ranked fire as the number nine hazard of concern. There is currently no accurate, available historical data for wildfires in Brown County.

Previous Occurrences for Fire Hazard

The Division of State Fire Marshall Office reports that in 2013 there were 1.2 million fires nationwide. Almost half a million were structure fires, causing 2,855 civilian deaths. In Brown County, there's been a significant decrease in the number of fires since 2009. Table 5-43 lists the detailed statistics provided by The Division of State Fire Marshall Office.

[29] U.S. Fire Administration. (2010). *Community Arson Prevention: National Arson Awareness Media Kit*. FEMA.

Table 5-43: Brown County All Fires

Year	Total Fires	Total Fatalities	Total Injuries	Total Arrest
2009	15	1 – Adult	1- Adult	5
2010	13	1 – Adult	5 – Adult	0
2011	9	2 – Adult	1 – Adult	0
2012	9	0	0	1
2013	9	0	0	1
2014	4	0	1- Juvenile	0

Geographic Location for Fire Hazard

Fire hazards occur countywide and therefore affect the entire county. Communities with older wooden structures or structures in close proximity to one another are more vulnerable to structural fires.

Hazard Extent for Fire Hazard

The extent of the fire hazard varies in terms of the severity of the fire and the type of material being ignited. All communities in Brown County are equally affected by fire.

Risk Identification for Fire Hazard

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
9	Fire	1+/year	Multi-jurisdictional	Cannot predict	Can prepare with additional resources to reduce human and economic impact	Minimal, in-place protective measures required	10% damage and/or destroyed and business interruption

Brown County ranked fire hazard as the number nine priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is over 100% (59 events/6 years of record.

Vulnerability Analysis for Fire Hazard

This hazard impacts the entire jurisdiction equally; therefore the entire population and all buildings within the county are vulnerable to fires and can expect the same impacts within the affected area.

Names and locations of all essential facilities, critical facilities, and community assets are in Appendix E. Because of the difficulty predicting which communities are at risk, the entire population and all buildings have been identified at risk.

Facilities

All facilities are vulnerable to fire hazards. An essential or critical facility will encounter many of the same impacts as any other building within the jurisdiction. These impacts include structural damage from fire and water damage from efforts extinguishing fire. Names and locations of critical and essential facilities, as well as community assets, are found in Appendix E.

Building Inventory

Impacts to the general buildings within the county are similar to the damages expected to the critical facilities. These impacts include structural damage from fire and water damage from efforts to extinguish the fire.

Infrastructure

During a fire the types of infrastructure that could be impacted include roadways, utility lines/pipes, railroads, and bridges. Since the county's entire infrastructure is equally vulnerable, it is important to emphasize that any number of these items could become damaged during a fire. Potential impacts include structural damage resulting in impassable roadways and power outages.

Vulnerability to Future Assets/Infrastructure for Fire Hazard

Any future development in Brown County will be vulnerable to these events.

Analysis of Community Development Trends

Fire-hazard events may occur anywhere within the county; because of this, future development will be impacted.

5.3.10 Landslide Hazard

Landslides are a serious geologic hazard common to almost every state in the United States. It is estimated that nationally they cause up to $2 billion in damages and from 25 to 50 deaths annually. Globally, landslides cause billions of dollars in damage and thousands of deaths and injuries each year.

The term landslide is a general designation for a variety of downslope movements of earth materials. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly. Gravity is the force driving landslide movement. Factors that allow the force of gravity to overcome the resistance of earth material to landslide movement include: saturation by water, steepening of slopes by erosion or construction, alternate freezing or thawing, earthquake shaking, and volcanic eruptions. There are three main types of landslides that occur in Ohio: 1) rotational slump, 2) earthflow, and 3) rockfall.

Rotational slumps are characterized by the movement of a mass of weak rock or sediment as a block unit along a curved slip plane. These slumps are the largest type of landslide in Ohio, commonly involving hundreds of thousands of cubic yards of material and extending for hundreds of feet. Rotational slumps may develop comparatively slowly and commonly require several months or even years to reach stability; however, on occasion, they may move rapidly, achieving stability in only a few hours.

Earthflows involve rock, sediment, or weathered surface materials moving downslope in a mass. While earthflows are the most common form of downslope movement in Ohio, they are comparatively smaller than rotational slumps. Characteristically, earthflows involve a weathered mass of rock or sediment that flow downslope as a jumbled mass, forming a hummocky topography of ridges and swales. Earthflows are most common in weathered surface materials and do not necessarily indicate weak rock. The rate of movement of an earthflow is generally quite slow.

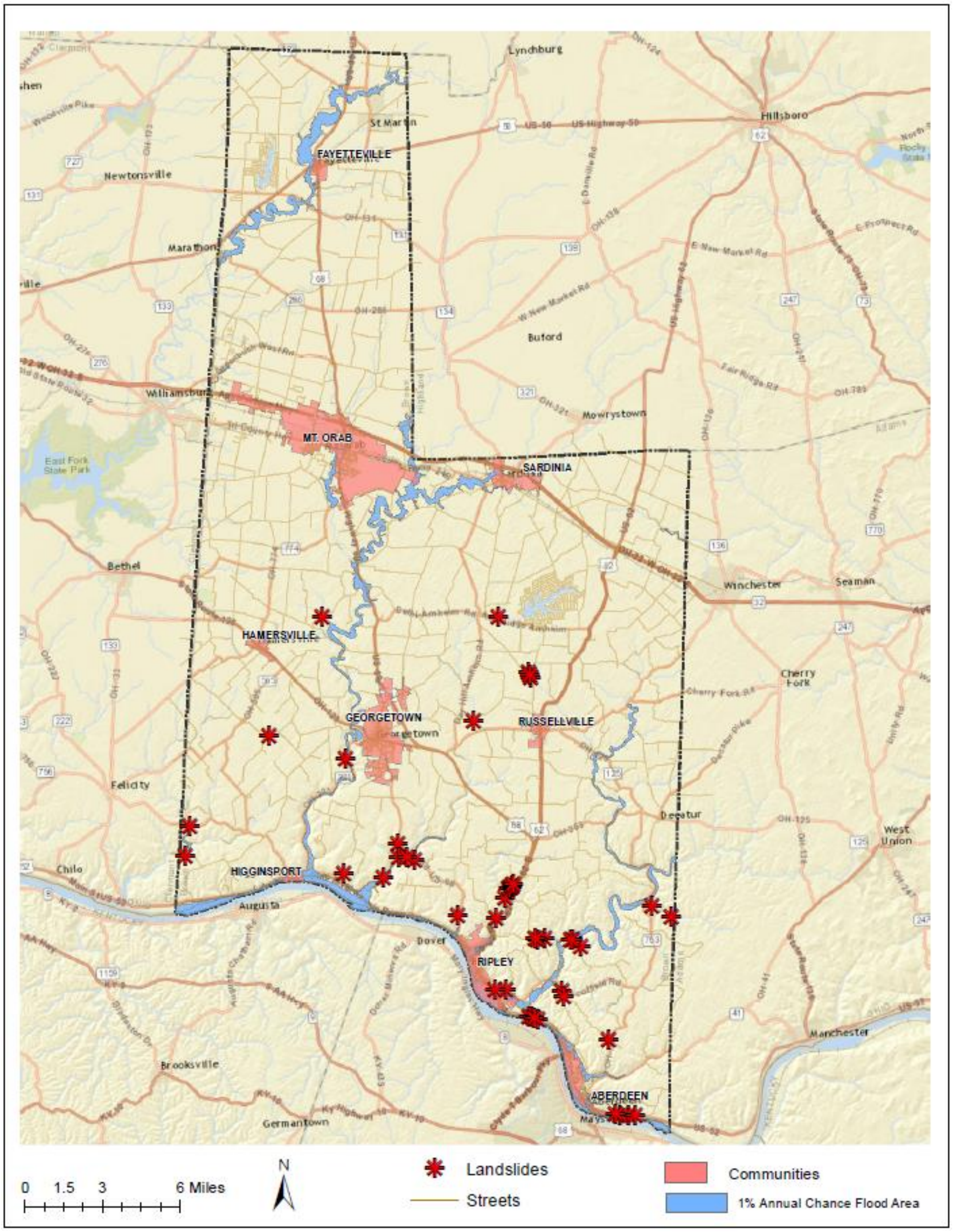
Rockfalls are extremely rapid, and potentially dangerous, downslope movement of earth materials. Large blocks of massive bedrock may suddenly become detached from a cliff or steep hillside and travel downslope in a free fall and rolling, bounding, or sliding manner until a position of stability is achieved. Most rockfalls in Ohio involve massive beds of sandstone or limestone. Surface water seeps into joints or cracks in the rock, increasing its weight and causing expansion of joints in freezing temperatures, prying blocks of rock away from the main cliff. Weak and easily eroded clay or shale beneath the massive bed is an important contributing factor to rockfall.

Landslides are typically associated with periods of heavy rainfall or rapid snow melt, and tend to worsen the effects of flooding that often accompany these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides.

Previous Occurrences of Landslides

Landslides are a significant problem in several areas of Ohio. The steep slopes of the Ohio River valley contribute too many of these problems. In early 2015, excessive snow and rainfall contributed to several landslides in southwest Ohio. The Brown County Engineer's Office is attempting to keep a geospatial log of landslide and road slip locations, however not all locations are logged nor is the data continuously maintained to check on the status of these landslide/road slip locations. See Figure 5-32 for the locations of landslides and road slip locations in Brown County.

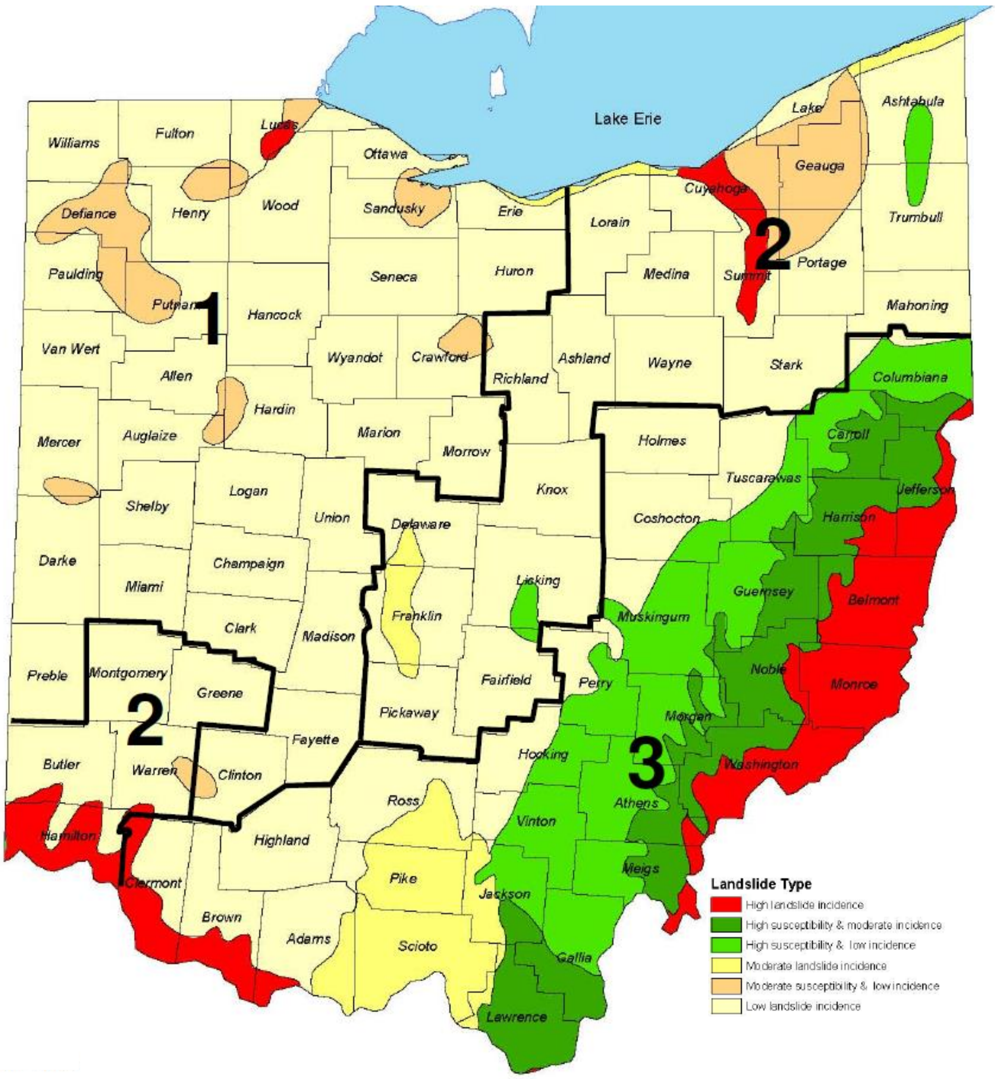
Figure 5-32: Brown County Landslide and Road-Slip Locations



Geographic Location for Landslide Hazard

Brown County is a region of high landslide susceptibility and hazard potential. The areas susceptible to landslides are located along streams and steep valleys that contain weak silts and clays, and where other unconsolidated glacial sediments are concentrated. The majority of bedrock slope failures are in the shale-dominated Kope Formation, and to a lesser degree in the Miamitown Shale. Figure 5-33 depicts landslide incidence and susceptibility in Ohio. Region 1 has relatively low landslide incidence. Region 2 primarily has a low landslide incidence except for the far southwest region of Ohio along the Ohio River that has a great susceptibility to landslides due to the hilly Ohio River valley and the soils. Region 3 has the most susceptible area to landslides with low to moderate incidences. However, Brown County, along with some neighboring counties, have a higher incidence (highlighted by the red coloring in Figure 5-33).[30]

Figure 5-33: Ohio Landslide Incidence and Susceptibility



Source: *Ohio Enhanced State Mitigaton Plan, & Ohio Department of Natural Resources*

Hazard Extent for Landslide Hazards

Landslides occur frequently along steep slopes and valleys, particularly in locations with unstable soils. Brown County's geographic location in the Ohio River Valley makes them highly susceptible to landslides. Brown County Engineer's office is currently documenting known locations of landslides and road-slips within the county, Figure 5-32.

Risk Identification for Landslide Hazards

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
6	Landslides	1 in 10	Multi-jurisdictional	Can predict hours ahead, cannot predict location	Preparation difficult, many resources needed to reduce human and economic impact.	Shelter and/or evacuation or other protective measures required for 75% of the population involved	25% damage and/or destroyed and business interruption

Brown County ranked landslide hazard as the number six priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is over 100% (the map in Figure 5-32 shows the 2013/2014 landslides).

Vulnerability Analysis for Landslides

Because of the steep slopes, soil types, and population growth within Brown County, there is an increased vulnerability to landslides. As vegetation is removed from steep slopes or these slopes are surcharged by development, the threat of landslides or slumps increases proportionally. As a result, the entire population and all buildings have been identified as at risk.

Essential Facilities

Any facility built along an unstable slope are susceptible to landslides. An essential or critical facility will encounter many of the same impacts as any other building within the affected area. These impacts include damages ranging from cosmetic to structural. Buildings may sustain minor cracks in walls due to a settling from land slippage, while in more severe cases the structure may erode downhill with the failing slopes. Table 4-5 lists the types and numbers of all the essential facilities in the area. Critical and essential facilities, as well as community assets, are included in Appendix E.

Building Inventory

The buildings within areas highly susceptible to landslides can all anticipate the same impacts, similar to those discussed for critical facilities. These impacts include damages ranging from cosmetic to structural. Buildings may sustain minor cracks in walls due to a settling, while in more severe cases the structure may erode downhill with the failing slopes.

Infrastructure

In the areas of Brown County that are highly susceptible to landslides, potential impacts to infrastructure include: broken, failed, or impassable roadways; broken or failed utility lines (e.g. loss of power or gas to community); and railway failure from broken or impassable railways. In addition bridges could fail or become impassable causing risk to traffic. These impacts may lead to protracted closures and costly repairs. The debris flows from landslides may also disturb natural habitats and ecosystems and accelerate surface erosion and sediment transport in watersheds.

Vulnerability to Future Assets/Infrastructure for Landslides

All future community assets and infrastructure in areas with high susceptibility to landslides will remain vulnerable to damages. In areas with higher levels of population the vulnerability is greater than in open areas with no infrastructure demands.

Analysis of Community Development Trends

Planning team discussed mitigation strategies to lessen the impacts of landslides by restricting new development in vulnerable areas.

5.3.11 Dam/Levee Failure Hazard

Dams are structures that retain or detain water behind a large barrier. When full, or partially full, the difference in elevation between the water above the dam and below creates large amounts of energy, creating the potential for failure. The same potential exists for levees when they serve their purpose, which is to confine flood waters within the channel area of a river and exclude that water from land or communities land-ward of the levee. Dams and levees can fail due to 1) water heights or flows above the capacity for which the structure was designed; or 2) deficiencies in the structure such that it cannot hold back the potential energy of the water. If a dam or levee fail, issues of primary concern include loss of human life/injury, downstream property damage, lifeline disruption (of concern would be transportation routes and utility lines required to maintain or protect life), and environmental damage.

Many communities view both dams and levees as permanent and infinitely safe structures. This sense of security may well be false, leading to significantly increased risks. Both downstream of dams and on floodplains protected by levees, security leads to new construction, added infrastructure, and increased population over time. Levees in particular are built to hold back flood waters only up to some maximum level, often the 100-year (1% annual probability) flood event. When that maximum is exceeded by more than the design safety margin, the levee will be overtopped or otherwise fail, inundating communities in the land previously protected by that levee. It has been suggested that climate change, land-use shifts, and some forms of river engineering may be increasing the magnitude of large floods and the frequency of levee failure situations.

In addition to failure that results from extreme floods above the design capacity, levees and dams can fail due to structural deficiencies. Both dams and levees require constant monitoring and regular maintenance to assure their integrity. Many structures across the U.S. have been under-funded or otherwise neglected, leading to the recognition that certain structures are unsafe or, rarely, can lead to actual failure. The threat of dam or levee failure may require substantial commitment of time, personnel, and resources. Since dams and levees deteriorate with age, minor issues become larger compounding problems, and the risk of failure increases.

Summary Vulnerability Assessment

This planning effort did not include inundation mapping for Brown County's dams. An inundation map, which requires a detailed engineering study, is required to accurately determine the numbers and replacement costs of facilities that reside downstream of dams. To estimate possible vulnerability, GIS was used to perform a simple analysis of building exposure within the 1% flood boundary five miles downstream of the two high hazard dams. The building exposure (not estimated losses) totals over $ 52,865,000.

Previous Occurrences for Dam and Levee Failure

According to the Brown County planning team, there are no records or local knowledge of any dam or certified levee failure in the county. State records indicate some spillway incidents at the Russellville Reservoir Dam and Wagon Wheel Lake Dam. Table 5-44 lists these incidences.

NID Number	Structure Name	Incident Date	Incident	Dam Failure (Y/N)
OH00770	Russellville Reservoir Dam	2/12/1998	Inadequate Spillway Capacity	NO
OH01268	Wagon Wheel Lake Dam	2/12/1998	Inadequate Spillway Capacity	NO

Geographic Location for Dam and Levee Failure

The United States Army Corps of Engineers (USACE) identified 20 dams in Brown County, the Ohio Department of Natural Resources (ODNR) identified an additional 5 dams. Brown County has all earthen dams. Seven of the dams are owned by the local government, one by the state (Lake Grant Dam) and the remaining dams are private. Table 5-45 lists the dams. The National Levee Database does not identify any levees within Brown County.

Table 5-45: ODNR Dam Information for Brown County

Facility Name	Hazard Potential	Name of River	Nearest City to Dam	Distance to Nearest City (mile)
Bailey Lake/Evans Lake Dam	L	Indian Creek-Tr	Blue Sky Park	12.9

Facility Name	Hazard Potential	Name of River	Nearest City to Dam	Distance to Nearest City (mile)
Dieckbrader Lake Dam	S	Salt Lick Creek-Tr	Chasetown	0.8
Fayetteville High School Lake Dam	H	E Fork Little Miami River-Tr	Fayetteville	0.4
Fichtelberg Lake Dam	L	Glady Run-Tr	Blowville	12.5
Georgetown Upground Reservoir	S	White Oak Creek-Os	Higginsport	7.5
Hrametz Lake Dam (ODNR)	L	White Oak Creek-Tr	Higginsport	8
Indian Valley Lake Dam (ODNR)	L	White Oak Creek-Tr	New Hope	1.5
Lake Grant Dam	S	Sterling Run	White Oak Valley	7.5
Lake Lorelei Dam	S	Glady Run	Blowville	10.6
Lake Lorelei Upground Reservoir (ODNR)	S	Glady Run-Os	Blowville	9.8
Lake Waynoka Dam	H	Straight Creek	Arnheim	1.9
Lake Waynoka Retention Dam	L	Sycamore Run	Arnheim	1.9
Lake Waynoka Upground Reservoir	S	Sycamore Run-Os	Arnheim	1.9
Mount Orab Upground Reservoir No. 2	S	Sterling Run-Os	Mt. Orab	0.4
Noe Lake/Brodie Lake Dam	L	West Branch Bullskin Creek-Tr	Rural	8
Possum Hollow Farm/Winandi Lake Dam	L	E Fork Little Miami River-Tr	Fayetteville	4.9
Pschesang Lake Dam	L	East Fork Little Miami Rv-Tr	Fayetteville	2.8
Russellville Reservoir Dam	L	West Fork Eagle Creek-Tr	Russellville	1.1
Russellville WWT Lagoon Basin #1	S	Eagle Creek	Neel	12
Russellville WWT Lagoon Basin #2	S	Eagle Creek	Neel	12
Saint Martin Reservoir Dam (ODNR)	S	Solomon Run	Fayetteville	3
Sardinia Reservoir Dam	S	East Fork White Oak Creek-Tr	Sardinia	0.4
Starling Lake Club Dam (ODNR)	L	Snow Run	Batavia	17
Wagon Wheel Lake Dam	S	Cloverlick Creek	Yankeetown	0.75
Waynoka Wwt Lagoon	S	Sycarmore Run-Tr	Village Of Arnheim	0.8

Hazard Extent for Dam and Levee Failure

When dams are assigned the low (L) hazard potential classification, it means that failure or incorrect operation of the dam will result in no human life losses and no economic or environmental losses. Losses are principally limited to the owner's property. Dams assigned the significant (S) hazard classification are those dams in which failure or incorrect operation results in no probable loss of human life; however it can cause economic loss, environment damage, and disruption of lifeline facilities. Dams classified as significant hazard potential dams are often located in predominantly rural or agricultural areas, but could be located in populated areas with a significant amount of infrastructure. Dams assigned the high (H) hazard potential classification are those dams in which failure or incorrect operation has the highest risk to cause loss of human life and significant damage to buildings and infrastructure.

The ODNR-Dam Safety Program assigns the hazard potential for dams and levees as Class I, Class II, Class III, and Class IV. An EAP is required by the State of Ohio for all dams and levees identified as Class I, II, or III under the state classification system. Table 5-46 describes each hazard and provides the corresponding federal classification. Table 5-47 describes each levee hazard classification.

Table 5-46: Ohio Dam Hazard Classifications

Ohio Classification	Federal Classification	Description
Class I	High	Probable loss of life, serious hazard to health, structural damage to high value property (i.e. homes, industries, major public utilities)
Class II	High	Flood water damage to homes, businesses, industrial structures (no loss of life envisioned), damage to state and interstate highways, railroads, only access to residential areas.
Class III	Significant	Damage to low value, non-residential structures, local roads, agricultural crops, and livestock.
Class IV	Low	Losses restricted mainly to the dam

Table 5-47: Ohio Levee Hazard Classifications

Hazard Classification	Description
Class I	Probable loss of human life, structural collapse of at least one residence or one commercial or industrial business
Class II	Disruption of a public water supply or wastewater treatment facility, or other health hazards; flooding of residential, commercial, industrial, or publicly owned structures; damage or disruption to major roads and access to critical facilities; damage or disruption to railroads or public utilities
Class III	Property losses including but not limited to rural buildings, not otherwise described; damage or disruption to local roads
Class IV	Levee having a height of not more than three feet; losses restricted mainly to the levee, owner's property and rural lands.

According to USACE two dams are classified as high hazard: Fayetteville High School Lake Dam and the Lake Waynoka Dam. Accurate mapping of the risks of flooding behind levees depends on knowing the condition and level of protection the levees actually provide. FEMA and the U.S. Army Corps of Engineers are working together to make sure that flood hazard maps clearly reflect the flood protection capabilities of levees, and that the maps accurately represent the flood risks posed to areas situated behind them. Levee owners—usually states, communities, or in some cases private individuals or organizations—are responsible for ensuring that the levees they own are maintained according to their design. In order to be considered creditable flood protection structures on FEMA's flood maps, levee owners must provide documentation to prove the levee meets design, operation, and maintenance standards for protection against the one-percent-annual chance flood.

Risk Identification for Dam/Levee Failure

Rank	Hazard	RISK PARAMETERS					
		History	Area	Prediction	Prep.	Human Impact	Economic Impact
10	Dam/Levee Failure	>100 years	Multi-jurisdictional	Cannot predict	Can only prepare to reduce human impact, cannot reduce economic impact	Shelter and/or evacuation or other protective measures required for 75% of the population involved	25% damage and/or destroyed and business interruption

Brown County ranked dam/levee failure hazard as the number ten priority hazard based on the frequency, preparedness and potential damage the disaster can cause. The probability of this disaster occurring, based on known recorded history, is 0%. However, Brown County recognizes the human and economical impact a dam or levee failure could have on the community.

Vulnerability Analysis for Dam and Levee Failure

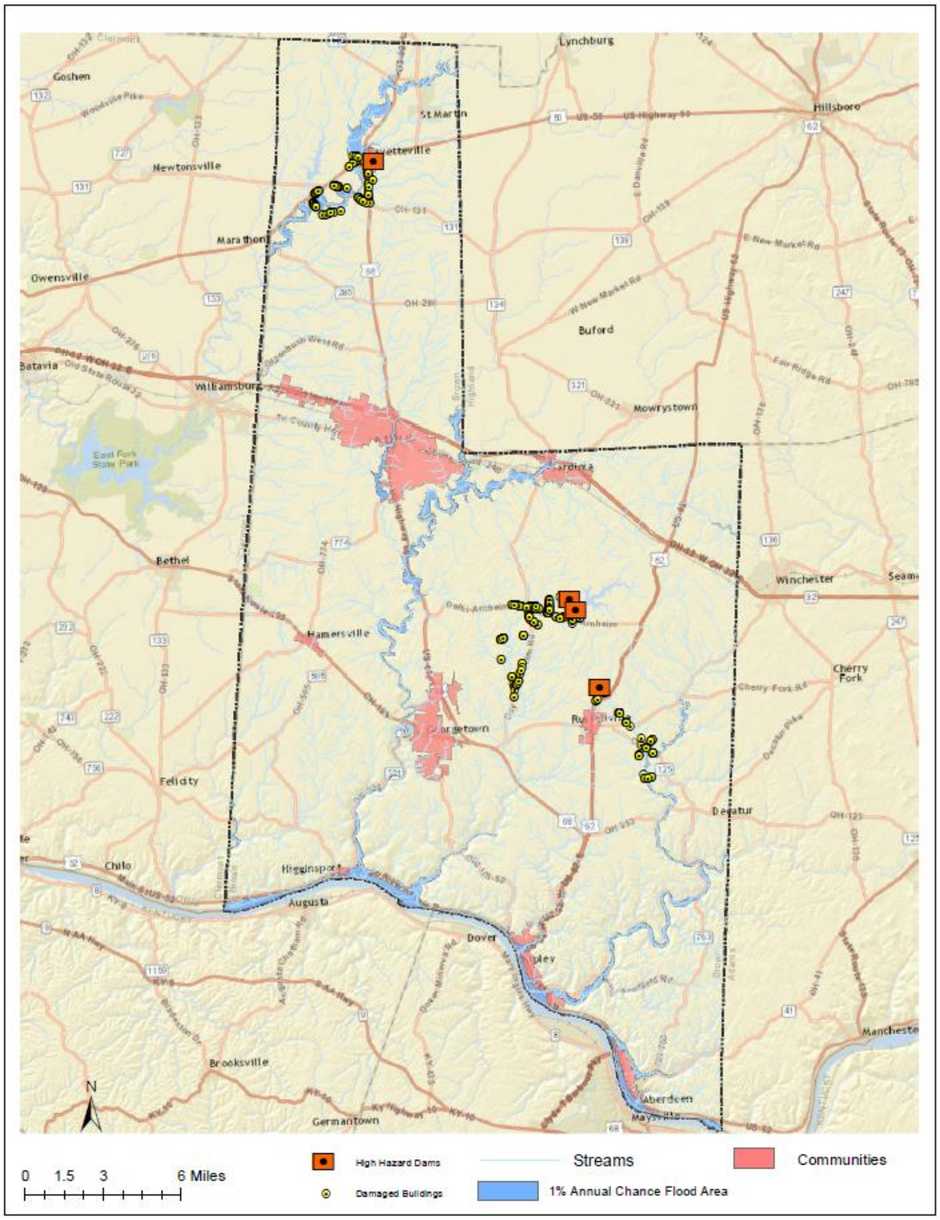
Inundation maps are required to assess the impacts of dam and levee failures on communities. In order to be considered creditable flood protection structures on FEMA's flood maps, levee owners must provide documentation to prove the levee meets design, operation, and maintenance standards for protection against the "one-percent-annual chance" flood.

To estimate possible exposure, to dam failure, analysts identified buildings within five miles downstream of the high hazard dams within the 1% flood hazard area. The results are depicted in Table 5-48 and Figure 5-34.

Table 5-48: Building Exposure (not potential losses) within 5-mile distance downstream from the High Hazard Dams

Facility Name	Name of River	Building Exposure ($)	Nearest City to Dam	Distance to Nearest City (mile)
Lake Waynoka Dam	Straight Creek	18,046,586	Arnheim	1.9
Fayetteville High School Lake Dam	E Fork Little Miami River-Tr	14,339,526	Fayetteville	0.4

Figure 5-34: Building Exposure within 5-mile distance from High Hazard Dams



Vulnerability to Future Assets/Infrastructure for Dam and Levee Failure

The county recognizes the importance of maintaining its future assets, infrastructure, and residents. Inundation maps can highlight the areas of greatest vulnerability in each community.