2.2 PROFILE HAZARDS

§201.6(c)(2)(i)	[The risk assessment shall include a] description of the…location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.

2.2.1 Section Overview

Several hazards affect Washington County, as noted in the Section 2.1 above. Those hazards; however, may not affect the county in ways that residents and planners may typically think. Additionally, while a hazard may occur frequently, it may cause little damage or disruption; conversely, a hazard that rarely occurs may cause significant damage and disruption. As such, this section contains a profile of each hazard considered by this plan, which provides details on how the hazard impacts the area. Additionally, this section discusses a number of complicating variables that could either result in emergencies on their own or add to the complexity of the profiled hazards.

2.2.2 DAM FAILURE

Dam Failure Snapshot	
"Dam failures pose the most extreme flood risk due to the sudden and severe impacts that can result" (Haddow, Bullock, & Coppola, 2014, pg.54).	
Period of Occurrence	At any time
Number of Events (1994-2015)	2
Probability of Event	0.1 *Dams that fail typically have some deficiency which should be detected by regular inspections and appropriate repair. Heavy rains or moderate earthquakes may also trigger a dam failure.*
Warning time	Minimal: Depends on frequency of inspection and repair.
Potential Impacts	Potential for loss of life, economic loss, environmental damage and distribution of life
Cause Injury or Death	Risk of multiple injuries and deaths.
Potential Facility Shutdown	30 days or more
Loss Estimate	$3,495,562.68/event

The Ohio Division of Natural Resources (ODNR) defines a dam as "an artificial barrier usually constructed across a stream channel to impound water" (ODNR, 2016.) In Ohio, a dam must have spillway systems to safely convey normal stream and flood flows over, around, or through the dam (ODNR, 2016). Most of the dams in Ohio were constructed by farmers and other individuals and are small dams. The State of Ohio operates more than 100 dams in the state, while the federal government operates over 30. Dams have a variety of uses, from flood control and water supply to recreation (ODNR, 2016). The ODNR is also the agency responsible for the regulation of levees in Ohio. According to the ODNR, "a levee is any artificial barrier together with appurtenant works that will divert or restrain the flow of a stream of other body of water for the purpose of protection an area from inundation by flood water" (ODNR, 2016). While dams constantly control the flow of water, most levees are built purely for flood control and protection.

Dams are classified into four categories by the ODNR based on their hazard potential, height, and/or their total storage volume. Dams are classified as Class I, Class II, Class III, or Class IV.

- **Class I:** Dams having a total storage volume of more than 5,000 acre-feet or having a height greater than 60 feet. Also includes dams where a sudden failure would result in the probable loss of human life or the structural collapse of one residence, one commercial structure or one industrial structure.
- **Class II:** Dams having a total storage volume of more than 500 acre-feet or having a height greater than 40 feet. Also includes dams where a sudden failure would result in:
  - Disruption of a public water supply or wastewater treatment facility, release of health hazardous industrial or commercial waste, or other health hazards
  - Flooding of residential, commercial, industrial, or publicly owned structures
  - Flooding of high-value property
  - Damage or disruption to major roads including but not limited to interstate and state highways, and the only access to residential or other critical areas such as hospitals, nursing homes, or correctional facilities as determined by the chief
  - Damage or disruption to railroads or public utilities
  - Damage to downstream class I, II or III dams or levees, or other dams or levees of high value. Damage to dams or levees can include, but is not limited to, overtopping of the structure

- **Class III:** Dams having a total storage volume greater than 50 acre-feet or a height greater than 25 feet. Also includes dams where a sudden failure would result in property losses including rural buildings and class IV dams and levees.
- **Class IV:** Dams having a total storage volume of 50 acre-feet or less and a height of 25 feet or less. Sudden failure of a Class IV dam would result in property losses restricted mainly to the dam and rural lands (ODNR, 2016).

The ODNR classifies levies in much the same way, however only the effects of a levee failing are considered for Classes I-III. Only Class IV has a height definition, which is not more than 3 feet.

According to the Ohio Hazard Mitigation Plan (HMP) the dam classification corresponds to the federal classification as follows: Class I corresponds to high hazard, Class II and III correspond to significant hazard, and Class IV corresponds to low hazard.

Dam failure is often the result of prolonged rainfall or flooding or, during prolonged dry periods, erosion. The primary hazard surrounding dam failure is the swift and

unpredictable flooding of areas immediately downstream. According to the Association of State Dam Safety Officials (ASDSO) most dam failures fall into one of three categories: structural failures, mechanical failures and hydraulic failures.

- Structural failures: Foundation defects, including settlement and slope instability or damaged cause by earthquakes, have cause about 30% of all U.S. dam failures.
- Mechanical failures: Malfunctioning gates, conduits or valves can cause dam failure or flooding both upstream and downstream.
- Hydraulic failures: Overtopping of a dam is often a precursor of dam failure. National statistics show that overtopping due to inadequate spillway design, debris blockage of spillways or settlement of the dam crest account for approximately 34% of all U.S. dam failures (2012, pg.8).

Because dam failures have the potential to result in loss of life and severe economic loss, the American Society of Civil Engineers (ASCE) recommends that all high hazard dams have any emergency action plan in the event of an impending failure (ASCE, 2013). An emergency action plan, or EAP, is “an essential plan used in the event of a dam failure to identify and notify people residing below the dam, and to coordinate their evacuation” (ASCE, 2013). The Ohio HMP states that “all classes are required to have EAPs and Class I’s are required to include dam failure inundation mapping” (2011).

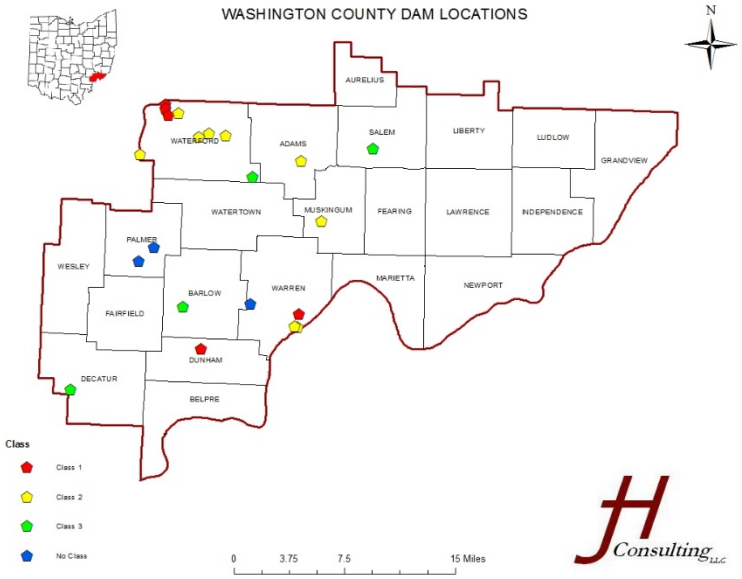
LOCATION

There are 21 dams located within Washington County according to information provided by Washington County officials. Five of these dams are Class I dams, nine are Class II dams and four are Class III dams. The remaining three are not classified in the ODNR database.

Name	Township	Class
BADGER POND DAM	DECATUR	3
CARMAN LAKE DAM	WATERFORD	2
CHOPPER S LAKE DAM	WATERFORD	2
DAVLIN LAKE DAM	BARLOW	3
ERAMET FLUID WASTE POND 1A	WARREN	2
ERAMET SLAG TAILINGS POND	WARREN	2
ERAMET WASTE RETENTION DAM	WARREN	1
GOODFELLOWS PARK LAKE DAM	WARREN	Other
MUSKINGUM RIVER LOCK AND DAM NO. 2	MUSKINGUM	2
MUSKINGUM RIVER LOCK AND DAM NO. 3	ADAMS	2
MUSKINGUM RIVER LOCK AND DAM NO. 4	WATERFORD	2
MUSKINGUM RIVER LOCK AND DAM NO. 5	WATERFORD	2
MUSKINGUM RIVER LOWER FLY ASH DAM	WATERFORD	1
MUSKINGUM RIVER MIDDLE FLY ASH DAM	WATERFORD	1
MUSKINGUM RIVER UPPER FLY ASH DAM	WATERFORD	1
STRAHLER S LAKE DAM	WATERFORD	3
UNITS 1-4 BOTTOM ASH POND DAM	WATERFORD	2
VETO LAKE DAM	DUNHAM	1
WAGNER POND DAM	PALMER	Other
WAGNER S POND DAM	PALMER	Other
WASHINGTON CO. FISH & GAME CLUB LAKE	SALEM	3

These dams extend over much of the western portion of Washington County, with Salem Township being the farthest east location. The map below shows the locations of the various dams in Washington County.

EXTENT



Of the twenty-one dams located within Washington County only one is listed as having an emergency action plan in place (Eramet Waste Retention Dam in Warren Township, a Class I dam.)

Three of the dams in Washington County are located near municipal areas. The Carman Lake Dam and the Muskingum River Lock and Dam #4 are both located on the edge of Beverly. The Muskingum River Lock and Dam #3 is located just west of the Lowell municipal limits. Additionally, a number of these dams are located along or near the Muskingum River. This river runs adjacent to Beverly, Lowell and the Devola area and through the heart of Marietta. Any failure or incidence that results in a large release into the river could have a significant impact downstream.

HISTORICAL OCCURRENCES

The Stanford National Performance of Dams Program (NPDP) tracks dam incidents that occur around the world and collects data related to these incidents. According to the NPDP there have been two incidents within Washington County in the last 21 years. Neither of these incidents resulted in damage to any property other than the dam.

Waterford Township, Ohio

The first of these events occurred on April of 1994 when a heavy rainfall resulted in the failure of the Choppers Lake Dam in Waterford Township. A breach approximately eight feet deep appeared after earth adjacent to the spillway eroded, causing the spillway discharge chute to collapse. The breach sent water from the dam into the Muskingum River. There was no downstream damage reported and it is unknown if an EAP was in place or implemented (Stanford NPDP).

Palmer Township, Ohio

The second dam failure in Washington County listed in the NPDP database occurred less than two years later, in February of 1996. This incident occurred at the Wagner S Pond

Dam in Palmer Township and was reported to be an incident of inadequate spillway capacity. The record shows that there was no uncontrolled release of the reservoir and there were no documented consequences. It is unknown if an EAP existed or was implemented (Stanford NPDP).

The Ohio HMP shows that are no levees or floodwalls located in or near Washington County.

VULNERABILITY ASSESSMENT

Loss estimates and vulnerable structures for a dam incident were generated using a multistep analysis. The total number of structures estimated by HAZUS-MH as moderately damaged by the 100-year flood was identified as 451. The number of total structures identified in this manor was then divided by the number of Class I, II, and III dams present in the county (18) to estimate the number of vulnerable structures for any one dam failure. This figure was then multiplied by the percentage of each structure type found in the county as generated by the Ohio EMA's HAZUS-MH loss estimate workbook. Average structural value for each type was also obtained from the loss estimate workbook, generating the figures in the table below.

Structure Type	Number	Loss Estimate
Residential	18	$2,482,275.34
Non-Residential	6	$838,681.71
Critical Facilities	1	$127,605.64
Total	**25**	**$3,495,562.68**

Research Sources:

- Ohio Division of Natural Resources (ODNR)
- Interviews with Local Officials
- American Society of Civil Engineers (ASCE)
- Ohio Emergency Management Agency
- Association of State Dam Safety Officials (ASDSO)
- Stanford University's National Performance of Dams Program

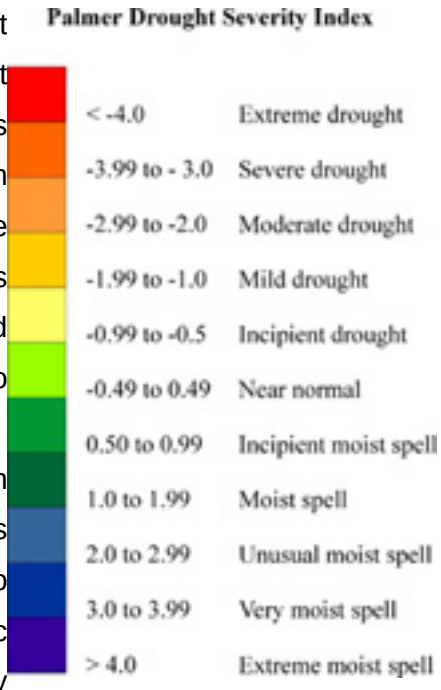
2.2.3 DROUGHT

Drought Snapshot	
"A prolonged shortage of available water, primarily due to insufficient rain and other precipitation or because exceptionally high temperatures and low humidity cause a drying of agriculture and a loss of stored water resources" (Haddow, Bullock, & Coppola, 2014, pg.51).	
Period of Occurrence	Warm weather months or periods of low to no precipitation
Number of Events (1999-2015)	6
Probability of Event	0.38
Warning time	Weeks
Potential Impacts	Industries that rely heavily on water usage will be disproportionately affected. These industries primarily include tourism and agriculture. The impact will spread as droughts extend and increase in severity.
Cause Injury or Death	None
Potential Facility Shutdown	None
Climate Change Impact	Significant
Extent	Countywide
Loss Estimates	Worst Case Scenario: Greater than $30 Million (Loss of an entire year's crop)

A drought, according to the National Climactic Data Center (NCDC), is a complex event that is difficult to monitor or define. There are four types of droughts, increasing in severity level; meteorological drought, hydrological drought, agricultural drought, and socioeconomic drought.

- Meteorological drought: dry weather patterns dominating an area.
- Hydrological drought: Usually after several months of meteorological drought, when low water supplies become noticeable. I.E. low water levels in streams and reservoirs.
- Agricultural drought: When crops become affected by the drought conditions.
- Socioeconomic drought: Relates the supply and demand of various commodities to drought.

The most prevalent method of measuring drought severity in the United States is the Palmer Drought Severity Index (PDSI) developed in 1965. The index takes a number of factors into account to assign a score between -4 (extremely dry) and +4 (extremely wet), with 0 being the "normal" value (Palmer, 1965.) Palmer drought values typically reflect long term drought, but can be calculated both monthly and weekly. The PDSI is shown graphically to the right.



Droughts can also impact drinking water both in terms of availability and demand. According to the EPA as temperatures rise, people and animals need more water to maintain health. Additionally a large number of economic activities require abundant water sources such as energy production (hydroelectric and nuclear power generation for example) and growing food crops. As available water sources are reduced by droughts water usage will need to be closely monitored to maintain enough for critical uses. This has been seen on numerous occasions in drought prone areas such as southern California.

LOCATION

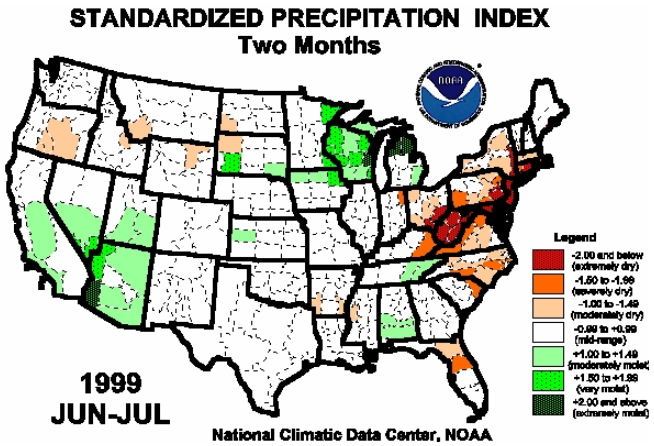
Washington County is susceptible to drought conditions, and has experienced these conditions in the past. Generally, the extent of drought conditions would encompass the entire county, as well as neighboring counties. This hazard is a countywide hazard that can affect all areas and jurisdictions of the county.

EXTENT

Droughts can do significant economic damage in heavily agrarian areas and can cause significant problems for societies in general, especially when occurring concurrently with high temperatures. Washington County does have a significant agricultural sector, according to the U.S. Department of Agriculture's (USDA) county profile. In 2012 Washington County had 1,122 farms, consisting of 138,940 acres and producing over $30 million of crops and livestock (USDA, 2012). An agricultural level drought would cause significant economic loss for the farmers in Washington County.

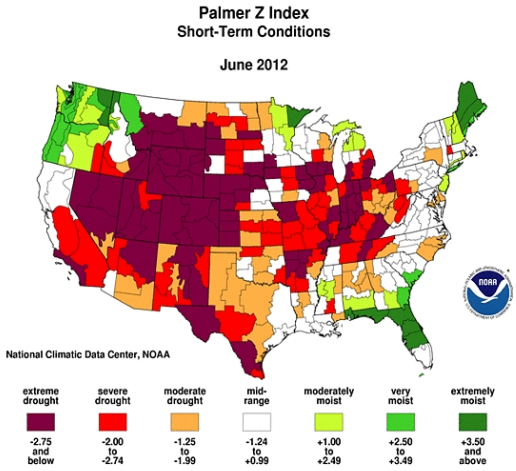
HISTORICAL OCCURRENCES

Washington County, Ohio



In the summer of 1999, a significant drought event impacted Washington County and the surrounding counties. The Standard Precipitation Index, as reported by the NCDC, in June and July 1999 was "-2.00 and below" in the southeastern portion of Ohio, indicating that that the area was extremely dry. In July of 1999 the same region saw between 20 and 25 days of 90 degree + temperatures. This was between 6 and 12 more days than average per the NCDC. The drought of 1999 is the most significant in the NCDC event archives for Washington County.

Washington County, Ohio



In the summer of 2012 a drought that had been limited to the southern United States spread throughout most of the county, as can be seen in the June Palmer index shown below. This drought impacted most of the state of Ohio, including Washington County. According to AON Benfield, an insurance broker, the 2012 drought resulted in over $35 billion in total damages in the U.S (2013).

VULNERABILITY ASSESSMENT

Structures are rarely affected by this type of hazard. Droughts usually affect people, animals, and crops.

Crop Loss Study

To determine the historical impact of a drought on the agricultural industry in Washington County a crop loss study was performed. A drought year (2012) was compared to a non-drought year (2011) to identify differences in output that may have resulted from the drought conditions.

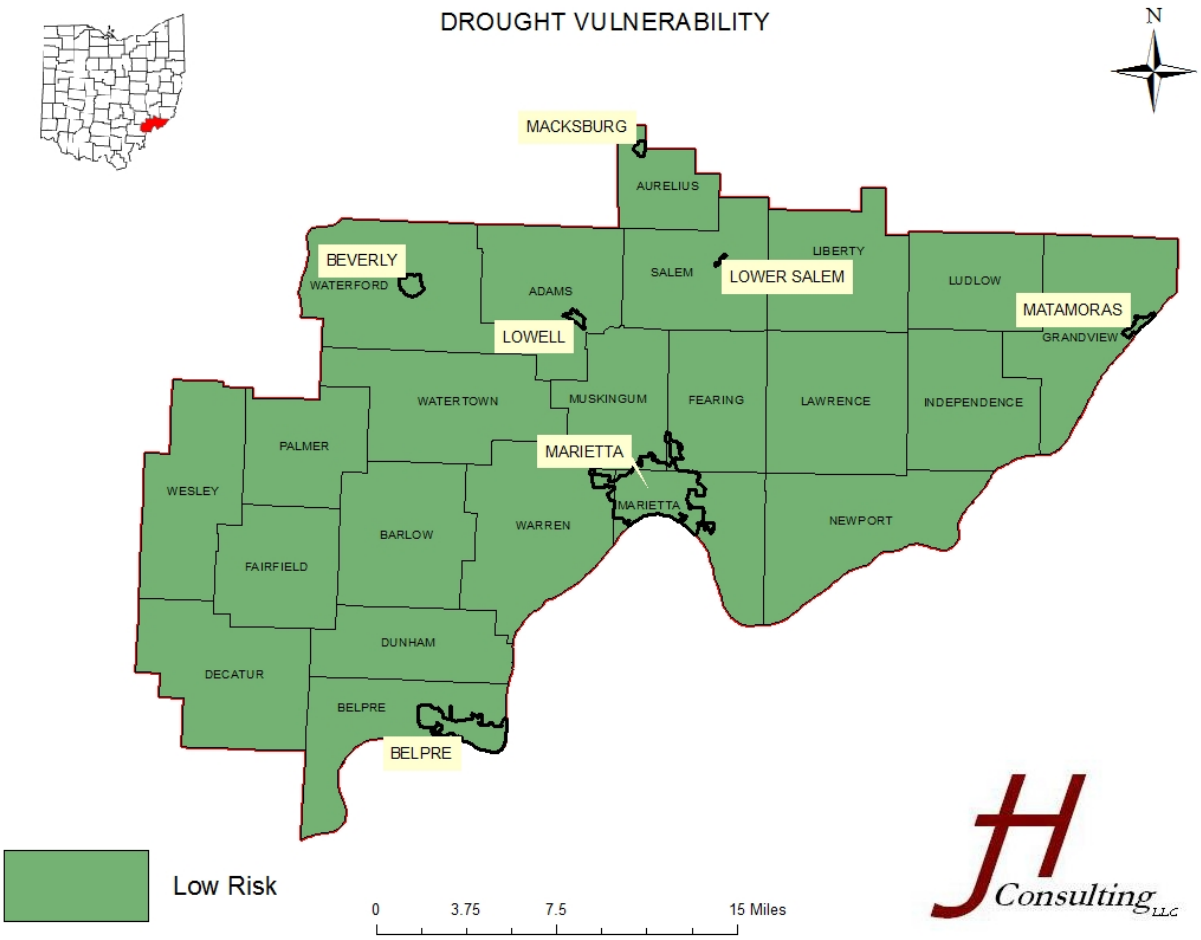
Using the USDA's National Agricultural Statistics Service (NASS), the crop production numbers for four major crops in Washington County were found for 2011 and 2012. Production of corn, hay (excluding alfalfa), soybeans and winter wheat were compared between the two years. The results are shown in the table below. Three of the four crops saw decreases in yield of varying amounts, while soybeans saw an increase in yield. Overall in Washington County agricultural yield decreased by 360,800 units, a reduction of 21.08%, between 2011 and 2012. Using the same data set from the USDA to obtain production amounts for 2013 show that this drop in production was most likely caused by the drought conditions. Production of corn, hay and winter wheat all recovered significantly in 2013 with corn production surpassing the number of bushels produced in 2011.

Production (Bushels or Tons)				
Product	2011	2012	Difference	%Δ
Corn	1,320,000	932,000	(388,000)	-29.39%
Hay	34,900	28,500	(6,400)	-18.34%
Soybeans	296,000	370,000	74,000	25.00%
Wheat	60,900	20,500	(40,400)	-66.34%
Total	1,711,800	1,351,000	(360,800)	-21.08%

Research Sources:

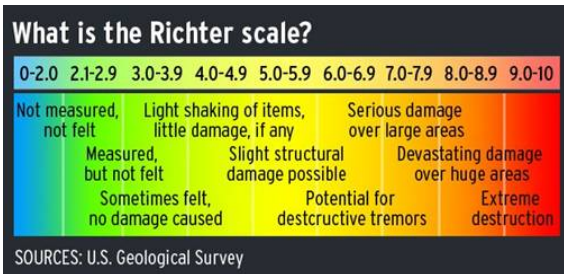
- NOAA National Climactic Data Center (NCDC) Storm Events Database
- USDA National Agriculture Statistics Service
- Environmental Protection Agency (EPA)

RISK MAP



2.2.4 EARTHQUAKES

Earthquake Snapshot	
"Sudden, rapid shaking of the earth's crust cause by the breaking and shifting of tectonic plates beneath the earth's surface" (Haddow, Bullock, & Coppola, 2014, pg.34).	
Period of Occurrence	At any time
Number of Events (2010-2015)	7
Probability of Event	1.4
Warning time	None to Limited
Potential Impacts	Little damage
Cause Injury or Death	Minor risk of injury
Potential Facility Shutdown	Hours
Extent	Marietta, Muskingum, and Newport Townships
Loss Estimate	HAZUS: $1,910,458,279



An earthquake's sudden release of stored energy may manifest itself by the shaking or displacement of the ground. The magnitude of an earthquake is a measurement of its severity and is measured using the Richter scale, developed in 1935. The magnitude of an earthquake can range between less than 2.0 and 9.0 and greater. The image to the right shows the Richter scale and what effects each magnitude can have. The effects of an earthquake can be felt far beyond the site of its occurrence.

According to the U.S. Geological Society, based on historical trends, the frequency of an earthquake occurrence is inversely related to its magnitude. There are an estimated 1.3 million earthquakes every year with a magnitude between 2.0 and 2.9 while there is, on average, 1 magnitude 8.0 or higher earthquake annually.

The modified Mercalli scale measures earthquakes based on their intensity on the surface. This scale, shown to the right, uses roman numerals I through XII to denote detection and damage levels associated with an earthquake.

Modified Mercalli Scale		Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	4.5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	5.5
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	6.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air	7
		7.5
		8

LOCATION

The location of these events has been confined to three of the county's twenty-two townships, located in the southern area of the county near the City of Marietta. The below image shows the location of epicenters within Ohio. Washington County has experienced 7 epicenters since 2010.

EXTENT

Ohio earthquakes are shallow focus events that occur in the upper portions of the earth's crust (Hansen, 2015). Hansen also relates that more than 200 earthquakes of magnitude 2.0 or greater have occurred in Ohio since 1776, with 15 of these events being known to cause damage of minor to moderate extent. Historically there have been zero deaths and minor injuries from these occurrences (2015). There are three fault lines either within or directly adjacent to Washington County. These fault lines are shown in the image to the right, from the Ohio Department of Natural Resources (ODNR). Six of the seven epicenters were of a 2.0 to 3.0 magnitude while the remaining epicenter was 4.0-5.0 in magnitude.

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HISTORICAL OCCURRENCES

While earthquakes have historically
have been eight earthquakes recorded sin
Geological Survey.

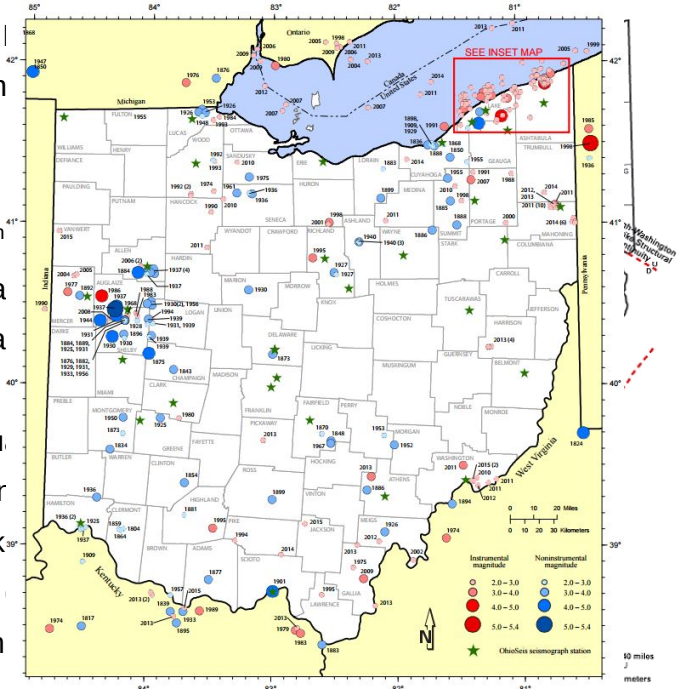
Marietta, Ohio

In the early morning of October 24th
five miles ENE of Marietta. Residents were a
followed by brief shaking that rattled glasswa

Marietta, Ohio

On August 31st, 2011, two earthqu
County. The first was a 2.8 magnitude ever
number of residents. A stronger aftershock
Marietta and neighboring communities. No
residents described hearing a loud boom
aftershock.

Marietta, Ohio



In the morning of September 4th, 2011, a small 2.6 magnitude earthquake was felt about 13 miles southeast of Marietta. Residents reported feeling the event, but no damage was reported.

Marietta, Ohio

The most recent event in the ODNR database was a 2.2 magnitude earthquake that occurred at 9:34 a.m. on July 19th, 2015. This event was recorded by the monitoring station in Marietta but no reports of feeling the earthquake were received.

All data on historical events are from the ODNR Division of Geological Survey (http://geosurvey.ohiodnr.gov/earthquakes-ohioseis/quakes-felt-in-ohio/catalog-of-past-ohio-quakes/20-quakes-by-year/2010-to-present).

FRACKING EFFECTS

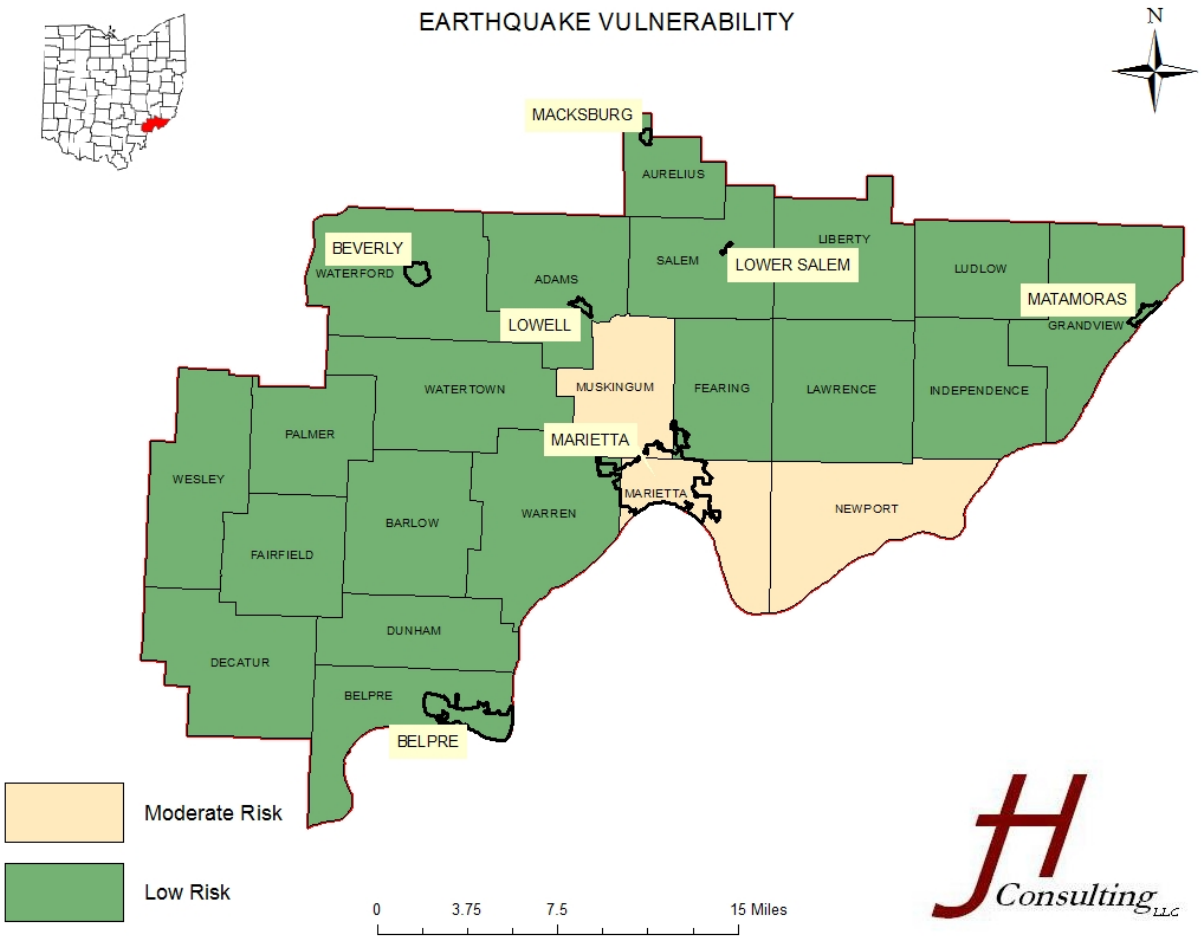
The growth of the practice of hydraulic fracturing, more commonly known as fracking, in the oil industry has led to the occurrences of earthquakes in areas of Ohio according to a study by a Miami University of Ohio graduate student. Skoumal, Brudzinski and Currie found that a well in Mahoning County, in eastern Ohio, was located near an unknown fault line and the fracking activity triggered “scores of small earthquakes in March 2014, including one large enough to be felt in nearby towns” (2015). A similar event occurred near Youngstown, OH in 2011, but was related to wastewater injection rather than hydraulic fracturing (Skoumal, Brudzinski and Currie, 2015). The oil and gas industry is highly active in Washington County, with large numbers of permitted and producing wells located in the county according to the Ohio DNR Division of Oil and Gas. While not all of these wells, or even most, are actively using hydraulic fracturing, the existence of multiple fault lines within and immediately adjacent to the county is a possible area of concern for future earthquake events.

VULNERABILITY ASSESSMENT

The effects of a potential earthquake striking Washington County was analyzed using the HAZUS program from the Federal Emergency Management Agency. The output was provided by the Ohio EMA. The scenario depicts a 5.4 magnitude occurring in downtown Marietta, within two blocks of the Marietta College campus. The table below, compiled from the HAZUS output via the loss estimation workbook provided by Ohio EMA, shows the number of structures damaged and the estimated damage cost.

Structure Type	Number	Loss Estimate
Residential	5,101	$1,227,121,559.74
Non-Residential	678	$590,194,007.11
Critical Facilities	203	$93,142,712.04
TOTALS	**5,886**	**$1,910,458,278,89**

RISK MAP



Research Sources:

- US Geological Survey (USGS)
- Ohio Division of Natural Resources (ODNR)
- Skournal, Brudzinski, and Currie (Miami University)
- Ohio Emergency Management Agency

2.2.5 EXTREME TEMPERATURES

Extreme Temperatures Snapshot	
"Major diversions in average seasonal temperatures can cause injuries, fatalities, and major economic impacts when they are prolonged or coincide with other natural or technological events" (Haddow, Bullock, & Coppola, 2014, pg.51).	
Period of Occurrence	Any season, but generally summer and winter
Number of Events (1996-2015)	46
Probability of Event	2.42
Warning time	Weeks
Potential Impacts	Economic impacts. Overloaded utility grids
Cause Injury or Death	Injury and potential deaths
Potential Facility Shutdown	Days to weeks
Extent	County wide
Loss Estimate	Yearly: $14,017.50 Worst Case Scenario: $115,000

Temperatures vary widely over the course of a year, but each season has general temperature ranges associated. Summer and winter have, generally, the highest and lowest range of temperatures, respectively. When the temperature is consistently greater than the normal in summer, meteorologists refer to it as a heat wave, which is defined as "temperatures of ten or more degrees above the average high temperature persist across the geographic region for several days or weeks" (Haddow, Bullock, & Coppola, 2014, pg.51). These conditions can be a

NOAA's National Weather Service

Heat Index

Temperature (°F)

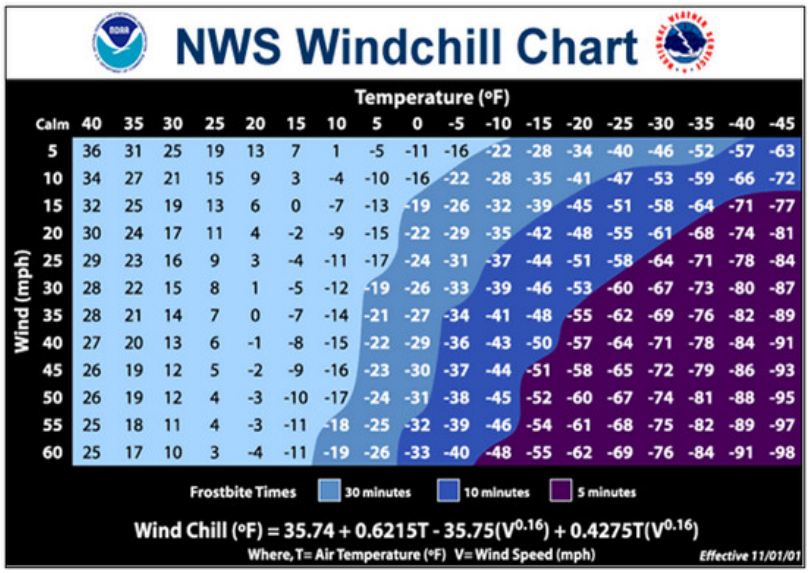
Relative Humidity (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	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

contributor to drought conditions when combined with a lack of rainfall. Excessive heat has a history of being deadly. In the United States "more than 1,500 die from exposure to excessive heat" (Haddow, Bullock, & Coppola, 2014, pg.52). These conditions can also have serious impacts on crops, causing below average harvests. Repeated years of extreme temperatures can easily cause significant economic impacts on agricultural industries.

While there is no widely accepted definition of extremely cold temperatures, periods of colder than average conditions can cause an array of negative consequences depending on their duration (Haddow, Bullock, & Coppola, 2014, pg.51). Extremely cold temperatures are immediately dangerous to both humans and livestock by causing frostbite and hypothermia, which can lead to permanent injury and death. The chart to the left shows how quickly frostbite can occur at different temperatures and wind speeds. In unprotected structures cold temperatures can freeze water pipes causing them to burst upon thawing, leading to significant damage. Cold snaps during typically warmer weather during the growing season can damage and destroy some crops, depending on their sensitivity to temperature.



NWS Windchill Chart

Wind (mph) \ Temperature (°F)	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

The National Climatic Data Center (NCDC) tracks four types of extreme temperatures: Cold/Wind Chill, Extreme Cold/Wind Chill, Heat, and Excessive Heat.

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

(typical value around -35 F or colder), on a widespread or localized basis. Normally these conditions should cause significant human and/or economic impact.

- **Heat:** A period of heat resulting from the combination of high temperatures (above normal) and relative humidity. A heat event occurs whenever heat index values meet or exceed locally/regionally established advisory thresholds or a directly-related fatality occurs due to the heat event.
- **Excessive Heat:** Excessive Heat results from a combination of high temperatures (well above normal) and high humidity. An Excessive Heat event occurs when heat index values meet or exceed locally/regionally established excessive heat warning thresholds, on a widespread or localized basis (National Weather Service Instruction 10-1605, 2007).

LOCATION

This hazard is a countywide hazard that can affect all areas and jurisdictions of the county.

EXTENT

Over the prior 19 years there have been forty-six recorded records of excessive temperature events that have occurred in Washington County per the NCDC. Excessive temperature events have a large extent by their nature. Generally such an event will occur in all parts of Washington County as well as in neighboring counties.

The table to the right shows the breakdown of these events by the types defined above. Cold events are more prevalent than heat events based on the historical data. Additionally, all the property damage listed in the NCDC data is associated with cold events, totaling $267,000 over the previous 19 years. Heat events can often be associated and occur at the same time as drought events, as an exacerbating factor. The data from the NCDC shows no deaths, injuries or crop damage associated with any of the extreme temperature events. Loss estimates can be found using the historical data found in the NCDC information. In this case since only cold events have historically caused damage, loss estimates are based on those events. In the past 19 years there have been 28 incidents, averaging to 1.47 per a year. On average, an event will cause $9,535.71 in

Type	#
Cold/Wind Chill	21
Extreme Cold/Wind Chill	7
Heat	10
Excessive Heat	8
Total	46

property damage. Therefore cold events will cause a loss of $14,017.50 in property damage yearly. The worst case scenario, historically, is an event that causes $115,000 in damage.

HISTORICAL OCCURRENCES

Washington County, Ohio

The two most recent heat events to occur in Washington County are recorded as being in late July of 2011. The NCDC event record reports that temperatures ranging into the mid-90s for three days (20th-22nd) were common, with the hottest temperatures being recorded near the Ohio River. Heat index values in the area reached around 105 degrees. Thunderstorms moving through the area provided some relief from the heat, but temperatures and humidity built again on the 28th and lasted until the 29th with temperatures again in the mid-90s and heat indexes between 100 and 105 degrees (NCDC).

Washington County, Ohio

In the early morning of January 6th, 2014, an arctic cold front swept through southeastern Ohio, causing temperatures to fall from the 40s into the 20s by daybreak. An Athens County woman left her home and slipped and fell a number of times before collapsing into a yard. She was not located until after daybreak and died from exposure. Temperatures continued to fall during the day on the 6th, reaching between 5 and 10 below by dawn on the 7th, with wind chill values reaching minus 25. Frozen water pipes, power outages, furnace difficulties, and vehicle engine problems were reported and school systems were closed. According to NCDC records this event caused $115,000 in property damage in Washington County (NCDC).

Washington County, Ohio

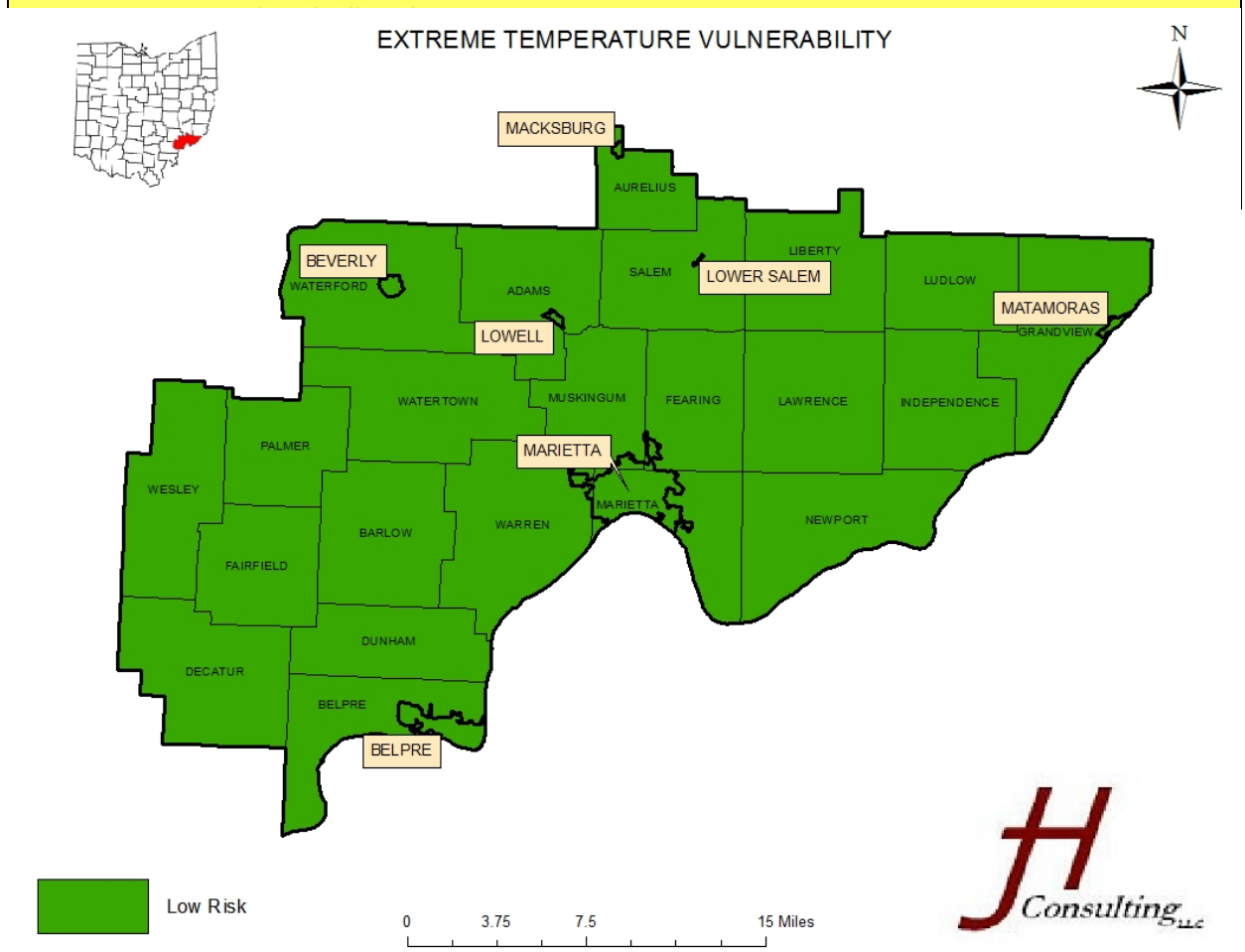
Artic air poured into southeast Ohio on January 27th, 2015, resulting in temperatures ranging from 5 to 20 below zero. A low temperature of minus 7 was recorded in Marietta, and the Watertown area reported an unofficial reading of 14 below. The cold streak continued for the next two nights with a reading of minus 19 recorded along I77 in northern Washington County. The NCDC record reported $100,000 in property damage as a result of this event (NCDC).

VULNERABILITY ASSESSMENT

Using the loss estimate generated above and the structural vulnerability data from the Ohio EMA's loss estimate workbook the following vulnerability table was created. The loss estimates for each structure type total less than the value of one structure.

Structure Type	Number	Loss Estimate
Residential	1	$9,952.43
Non-Residential	1	$3,364.20
Critical Facilities	1	$700.88
TOTALS	**3**	**$14,017.51**

Research Sources:



2.2.6 FLOODING

Flooding Snapshot	
"An overabundance of water that engulfs land and other property that is normally dry" (Haddow, Bullock, & Coppola, 2014, pg.32.)	
Period of Occurrence	Flooding has historically occurred any time of the year.
Number of Events (1996-2015)	45
Probability of Event	2.36
Warning time	Minutes to hours to days depending on the type of flood and situation
Potential Impacts	Impacts to all aspects of life: safety, health and economic. Utility damage and outages, structural and infrastructure damage, fire, loss of critical facilities.
Cause Injury or Death	Injury and moderate risk of death.
Potential Facility Shutdown	Days to weeks
Extent	County-wide
Loss Estimate	Yearly: $1,647,280

Flooding is considered to be one of the most frequent of the natural hazards faced by communities across the country as well as one of the most costly. There are a number of types of flood, each with their own time frame. River floods typically develop over a period of days and occur when a river gradually rises and overspills its banks. These floods can be attributed to large amounts of rain or snowmelt both in the region impacted and upstream. Due to their nature of gradually building up, these types of floods will typically have a warning period of a few days.

The other type discussed in this section is a flash flood. According to the National Flood Insurance Program (NFIP), flash floods are the most common severe weather emergency in the United States (2016.) The NFIP also states that a flash flood is defined as "a rapid flooding of low-lying areas in less than six hours, which is caused by intense rainfall from a thunderstorm or several thunderstorms" (2016.) Flash floods are a common concern in the region and have historically occurred frequently. Of the 187 flooding events compiled by the NCDC in the studied time period, 120 were classified as flash floods. Flash floods develop more quickly that river flooding, and are harder to predict. Unlike river flooding, flash

floods can occur in many places that river flooding does not. These areas are less prepared for flooding, leading to greater danger and potential for property damage.

The third type of flooding is cause by dam failures, which are discussed in more detail in the “Dam Failure” section of this plan.

LOCATION

Historically, severe flooding has occurred along the numerous streams, creeks and rivers that run through Washington County. Additional flooding can occur due to inadequate storm drain capacity and/or ground saturation.

EXTENT

Washington County has a history of being vulnerable to flooding county-wide. The county is bordered by the Ohio River to the east and has the Muskingum River running through the middle. Additionally, a number of creeks and streams are present throughout the county, including Duck Creek and Davis Creek among others. Members of the hazard mitigation planning committee related that flooding is one of the biggest hazards present within their county. All ten of the committee members who responded to the question “to what hazard do you feel Washington County is most vulnerable?” included flooding in their responses. Duck Creek floods the most according to the members, and it was related that the detours around flooded areas lead to heavily damaged backroads. The members identified locally specific areas that historically have been vulnerable to flooding:

- **Macksburg:** Floods will make both the upper and lower bridges impassable.
- **Matamoras:** The town is essentially cut off via the main road during flooding events.
- **Beavertown:** A recent flood led to the need to use a boat to reach a resident having a medical emergency.
- **Lower Salem:** Flooding is a common occurrence in Lower Salem, and has caused mass movement events within the Village.

The Ohio Department of Transportation (ODOT) keeps records on specific roads that have been closed due to flooding in Washington County. Between 2011 and 2015, eleven road locations were closed or restricted a total of 50 times. In total, the roads were closed for nearly 1200 hours. Generally, according to the ODOT data, more than one road is being restricted or closed for any given event.

The data from ODOT does identify locations that are most prone to closure or restriction due to flooding. Between 2011 and 2015, State Route (SR) 26 between Marietta and SR 260 was closed seven times and restricted five times while another stretch of SR 26 between SR 260 and the Monroe County line was closed nine times and restricted three times. These two stretches of the same route account for nearly half the closings and restrictions.

The respondents to the community survey also overwhelmingly identified flooding as the hazard that their community is at risk for. When asked to choose the top three hazards present in the community, flooding received 60 “largest risk” votes. The next closest risk received 13.

HISTORICAL OCCURRENCES

Washington County, Ohio

Thunderstorms struck southeastern Ohio over three consecutive nights in late June of 1996. Large amounts of rainfall over a short time frame caused the West Fork of Duck creek to rise approximately 20 feet and flood Macksburg and the Elba area, with water some four feet deep in residences. The flooding spread downstream, inundating Lower Salem and causing storm sewers to overflow in Marietta. Duck Creek was 20 to 30 feet out of its banks in some areas. It was reported by the County Engineer that 18 bridges in the country were damaged or washed out by the event. This event is also the only instance in the NCDC records of a flooding fatality. The fatality occurred when the truck the man was riding in was driven into high waters along Grandview Township Route 66. The driver and another passenger escaped but the victim was unable to and was trapped in the vehicle as it was swept down Mill Creek. This flooding event caused $10 million in property damage (NCDC).

Washington County, Ohio

Flood Photo Courtesy of Barb Mackey

The most damaging flood over the last decade occurred across Washington County in September of 2004. According to NCDC reports the area was already saturated following the remnants of Hurricane Frances moving through the area when heavy rains associated with the remnants of Hurricane Ivan struck the area. Within 30 hours between 4 and 6.5 inches of rain had fallen across much of the area, leading to flooding of creeks and rivers across the region. The Ohio River reportedly rose 22 feet in 24 hours in Marietta, the largest rise in a 24 hour period in recorded history. The flood stage of the Ohio was at its highest since March of 1964 through Washington County, from New Matamoras through Belpre and beyond. The Red Cross surveyed 159 homes with major damage in Washington County alone, with reports of water 2 to 4 feet deep inside hundreds of Marietta businesses. Sixty homes were destroyed and $17 million in property damage was reported in Washington County alone (NCDC).

Marietta and Belpre, Ohio

Flash flooding that occurred across southern Washington County in August of 2013 caused the most flooding damage in the last five years for the county. Rain totals were measured at 4 inches in Marietta, causing significant flash flooding to occur in Marietta and Belpre, with one resident reporting two feet of water in their basement. Several vehicles were caught in flood waters along the Little Hocking River, however no injuries or deaths were reported. The flood caused $450,000 in property damage (NCDC).

REPETITIVE LOSS PROPERTIES

Within Washington County, and its municipalities, there are 193 repetitive loss properties, 97 residential and 96 non-residential. Repetitive loss figures are shown in the table below. In total, the 97 repetitive loss residential properties have had 233 losses and had total payouts of $3.3 million while the 96 non-residential properties have had 245 losses with total payouts of $7.9 million. According to information provided from Washington County EMA (obtained from the SHARPP database), fourteen property buyouts have occurred in Washington County. One of these occurred in the Village of Lower Salem, two occurred in the Village of Macksburg, and twelve occurred in Elba (vacant lots and houses).

Community	Number	Type	# of Losses	Building Payments ($)	Contents Payments ($)	Total Payments ($)
Washington County	46	Residential	112	$1,653,840.56	$254,357.11	$1,908,197.67
	8	Non-Residential	20	$459,254.38	$54,560.26	$513,814.64
City of Belpre	13	Residential	30	$377,651.33	$6,262.74	$383,914.07
	3	Non-Residential	14	$380,661.07	$28,669.50	$409,330.57
City of Marietta	33	Residential	77	$697,591.13	$31,788.19	$729,379.32
	84	Non-Residential	209	$6,250,151.98	$782,597.81	$7,032,749.79
Village of Beverly	2	Residential	5	$75,805.73	$0.00	$75,805.73
	1	Non-Residential	2	$37,775.02	$0.00	$37,775.02
Village of Lower Salem	3	Residential	9	$219,435.58	$15,323.08	$234,758.66
	0	Non-Residential	0	$0.00	$0.00	$0.00
Totals	97	Residential	233	$3,024,324.33	$307,731.12	$3,332,055.45
	96	Non-Residential	245	$7,127,842.45	$865,827.57	$7,993,670.02

There are also a number of Severe Repetitive Loss properties in Washington County

Community	Number	Type	# of Losses	Building Payments ($)	Contents Payments ($)	Total Payments ($)
Washington County	2	Residential	10	$86,443.84	$20,528.46	$106,972.30
	0	Non-Residential	0	$0.00	$0.00	$0.00
City of Belpre	1	Residential	4	$44,404.76	$0.00	$44,404.76
	1	Non-Residential	7	$229,412.85	$15,000.00	$244,412.85
City of Marietta	0	Residential	0	$0.00	$0.00	$0.00
	7	Non-Residential	38	$947,019.45	$212,728.83	$1,159,748.28
Village of Lower Salem	1	Residential	3	$54,478.82	$6,322.57	$60,801.39
	0	Non-Residential	0	$0.00	$0.00	$0.00
Totals	4	Residential	17	$185,327.42	$26,851.03	$212,178.45

	8	Non-Residential	45	$1,176,432.30	$227,728.83	$1,404,161.13

VULNERABILITY ASSESSMENT

The following table was created using building exposure data from the HAZUS-MH report based on 25, 50, and 100 year flood events and compiled using the Ohio EMA loss estimate workbook.

100 YEAR FLOOD

Structure Type	Number	Loss Estimate
Residential	7,350	$1,025,618,000
Non-Residential	4,421	$616,304,000
Critical Facilities	459	$63,996,000
TOTALS	**12,230**	**$1,705,918,000**

50 YEAR FLOOD

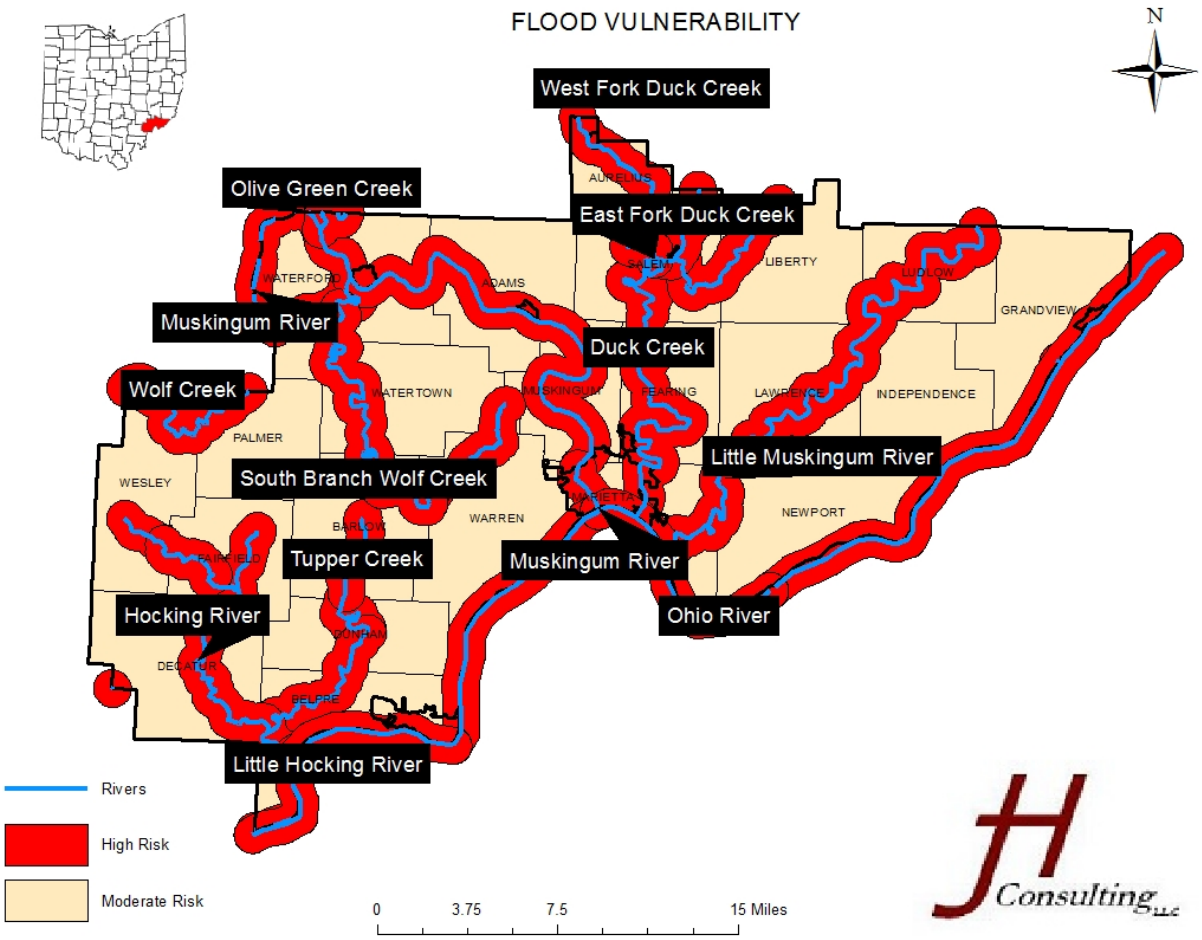
Structure Type	Number	Loss Estimate
Residential	7,194	$1,003,819,000
Non-Residential	2,463	$343,454,000
Critical Facilities	453	$63,160,000
TOTALS	**10,110**	**$1,410,433,000**

25 YEAR FLOOD

Structure Type	Number	Loss Estimate
Residential	6,974	$973,061,000
Non-Residential	2,400	$334,707,000
Critical Facilities	450	$62,839,000
TOTALS	**9,824**	**$1,370,670**

In addition to the HAZUS data, the Buckeye Hills – Hocking Valley Regional Development District has developed a GIS based web application for the City of Marietta to identify which parcels will be at risk with the Ohio and Muskingum Rivers, and the Duck Creek, are at certain flood levels. The gauge for this is located at the confluence of the Muskingum and Ohio rivers. The viewer can be found at http://bhgis.org/marietta/floodimpacts/.

RISK MAP



Research Sources:

- NOAA National Climatic Data Center (NCDC)
- National Flood Insurance Program (NFIP)
- FEMA's HAZUS MH
- ESRI river data

2.2.7 MASS MOVEMENTS

Mass Movements Snapshot	
"Mass movements include several different hazards caused by the horizontal or lateral movement of large quantities of physical matter" (Haddow, Bullock, & Coppola, 2014, pg.46.)	
Period of Occurrence	At any time. Increased chance following long periods of heavy rain, snowmelt or near construction activity
Number of Events (Landslides 2009-2015)	15 *(Landslides affecting roadways)*
Number of Events (Mine Subsidence Annually)	25 events state wide
Probability of Event	2.5 *(Landslides affecting roadways)*
Warning time	Ranging from no warning to months
Potential Impacts	Damage to infrastructure, decreased land values, agribusiness losses, cost of detours on impacted roads, and cost of litigation
Cause Injury or Death	Injury, possibly fatalities
Potential Facility Shutdown	Days to weeks or months
Extent (Landslides)	Eastern section has high incidence occurrence. Remaining western section of the county has high susceptibility and moderate incidence occurrence.
Extent (Mine Subsidence)	Events and investigations have occurred across the county.
Loss Estimate (Landslides)	Road Repairs: $1,583,332.5/year Estimated Structural Loss: $725,271
Loss Estimate (Mine Subsidence)	Roadway Repairs: $1,000,000 / land mile to replace

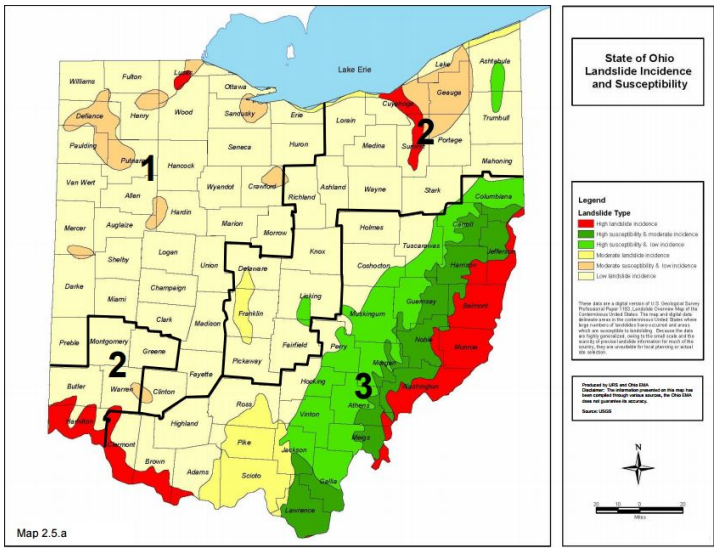
Mass movements cause damage and loss of life through several processes. Mass movements include pushing, crushing or burying objects in their path and the damming of rivers and waterways (Haddow, Bullock, & Coppola, 2014, pg.46.) There are numerous categories of mass movements: landslides, mudflows, rock falls, land subsidence and expansive soils.

- **Landslides:** Landslides occur when areas of relatively dry rock, soil or debris move uncontrollably down a slope. Landsides may be localized or massive in size and can move at high rates of speed.

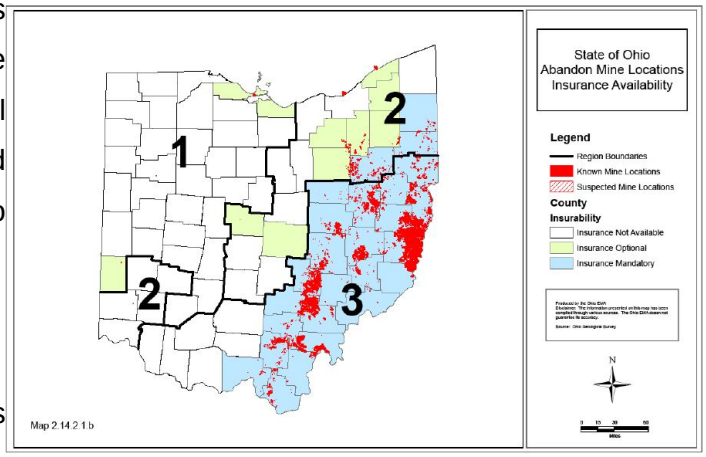
- **Mudflows:** Mudflows are water saturated rivers of earth, rock and debris. Mudflows develop when water rapidly accumulates in the material, such as during heavy rainfall or rapid snowmelt. Mudflows can develop and move quickly, giving little to no warning.
- **Rockfalls:** Rockfalls occur when rocks or other materials detach from a slope or cliff and descend in a freefall, rolling or bouncing manner. Rockfalls can occur naturally, through faults and seismic activity, or as a product of human activity, such as blasting.
- **Land Subsidence:** Land subsidence is the loss of elevation cause by the removal of support below the surface. These events can range in size from large regional lowering to severe localized collapses, such as sinkholes. The primary cause of land subsidence is human activity such as mining and the extraction of groundwater or petroleum.
- **Expansive Soils:** Expansive soils are soils or soft rocks that will swell or shrink depending on their moisture content. The swelling and shrinking action can cause extensive damage to transportation routes, such as highways and rail line, and structures that are built over these areas.

LOCATION

The State of Ohio hazard Mitigation Plan (HMP) states that large portions of the eastern half of Washington County are areas of high landslide incidence. The western part of the county has a high susceptibility and moderate level of incidence. The image below, taken from the Ohio HMP.

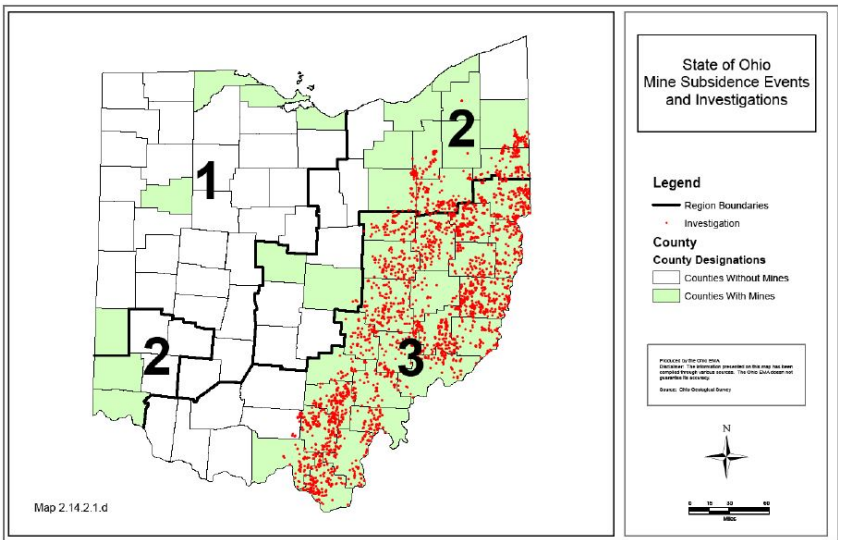


Washington County is also at risk of land subsidence related to abandoned mines located throughout the region. According to the land subsidence profile in the statewide Hazard Mitigation Plan (HMP), Washington County is located in the region of the state with multiple known mine locations and insurance is mandatory for land owners in the county. The image below is the depiction of abandoned mine locations and insurance availability from the statewide plan. The Ohio HMP also shows where mine subsidence events and investigations have occurred, which is shown in the image below. There are an estimated 7,000+ underground mines across Ohio, but only 50% of these are recorded in the Department of Natural Resources' database by 2005 and 2,700 are unmapped (State of Ohio Hazard Mitigation Plan, 2011.)



EXTENT

Washington County has experienced mass movement events on a number of occasions in its history. According to Ohio Department of Transportation (ODOT) records, roads in Washington County have had to be repaired 15 times from landslides/land slips between 2009 and 2015. In total, the road repairs have cost $9.5 million dollars. Landslides, land slips, and mud slides have been included in four of the 15 disaster declarations for the county since 1964. Loss estimates for landslides are limited to the data available, which are road repair costs. On average a road has to be repaired due to a landslide event 2.5 times a year. Each event will cost an average of $633,333. Therefore Washington County can expect $1,583,333 in road repair costs yearly.



The Ohio HMP estimates that Washington County will see $725,271 in structural losses based on landslide incidence and susceptibility.

Mine subsidence events will most likely occur with little to no warning, especially if involving an unmapped and unregistered abandoned mine site. While the area of the subsidence will most likely be small, damage to roads and structures located within or adjacent to the event can be significant. The potential damage increases as the size of the mine increases. Roadways that are damaged by these types of events will need significant repairs, including the reinforcement of the roadbed. Detours of major travel routes will have significant economic impacts. Detour cost calculations provided by ODOT show that a road closure of 20 days resulting in an 11 minute longer drive time will cost drivers an average of $1,952.06 per day.

HISTORICAL OCCURRENCES

Grandview Township

A 500 foot long landslide affected both lanes of Route 7 just north of Matamoras in early 2014. Repairing the roadway cost $839,433.23.

Fearing & Muskingum Townships

In mid-2014, a 200 foot long landslide affected the southbound shoulder of Interstate 77 north of Marietta. Repairing the roadway cost $180,886.60.

Fearing Township

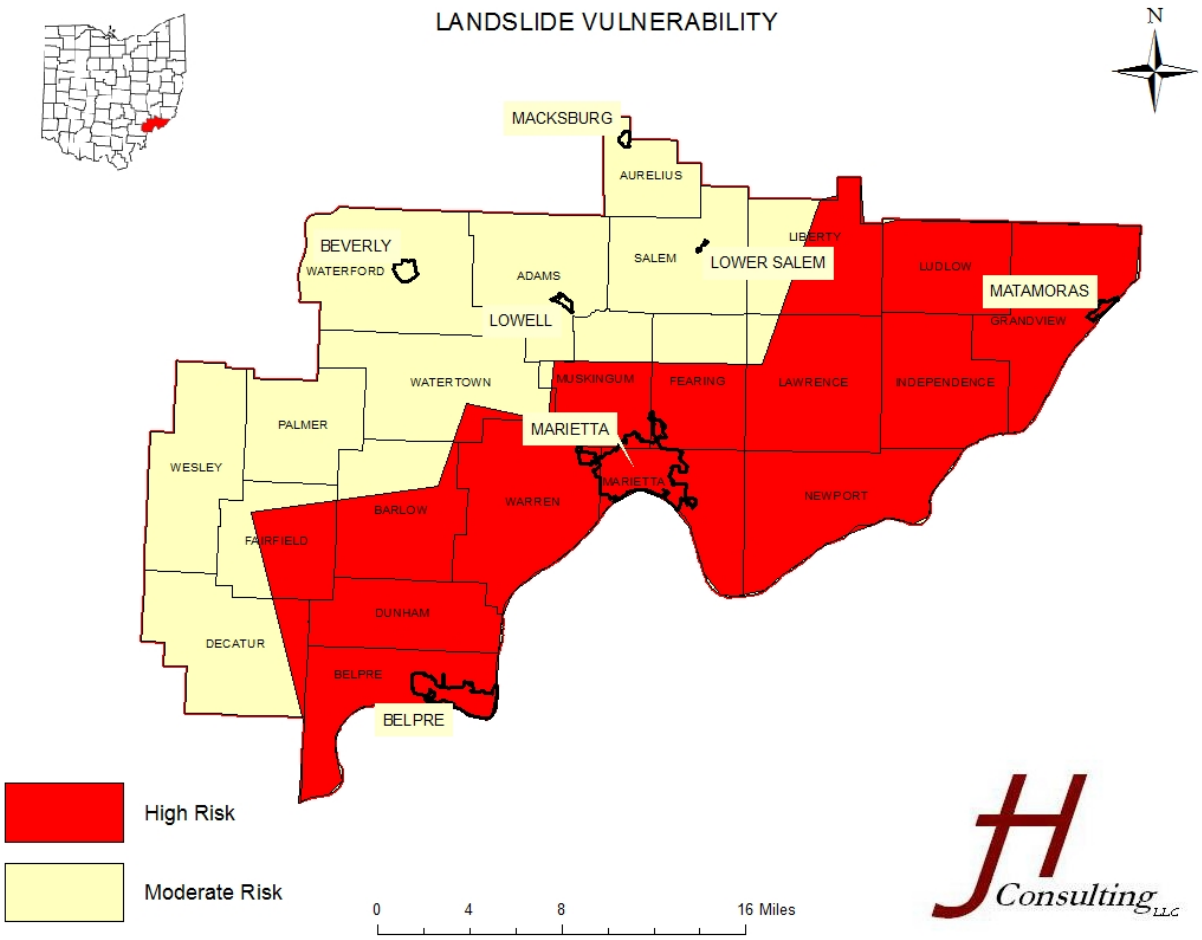
In early 2015, State Route 821 was realigned to stabilize the route from a number of landslides that had affected it and repair damages made by those slides. This project cost $5,914,365.91.

VULNERABLE STRUCTURES

Vulnerable structure estimates for this hazard are based on the estimation from the Ohio Hazard Mitigation Plan that Washington County is vulnerable to $751,271.00 in structural loss yearly. This figure was broken down into loss estimates for the three categories using the Ohio EMA's HAZUS-MH loss estimation workbook. The loss estimate for each structural category was then divided by the average structure value found in the loss estimation workbook. The table below is the result of these calculations.

Structure Type	Number	Loss Estimate
Residential	4	$515,667.68
Non-Residential	1	$171,889.23
Critical Facilities	1	$37,714.09
TOTALS	**6**	**$751,271.00**

RISK MAP



Research Sources:

- USGS
- State of Ohio 2011 Hazard Mitigation Plan
- Ohio Department of Transportation (ODOT)
- Ohio EMA

2.2.8 SEVERE WEATHER

Severe Weather Snapshot	
Various types of severe weather can occur throughout the year, typically defined by seasonal meteorological activity. Severe weather "affects considerable portions of North America and cause significant death and destruction each year" (DeVecchio & Keller, 2015). This severe weather hazard profile includes instances of hail, heavy snow, high wind, lighting, strong wind, thunderstorm wind, winter storms and winter weather as defined by NOAA.	
Period of Occurrence	The various types of severe weather can occur year-round.
Number of Events (1974-2016)	243
Probability of Event	5.93
Warning time	Can range from seconds to days.
Potential Impacts	Property and crop damage.
Cause Injury or Death	Severe weather can potentially cause death and injury.
Potential Facility Shutdown	Ranges from minimal to significant impacts.
Extent	Countywide. Some areas of Washington County are historically more susceptible to certain types of events than others.
Loss Estimates	Yearly: $150,878.05 Worst Case Scenario: $3 Million

In the prior iterations of the Washington County Hazard Mitigation Plan (HMP) different severe weather types were listed separately, with separate hazard profiles and analysis. It was the considered opinion of the Hazard Mitigation Committee to combine a number of these event types into one more general severe weather hazard profile. The committee felt that the effects of these events, and the potential mitigation efforts that can be undertaken in reference to them, are similar enough to be considered together. The majority of these events involve storm systems consisting of precipitation and high winds. Tornados were not included in this profile due to their unique formation and potential for large scale damage.

The National Severe Storms Laboratory (NSSL), a division of NOAA, defines hail as "a form of precipitation that occurs when updrafts in thunderstorms carry raindrops upward

into extremely cold areas of the atmosphere where they freeze into balls of ice" ("Severe Weather 101.) Hail can damage aircraft, homes, cars, and can even injure or be deadly to livestock. Obviously, the larger the size of the hail the more potential it has to cause damage or injury. The NSSL considers a severe hailstorm to contain hail that is one inch or more in diameter. This is approximately the size of a quarter.

The wind gusts and lightning associated with thunderstorms can pose a threat to life and property. Thunderstorms also have the potential to produce hail and tornados, which are discussed elsewhere in this risk assessment. Thunderstorms are typically associated with cold fronts and can move in "lines," meaning that a location can possibly be struck by several storms in the course of minutes or hours. The heavy rainfall associated with one or multiple storms has been known to create flash floods in the presence of oversaturated soils. A major secondary threat associated with thunderstorms is lightning. Individual lightning strikes occur with no warning and kill between 75 and 100 Americans every year (Haddow, Bullock, & Coppola, 2014, pg.51.) Lighting can reach a significant distance from a storm, up to 25 miles according to the National Severe Storms Library (NSSL). While lightning is a common occurrence and can be seen in most thunderstorms, only about 20% of the lighting observed in a storm will strike the ground.

A wind event is typically not associated with other hazards, such as thunderstorms. Wind events will have little or no rain associated with them and may last considerably longer than other events like thunderstorm wind and tornados. Wind events can result in a number of impacts, including blowing tree limbs and trees onto structures, roadways, and power lines. The National Climatic Data Center (NCDC) records two types of stand-alone wind events: high wind events and strong wind events. (National Weather Service Instruction 10-1605.)

The National Climatic Data Center (NCDC) compiles data on a number of different types of winter weather events. Included in the research for this hazard profile are blizzards, ice storms, heavy snow, winter storms and winter weather. Winter storms make it extremely difficult and hazardous to travel, and can lead to wide spread utility outages. The NCDC defines these events as follows:

- **Blizzard:** A winter storm which produces the following conditions for 3 hours or longer: (1) sustained winds or frequent gusts 30 knots (35 mph) or greater, and (2) falling and/or blowing snow reducing visibility frequently to less than 1/4 mile, on a widespread or localized basis.

- **Ice Storm:** Ice accretion meeting or exceeding locally/regionally defined warning criteria (typical value is 1/4 or 1/2 inch or more), on a widespread or localized basis.
- **Heavy Snow:** Snow accumulation meeting or exceeding locally/regionally defined 12 and/or 24 hour warning criteria, on a widespread or localized basis. This could mean such values as 4, 6, or 8 inches or more in 12 hours or less; or 6, 8, or 10 inches in 24 hours or less.
- **Winter Storms:** A winter weather event which has more than one significant hazard (i.e., heavy snow and blowing snow; snow and ice; snow and sleet; sleet and ice; or snow, sleet and ice) and meets or exceeds locally/regionally defined 12 and/or 24 hour warning criteria for at least one of the precipitation elements, on a widespread or localized basis.
- **Winter Weather:** A winter precipitation event that causes a death, injury, or a significant impact to commerce or transportation but does not meet locally/regionally defined warning criteria. A Winter Weather event could result from one or more winter precipitation types (snow, or blowing/drifting snow, or freezing rain/drizzle), on a widespread or localized basis (National Weather Service Instruction 10-1605.)

LOCATION

This hazard is a county wide hazard that can affect all areas and jurisdictions of the county.

EXTENT

Hailstorms are fairly often events in Washington County. On average there will be two hailstorm events per a year, with 69 events having occurred since 1980. Some of these storms can produce hail of enough magnitude (size) to cause structural and property damage while most will not. The National Climatic Data Center (NCDC) records show that eight hail storm events since 1980 have caused property damage totaling $57,000. None of the events are recorded as causing deaths, injuries or crop damage. Hail storms can potentially happen anywhere within the county as storm lines move through the area.

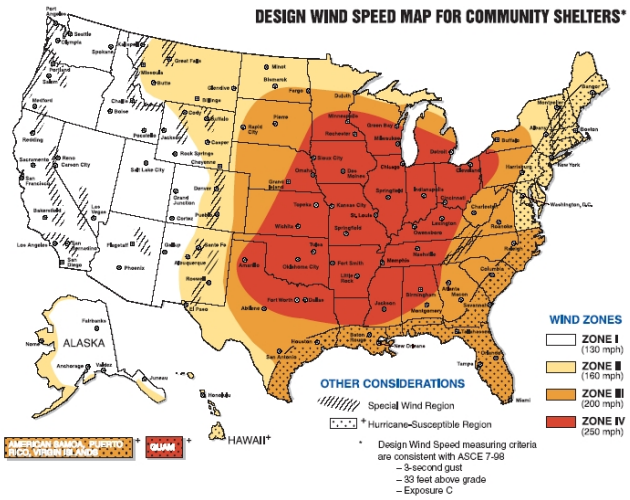
One of the more well-known aspects of hail storms is that a significant amount of the damage is incurred by vehicles. A 2012 report from The Highway Loss Data Institute (HLDI), a division of the Insurance Institute for Highway Safety (IIHS), found that the number of vehicular hail damage claims nationally has increased significantly between 2008 and 2011. There were nearly 245,000 claims filed in 2011, compared to nearly 175,000 claims in 2008.

The average severity of each claim in 2011 was $3,256. According to the research from the HLDI in Ohio in 2011 there were 1,429,586 claims for vehicle hail damage, averaging $3,254 for a total of $23,863,642.

Hail also has the ability, dependent on its magnitude, to cause significant structural property damage. Verisk Insurance Solutions used data collected from around the country, totaling nearly 9 million residential and commercial property hail claims between 2000 and 2013. The analysis shows a significant increase in hail damage claims in residential and commercial properties as well as an increase in average annual claim severity. During this timeframe, Ohio had the sixth highest average claim loss per year with $177,108,000 and the ninth highest average annual claim severity at $6,700/claim.

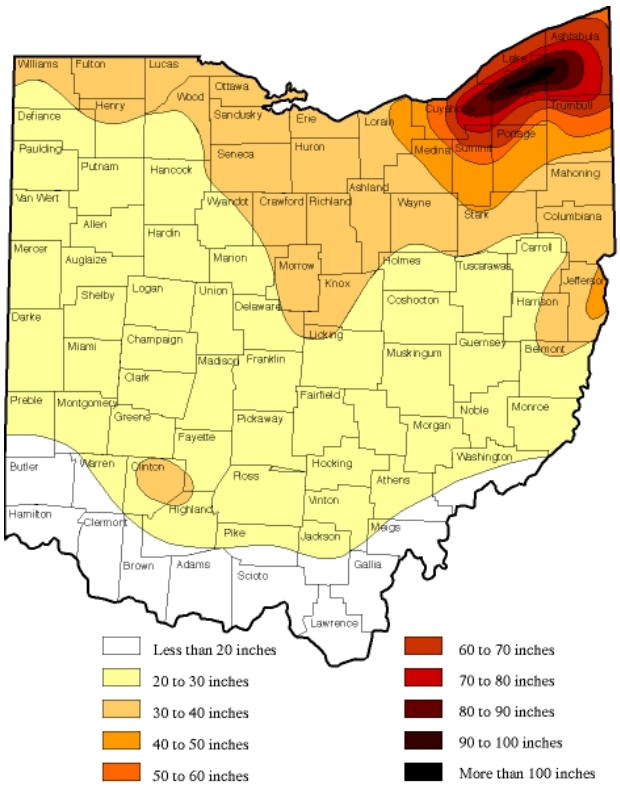
The wind gusts associated with thunderstorms pose a threat to life and/or property. These storms may contain frequent cloud-to-ground lightning and heavy downpours which can lead to localized flooding.

A wind storm is a severe weather condition indicated by high winds and with little or no rain. Localized geographical conditions can exacerbate the damages from high winds and cause increases in wind intensity. The "Design Wind Speed Map for Community Shelters" is one way of graphically analyzing wind risks. As can be seen, Washington County is in a "Zone IV" with respect to design wind speeds, which means that shelters constructed for protective purposes (from wind hazards) should be designed to withstand up to 250 mph winds.



Structures that are most vulnerable will be lightweight structures such as outbuildings, mobile homes and new light weight construction. Severe wind events can cause a variety of secondary, or cascading, hazard events. For instance, wind may blow limbs from trees down knocking out electric power or blocking roadways. Wind often results in damages to roofs and other home finishings (such as siding, etc.).

Winter weather is an annual occurrence in Washington County, though many events are more a nuisance than truly damage causing. The image shown, obtained from the Ohio Department of Transportation, illustrates that Washington County is divided between two average snow fall categories. The upper half of the county, including Beverly, Mack burg, Lowell, and Lower Salem receive between 20 and 30 inches of snow annually. The rest of the county, including Marietta, Belpre, and Matamoras receive less than 20 inches of snow annually.



HISTORICAL OCCURRENCES

Marietta Township, Ohio

The most damaging hail event occurred on June 21st, 2011 in Marietta Township. A storm line moving through the county produced golf ball sized hail that caused $20,000 in property damage (NCDC, 2016.)

Washington County, Ohio

The destructive power of thunderstorms was evidenced in the Derecho of June 29th, 2012. The storm front developed in the late afternoon and early evening and swept through multiple states with little warning. Over a million customers in Ohio were without power, covering nearly two –thirds of the state. The NCDC reports that nearly 25,000 customers lost power in Washington County.

Washington County sustained over $3.5 million in property damage as a result of the storm with the largest damage occurring in the Bartlett area of Wesley Township. The cascading effects of this storm, mainly downed trees and power outages, were especially significant due to a heat wave that was occurring in the area. Citizens that relied on well water had no power to pump the water from their wells. The NCDC record reports that some areas were without power for 4 to 7 days after the storm (NCDC, 2016).

Belpre and Marietta Townships, Ohio

The highest occurrence of property damage associated with a wind event in Washington County was a high wind event that started late in the evening on December 11th, 2000 and stretched into early morning on the 12th. Wind gusts of 40 to 50 mph were common following a cold front, with gusts nearing 60 mph reported in Washington County. One house in Belpre and one in Reno sustained severe roof damage. A spokesman for the electric company reported scattered power outages throughout southeast Ohio due to downed trees (NCDC).

Washington County, Ohio

The most recent major snow event to occur in Washington County, according to NCDC records, was winter storm Jonas. Jonas swept through the area, along with much of the east coast, in late January, 2016. By late morning on January 23rd Marietta had already accumulated 11 inches of snow (Lane, Rouan & Sutherly, 2016.) The storm put the Washington County Public Schools over their snow removal budget by $2,000 while closing the schools for a week. In total there was a reported 23 to 31 inches in various parts of the county (Greene, 2016.)

VULNERABLE STRUCTURES

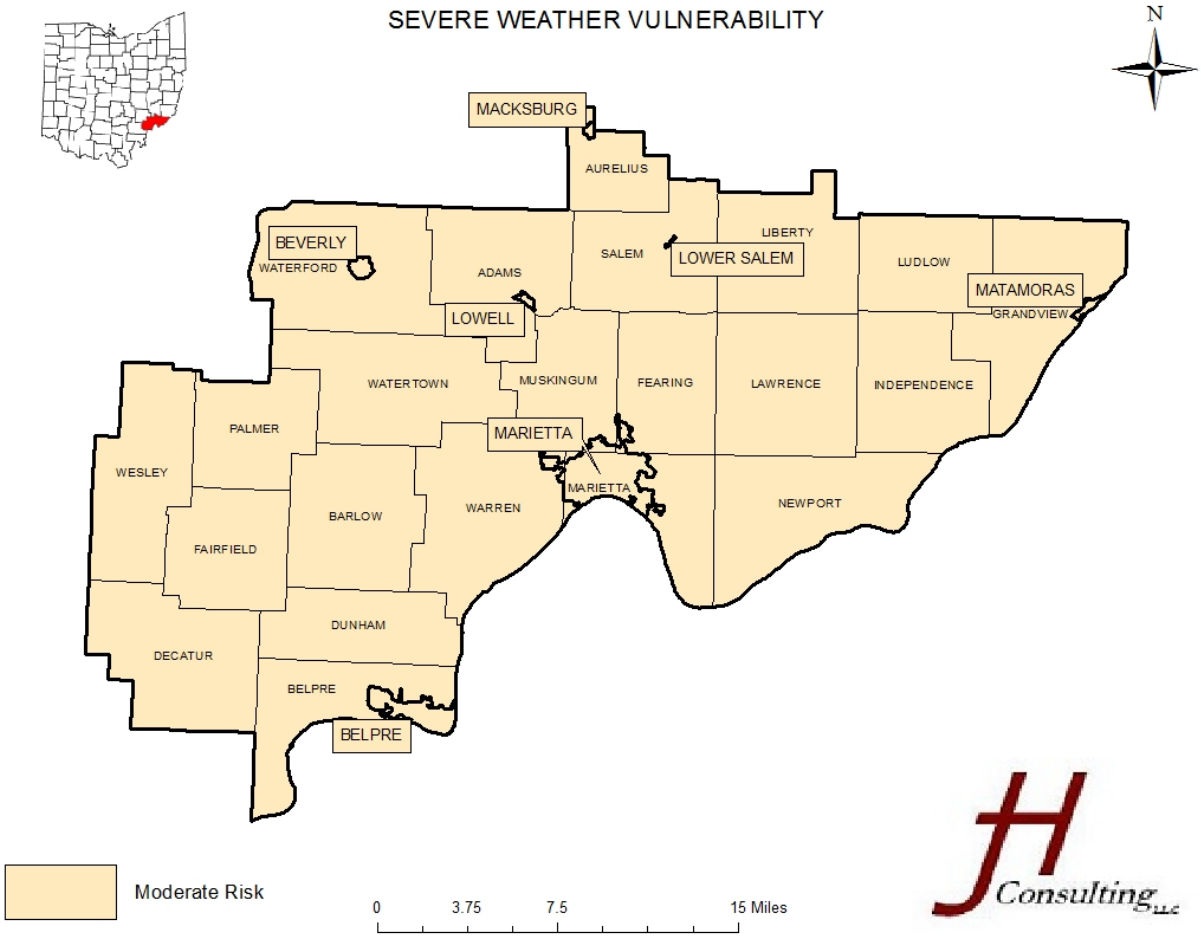
The NCDC event records enable the calculation of a historical loss estimate for Washington County related to all types of severe weather included in this profile. The number of events per year was calculated for each severe weather hazard and multiplied by the average per event property damage. The yearly property damage estimates were summed to find the property loss estimate for severe weather, which was found to be $165,601.16. The worst case scenario, historically, is a loss of $3.5 million, which occurred on June 29th, as a result of thunderstorm wind associated with the Derecho of 2012.

The number of structures vulnerable to severe weather can be estimated using the historical loss estimates and the HAZUS MH loss estimation workbook from the Ohio EMA. The overall loss estimate of $165,601.16 was broken down into loss estimates for each

structure type using the data found in the loss estimates workbook. These figures were then divided by the average structure value, also from the loss estimation workbook, to find the number of each type of structure. The results show that less than one structure from each category is vulnerable to these hazards.

Structure Type	Number	Loss Estimate
Residential	1	$117,742.42
Non-Residential	1	$39,247.47
Critical Facilities	1	$8,611.26
TOTALS	**3**	**$165,601.16**

RISK MAP



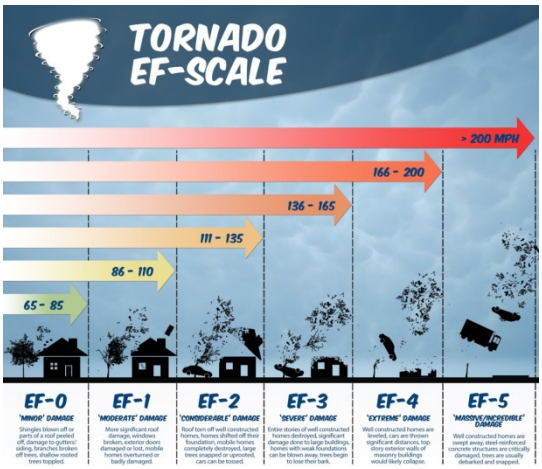
Research Sources:

- NOAA National Climatic Data Center (NCDC)
- NOAA National Severe Storms Laboratory (NSSL)
- Highway Loss Data Institute (HLDI)
- Verisk Insurance Solutions
- Marietta Times

2.2.9 TORNADOS

Tornado Snapshot	
"A rapidly rotating vortex or funnel of air extending groundward from a cumulo-nimbus cloud, exhibiting wind speeds of up to 300 mph" (Haddow, Bullock, & Coppola, 2014, pg.42.)	
Period of Occurrence	At any time. Primarily between March and August
Number of Events (1971-2015)	7
Probability of Event	0.16
Warning time	Seconds to minutesi
Potential Impacts	Loss of life and severe property damage. Infrastructure damage
Cause Injury or Death	Potential to cause injury and death
Potential Facility Shutdown	Hours to days or more.
Loss Estimate	Every Six Years: $202,143 Worst Case Scenario: $250,000

Tornados are typically associated with the strongest thunderstorms and are capable of causing tremendous damage. Tornados are measured on the Enhanced Fujita Scale (EF Scale) which categorizes these events based on wind speed. There are six categories in the EF Scale, from EF0 through EF5. An EF0 tornado will cause some minor damage, while an EF5 is considered to cause massive destruction. The following graphic developed by the Insurance Institute for Business & Home Safety and StateFarm shows the wind scales and the damaged expected in each category.



Tornados are historically very difficult to predict. The storms that may produce a tornado can be forecasted, but not every storm with that potential will spawn a tornado and predicting where and when that will happen is incredibly difficult. Historical trends show that some areas of the country, such as the Midwest plain states,

have a higher probability of tornado occurrence. However, they can and have struck in many other areas.

LOCATION

This hazard is a county wide hazard that can affect all areas and jurisdictions of the county.

EXTENT

The National Climatic Data Center (NCDC) and The Tornado Project keep records regarding tornado occurrences across the country. There have been seven tornados in Washington County since 1971. No deaths have been reported for any of these events. In total, tornados in Washington County have caused nearly $1.5 Million in property damage. The intensity of these storms has been fairly low. Two of the events have reached the F/EF 2 level while the remaining five have been F/EF 0 and 1. The only injuries caused by a tornado in the county are associated with the 1981 EF2 event.

Loss estimates related to tornado events can be found using the historical data from the NCDC. In forty-four (44) years there have been seven (7) tornado events within Washington County. Based on this data there will be, on average, one event every 6 years. The total historical damage caused by these events is $1,415,000, which is an average of $202,143 per an event. Therefore Washington County can expect $202,143 in property damage from tornados every 6 years. The worst case scenario, historically, is property damage of $250,000 per an event. Nationally, tornados caused $12.3 billion in insured loss in 2014 according to the Insurance Information Institute.

HISTORICAL OCCURRENCES

Fairfield Township, Ohio

A tornado in the far western reaches of Washington County in mid-September of 1990 caused $250,000 in property damage when it removed the roof of a building, moved a large shed off its foundation and broke the windows in a van (NCDC).

Waterford Township, Ohio

In May of 2000 an EF1 tornado touched down on County Route 32 near Waterford and destroyed a barn, throwing the debris through the wall of a nearby home. This tornado also moved several trailers, cottages and outbuildings off their foundation while depositing debris in Beverly, across the Muskingum River (NCDC). The most recent tornado event in

Washington County occurred in June of 2015 when a small tornado (EF0) carried a boat through a neighborhood in the rural western part of the county while also damaging a residential roof (NCDC).

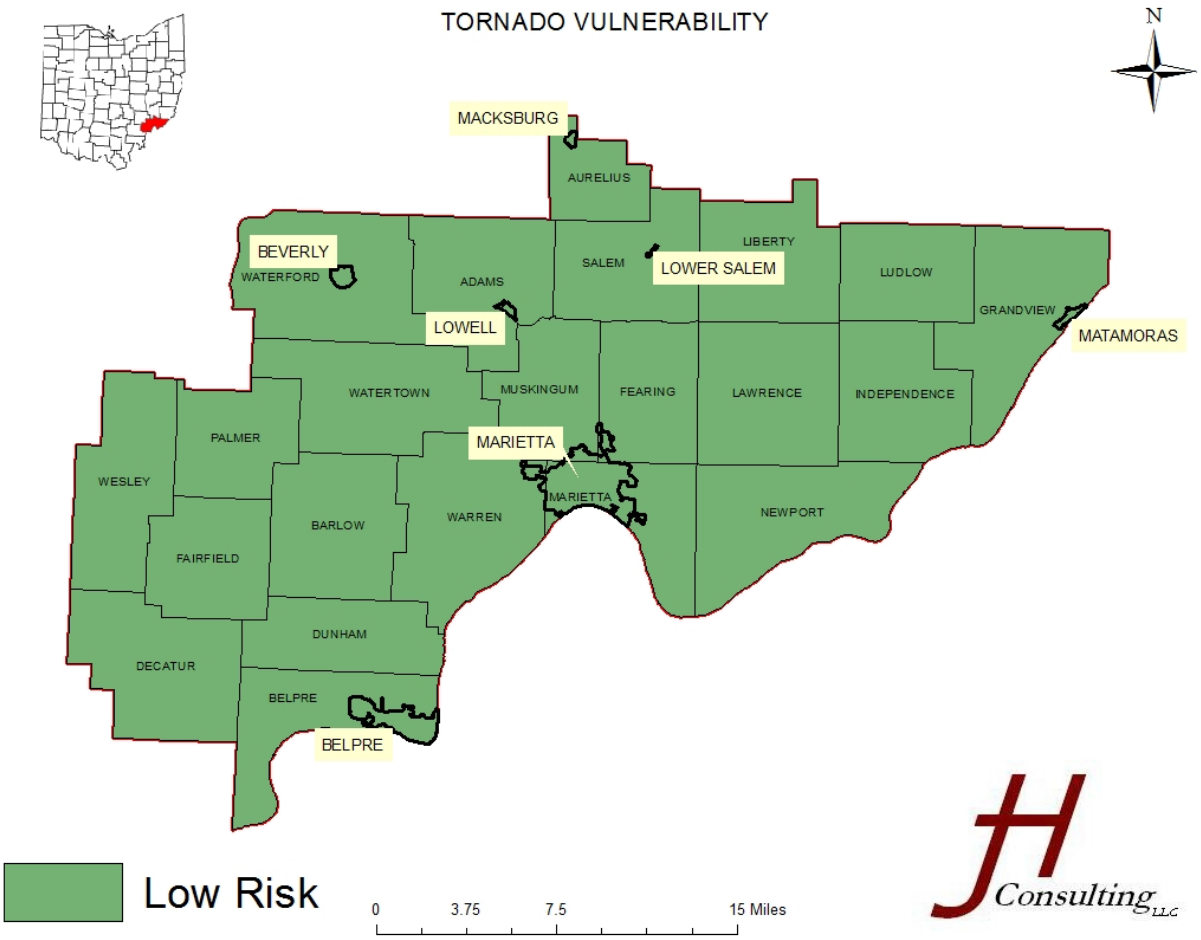
VULNERABLE STRUCTURES

The geography of Washington County does not vary considerably from area to area, and the location of tornado events have been spread around the county. Tornados are by nature difficult to predict. Therefore, predicting geographically what structures are more at risk than others is not possible. Generally speaking, structures that are built of lightweight materials such as newer homes and mobile homes have the highest risk since even a low scale tornado can cause significant damage to these structures.

The number of structures vulnerable to property damage from tornados can be found using the established loss estimate and the Ohio EMA's HAZUS MH loss estimation workbook. The total loss estimate was multiplied by the percentage of each structure type in Washington County, obtained from the loss estimation workbook, to yield the loss estimate for each. This number was then divided by the average structural value, also found in the loss estimation workbook, to calculate the number of each type of structure. The results are found in the table below. It is important to reiterate that this type of event will occur, on average once every six years. These loss estimates are based on that timeline, rather than a yearly loss.

Structure Type	Number	Loss Estimate
Residential	1	$143,521.53
Non-Residential	1	$48,514.32
Critical Facilities	1	$10,107.15
TOTALS	**3**	**$202,143**

RISK MAP



Research Sources:

- NOAA National Climatic Data Center
- The Tornado Project

2.2.10 Systems Disruption and Complicating Variables

A number of situations could occur that would result in a disruption to a number of critical systems throughout Washington County. As eluded to in the severe weather profiles above, some hazards are complicated by a series of loosely-related variables. Such variables are often considered *cascading hazards*. A particularly poignant, nationwide example is that of Hurricane Katrina in New Orleans in 2005. The direct impacts of the storm missed the city; however, increased rainfall and storm surge ultimately resulted in a failure of the levee system that protected the city, causing widespread and major flooding in many areas (Drabek, 2010). For example, high winds may cause sporadic damage throughout the county, but often do not become a significant countywide concern until a large number of residents are without power. In addition to weather-related power outages, cascading hazards in Washington County could include (but not be limited to) the following.

- Structural damage following flooding
- Flooding of downstream areas in the event of a dam failure
- Drinking water supply shortages following severe and prolonged drought conditions
- Power outages, ruptured gas lines, etc. following earthquakes
- Public health concerns following flooding conditions
- Road closures resulting from land subsidence

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i The National Weather Service can warn of thunderstorms with the potential to spawn a tornado hours in advance, but warning time of the actual formation of a tornado is much shorter.