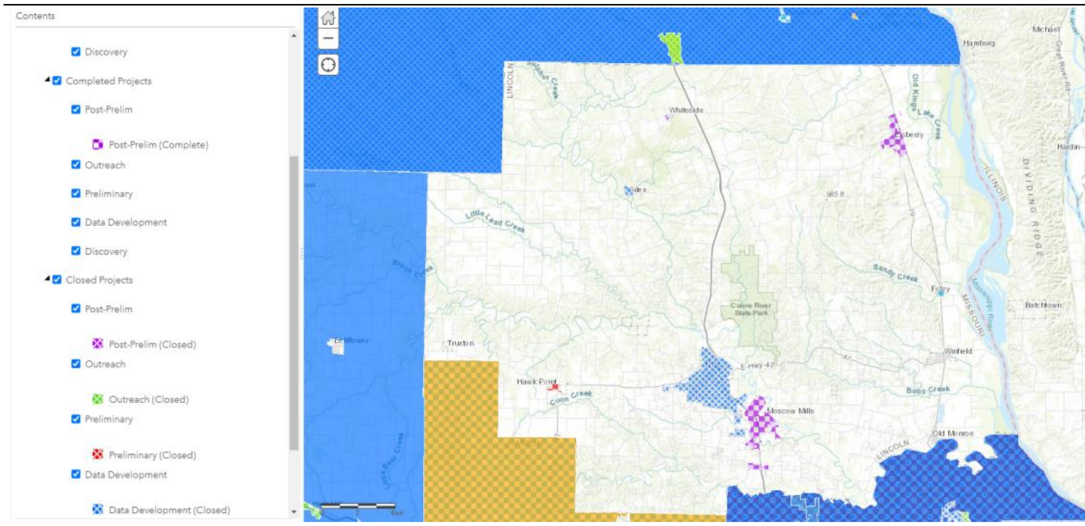
Figure 3.19. RiskMap Study Status Map for Lincoln County



The following National Centers for Environmental Information table shows 32 flood events from the last 21 years. Twenty-one years of history is generally adequate for a trend analysis. Although only 32 events are recorded for Lincoln in the past 21 years, this is considered adequate to establish risk in Lincoln County.

Table 3.23. Lincoln County NCEI Flash Flood Events by Location, 2000-2020

Jurisdiction	# of events
Countywide	19
Chain of Rocks	0
Elsberry	0
Foley	0
Fountain N Lakes	0
Hawk Point	0
Moscow Mills	0
Old Monroe	3
Silex	0
Troy	5
Truxton	1
Whiteside	3
Winfield	1

Special Flood Hazard Areas (SFHAs) are the land areas covered by the floodwaters of the base flood (a flood with a 1% annual chance of occurrence) is the Special Flood Hazard Area (SFHA) on NFIP maps. The SFHA is the area where the National Flood Insurance Program's (NFIP's) floodplain management regulations must be enforced and the area where the mandatory purchase of flood insurance applies." Therefore, all areas shaded in blue on the city and county FIRMs are SFHAs.

Strength/Magnitude/Extent

Missouri has a long and active history of flooding over the past century, according to the 2018 State Hazard Mitigation Plan. Flooding along Missouri's major rivers generally results in slow-moving disasters. River crest levels are forecast several days in advance, allowing downstream communities sufficient time to take protective measures, such as sandbagging and evacuations. Nevertheless, floods exact a heavy toll in terms of human suffering and losses to public and private property. By contrast, flash flood events in recent years have caused a higher number of deaths and major property damage in many areas of Missouri.

According to the U.S. Geological Survey, two critical factors affect flooding due to rainfall; rainfall duration and rainfall intensity – the rate at which it rains. These factors contribute to a flood's height, water velocity and other properties that reveal its magnitude.

National Flood Insurance Program (NFIP) Participation

NFIP participation for the communities in the planning area is shown below and a second table shows the number of policies in force, amount of insurance in force, number of closed losses, and total payments for each jurisdiction, where applicable. Information in the charts was taken between January 1, 1978 and September 30, 2018. Sanctioned (S) communities are those communities that are not currently participating in the NFIP and where a Flood Hazard Boundary Map or Flood Insurance Rate Map has been issued.

Table 3.24. NFIP Participation in Lincoln County

Community ID Number	Community Name	NFIP Participant (Y / N)	Current Effective Map Date	Regular-Emergency Program Entry Date
290750	Village of Chain of Rocks	Y	9/29/2010	8/9/2011
290209	City of Elsberry	Y	9/29/2010	5/2/1977
290210	City of Foley	Y	9/29/2010	3/1/1978
290869	Lincoln County	Y	9/29/2010	3/15/1984
290211	City of Old Monroe	Y	9/29/2010	8/15/1978
290546	City of Moscow Mills	Y	9/29/2010	6/26/2006
290212	Village of Silex	Y	9/29/2010	9/16/1982
290641	City of Troy	Y	9/29/2010	5/5/1981

Community ID Number	Community Name	NFIP Participant (Y / N)	Current Effective Map Date	Regular-Emergency Program Entry Date
290213	City of Winfield	Y	9/29/2010	11/17/1982

*Source: NFIP Community Status Book, 9/26/2013;*http://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-community-status-book;

Table 3.25. NFIP Policy and Claim Statistics as of 08/21/2020

Community	Total policies	Total coverage	Total Losses	Total net dollar paid
Chain of Rocks	2	$300,000	3	$166,209
Elsberry	17	$1,084,800	16	$297,446
Foley	19	$1,482,100	87	$3,069,684
Incorporated County	156	$20,242,900	651	$25,566,459
Moscow Mills	14	$1,593,900	0	0
Old Monroe	39	$4,551,300	81	$1,328,130
Silex	6	$544,200	31	$1,448,479
Troy	12	$3,073,000	6	$190,601
Winfield	19	$1,590,600	85	$3,080,740

Source: SEMA

Repetitive Loss/Severe Repetitive Loss Properties

Repetitive Loss Properties are those for which two flood insurance payments are at least $1,000 or more in a 10 year period. According to the Flood Insurance Administration, jurisdictions included in the planning area have a combined total of eleven repetitive loss properties. As of November, 2021-95 properties has been mitigated, leaving 57 un-mitigated repetitive loss properties.

Severe Repetitive Loss Properties (SRL)

A SRL property is defined it as a single family property (consisting of one-to-four residences) that is covered under flood insurance by the NFIP; and has (1) incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage with the amount of each claim payment exceeding $5,000 and with cumulative amounts of such claims payments exceeding $20,000; or (2) for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property.

The table below provides a summary of the repetitive loss properties in the planning area.

Table 3.26. Lincoln County Repetitive Loss Properties

	Repetitive loss properties	Total Losses	Total Building Payments	Total Contents Payments	Total Payments	Single Family
CHAIN OF ROCKS, VILLAGE OF	1	6	$154,659.76	$65,296.25	$ 219,956.01	1
LINCOLN COUNTY	11	61	$1,141,602.48	$196,502.78	$ 1,338,105.26	11
WINFIELD, CITY OF	2	10	$90,831.48	$17,935.80	$ 108,767.28	2
	14	***77***	***$1,387,093.72***	***$279,734.83***	***$ 1,666,828.55***	***14***

Source: SEMA

Previous Occurrences

The largest disaster to impact Lincoln County in recent years was the Great Flood of 1993. Flooding covered the eastern part of the county along its 25-mile border with the Mississippi River. Two major Mississippi River levees were breached by the relentless volume of water. In addition, heavy and frequent rain events along the Cuivre River and the North Fork of the Cuivre River caused flash flooding on the western side of the county.

During the 1994 flood, the Cuivre River also flooded farmland and parts of Old Monroe. East of Troy, where the flood stage is 21 feet, the river crested at 33 feet. At Old Monroe, with flood stage at 24 feet, the crest reached 32.9 feet.

During June 2008 the Mississippi overflowed 90% of the levees in eastern Lincoln County, rushing into Foley and other towns. The Army Corps of Engineers estimated the river would have reached 39.2 feet, which is 13-14 feet above flood stage for many communities in the county. In total, up to 350 homes were flooded and most residents east of highway 79 left their homes. Four homes were destroyed and 161 more homes received major damage. MoDOT closed 37 roads in eastern Missouri and railroad lines, barges, and river locks and dams were shut down.

Within the past 15 years flood events have not resulted in any deaths or injuries within Lincoln County. However, while not included in the table below, flooding was severe during June and December 2015 and resulted in U.S. 61 and MO 79 being closed a total of 12 times due to high water. Some roads and bridges required extensive maintenance as a result of the flooding.

The table below summarizes FEMA Declared Flood Events from the past 20 years.

Table 3.27. NCEI Lincoln County Flood events and Flash Flood Events Summary, 2000 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
2000	2	0	0	0	0
2001	2	0	0	0	0
2002	6	0	0	0	0
2003	3	0	0	0	0
2007	1	0	0	0	0
2008	6	0	0	2675000	0
2009	3	0	0	0	0
2010	3	0	0	0	0
2011	2	0	0	0	0
2013	3	0	0	53000	20000
2014	2	0	0	0	0
2015	5	0	0	240000	0
2016	1	0	0	0	0
2017	3	0	0	0	0
2019	3	0	0	740000	0
2020	3	0	0	0	0

Source: NCEI

Table 3.28. NCEI Lincoln County Riverine Flood Events Summary, 2000 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damages
2000	1	0	0	0	0
2001	1	0	0	0	0
2007	1	0	0	0	$5,000
2010	1	0	0	0	0

Source: NCEI

Probability of Future Occurrence

For flooding events, flash flooding is the most likely to occur. The flash flood chart above shows 48 flash floods occurred during the 21-year period between 2000 and 2020. Expressed mathematically, this is 18 floods divided into 21 years for one flood per year, or a 228% probability of a flash flood occurring somewhere in Lincoln County during any given year. This probability is just a measurement tool, as you can see in the chart, some years had several flash floods while other years had none.

The above riverine flooding table shows 4 flooding events over a 21-year period. Applying the same formula used above, this would be a 19% probability of a riverine flood occurring somewhere in Lincoln County during a 12-month period.

Changing Future Conditions Considerations

Lincoln County should begin to consider the possibility that traditional climate patterns are changing. According to the 2018 State Plan, if departure from normal with respect to increased precipitation intensity continues, frequency of floods in Missouri is likely to increase as well. Over the last half century, average annual precipitation in most of the Midwest has increased by 5 to 10 percent. But rainfall during the four wettest days of the year has increased about 35 percent, and the amount of water flowing in most streams during the worst flood of the year has increased by more than 20 percent.

It is likely (66-100% probability) that the frequency of heavy precipitation or the proportion of total rainfall from heavy storms will increase in the 21st century across the globe. More specifically, it is "very likely" (90-100% probability) that most areas of the United States will exhibit an increase of at least 5% in the maximum 5-day precipitation by late 21st century. As the number of heavy rain events increase, more flooding and pooling water can be expected.

The expected increases in rainfall frequency and intensity are likely to put additional stress on natural hydrological systems and community storm water systems. Heavier snowfalls in the winter will lead to intensified spring flooding, and groundwater levels will remain high even in non-floodplain areas. Such changes in climate patterns can lead to the development of compounding events that interact to create extreme conditions. Flooding caused by high groundwater levels typically recedes more slowly than riverine flooding, slowing the response and recovery process. Groundwater-fed rivers and streams are also likely to experience heightened flooding when groundwater levels are high. Jurisdictions updating or installing storm water management systems should consider potentially larger future discharge amounts when sizing culverts and drainage ways; storage

capacity can also be increased by building retention basins to hold excess storm water. Communities already prone to flooding should be prepared for a potential increase in facility closures and/or damages, as well as an increase in public demand for flood response and assistance. Natural features that experience repeated flooding may manifest changes in the form of stream bank instability and changing shoreline, floodplain, and wetland boundaries. Communities may also wish to plan for the potential loss of cropland and damage to both private property and public infrastructure such as bridges.

The environmental impacts of flooding include erosion, surface and groundwater contamination, and poor quality water. The threat of more frequent flood events may thus be a concern particularly for communities who depend on lakes, rivers, or trout streams for tourism. Rural communities may experience increases in well contamination and road washouts, while urban areas may be particularly vulnerable to flash flooding as heavy rain events quickly overwhelm the ability of a more impermeable environment to absorb excess storm water.

More climate information is available from the following sources:

- 2018 State Plan, see Chapter 3, Section 3.3.1, Changing Future Conditions Considerations, page 3.100
- US Climate Resilience Toolkit; https://toolkit.climate.gov/tools/climate-explorer

- National Climate Assessment; https://nca2014.globalchange.gov/

Vulnerability

Vulnerability Overview

Flooding presents a danger to life and property, often resulting in injuries, and in some cases, fatalities. Floodwaters themselves can interact with hazardous materials. Hazardous materials stored in large containers could break loose or puncture as a result of flood activity. Examples are bulk propane tanks. When this happens, evacuation of citizens is necessary.

Public health concerns may result from flooding, requiring disease and injury surveillance. Community sanitation to evaluate flood-affected food supplies may also be necessary. Private water and sewage sanitation could be impacted, and vector control (for mosquitoes and other entomology concerns) may be necessary.

When roads and bridges are inundated by water, damage can occur as the water scours materials around bridge abutments and gravel roads. Floodwaters can also cause erosion undermining road beds. In some instances, steep slopes that are saturated with water may cause mud or rock slides onto roadways. These damages can cause costly repairs for state, county, and city road and bridge maintenance departments. When a sewer back-up occurs, this can result in costly clean-up for home and business owners as well as present a health hazard. Refer back to the section of the plan where scour critical bridges were identified.

For Lincoln County, according to the 2018 State Plan, this can mean building exposure for a 100-year flood of $1,374,650 and impact as many as 1,678 buildings and up to 2382 residents.Potential Losses to Existing Development

The Mississippi River Floodplain remains agricultural in nature with family farms sparely distributed within them. Most of the residential properties have been demolished in Elsberry, Old Monroe, Silex and Winfield.

Impact of Previous and Future Development

Development upstream, in the form of additional levees, creates the greatest impact to Missouri River flooding in Lincoln County due to channeling additional water into waterways. The county regulates development within incorporated areas located in the floodplain of the Missouri River. Flash floods will continue to impact residents choosing to live in rural areas where low water crossings are required to access their homes. There is anticipated to be little or no increase in run off created by potential development.

Hazard Summary by Jurisdiction

Chain of Rocks- no structures located in floodplain.

Elsberry- all the structures in the floodplain are bought out and the city has flood permit regulations in place.

Foley- no structures located in floodplain.

Fountain N Lakes- not located in floodplain

Hawk Point- not located in floodplain

Moscow Mills- there are some structures in floodplain; the city has flood permit regulations in place.

Old Monroe- all the structures in the floodplain are bought out and the city has flood permit regulations in place.

Silex- all the residential structures are relocated to a new location out of the floodplain; the city has flood permit regulations in place.

Troy- there are some structures in floodplain; the city has flood permit regulations in place.

Truxton- not in floodplain

Whiteside- not in floodplain

Winfield- there are some structures in floodplain; the city has flood permit regulations in place.

Unincorporated county- there are more than 100 vacant structures located in the floodplain and the county has flood permit regulations in place. Many rural roads within the county are dependent upon low water crossings which are not navigable during periods of high water. There are 4 remaining low water crossings in Lincoln County that need to be addressed as any one of which can be inundated anytime three or more inches of rain falls within a short interval and ground is saturated. During times of flash flooding, these low water crossings can present a risk to life and property if an attempt to cross is made. An action item has been included to study and find funding for installing flood gates for low water crossings.

None of the school districts are located in the floodplain.

Problem Statement

Lincoln County faces two major risk factors for flooding; flooding from the Mississippi River and flash flooding by numerous smaller rivers and creeks, principally, the Cuivre River. According to the federal government's Flood Insurance Rating Maps (FIRM), for Lincoln County 22% of the land lies within the 100-year floodplain. The majority of that 22% lies directly adjacent to Mississippi and Cuivre Rivers. Flooding, particularly flash flooding, in the planning area's rivers and creeks will continue to be an issue due to the geography. The incorporated cities and Lincoln County have floodplain permit in place to restrict development in the floodplain.

3.4.6 Levee Failure

Hazard Profile

Hazard Description

Levees are earth embankments constructed along rivers and coastlines to protect adjacent lands from flooding. Floodwalls are concrete structures, often components of levee systems, designed for urban areas where there is insufficient room for earthen levees. When levees and floodwalls and their appurtenant structures are stressed beyond their capabilities to withstand floods, levee failure can result in injuries and loss of life, as well as damages to property, the environment, and the economy.

Levees can be small agricultural levees that protect farmland from high-frequency flooding. Levees can also be larger, designed to protect people and property in larger urban areas from less frequent flooding events such as the 100-year and 500-year flood levels. For purposes of this discussion, levee failure will refer to both overtopping and breach as defined in FEMA's Publication "So You Live Behind a Levee" (http://content.asce.org/ASCELeveeGuide.html). Following are the FEMA publication descriptions of different kinds of levee failure.

> **Overtopping: When a Flood Is Too Big**
>
> Overtopping occurs when flood waters exceed the height of a levee and flow over its crown. As the water passes over the top, it may erode the levee, worsening the flooding and potentially causing an opening, or breach, in the levee.
>
> **Breaching: When a Levee Gives Way**
>
> A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters may pass. A breach may occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. The resulting torrent can quickly swamp a large area behind the failed levee with little or no warning.

Earthen levees can be damaged in several ways. For instance, strong river currents and waves can erode the surface. Debris and ice carried by floodwaters—and even large objects such as boats or barges—can collide with and gouge the levee. Trees growing on a levee can blow over, leaving a hole where the root wad and soil used to be. Burrowing animals can create holes that enable water to pass through a levee. If severe enough, any of these situations can lead to a zone of weakness that could cause a levee breach. In seismically active areas, earthquakes and ground shaking can cause a loss of soil strength, weakening a levee and possibly resulting in failure. Seismic activity can also cause levees to slide or slump, both of which can lead to failure.

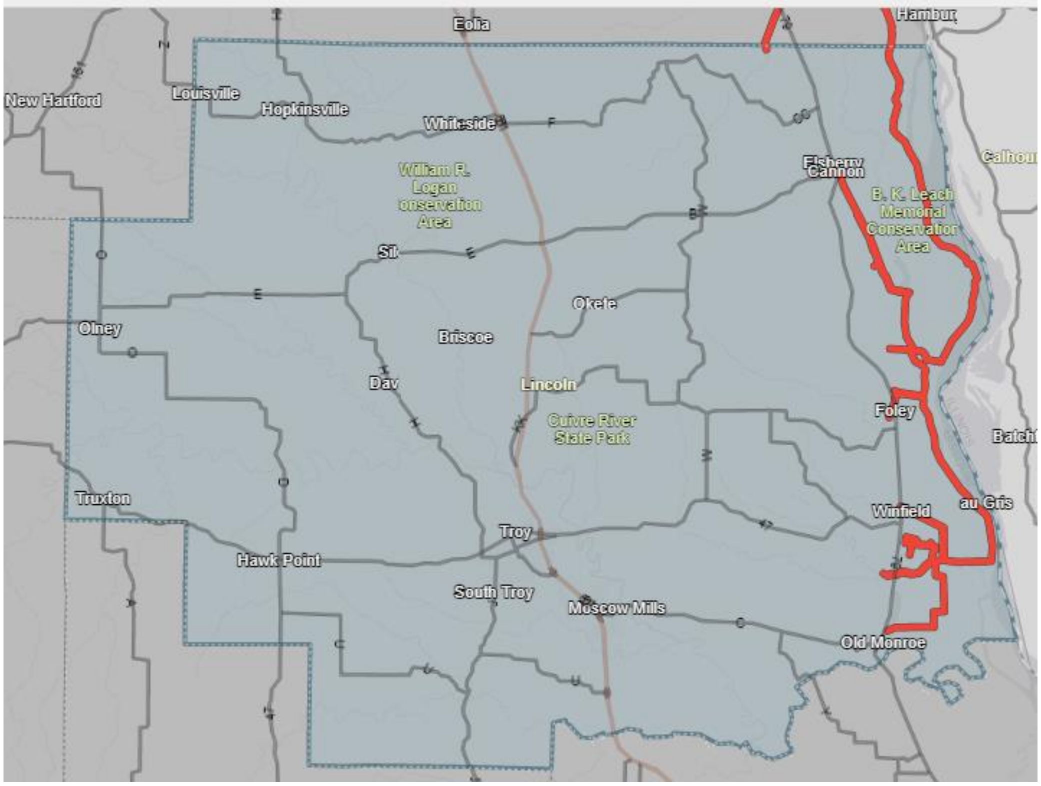
Geographic Location

Missouri is a state with many levees. Currently, there is no single comprehensive inventory of levee systems in the state. Levees have been constructed across the state by public entities and private entities with varying levels of protection, inspection oversight, and maintenance. The lack of a comprehensive levee inventory is not unique to Missouri.

There are two concurrent nation-wide levee inventory development efforts, one led by the United State Army Corps of Engineers (USACE) and one led by Federal Emergency Management Agency (FEMA). The National Levee Database (NLD), developed by USACE, captures all USACE related levee projects, regardless of design levels of protection. The Midterm Levee Inventory (MLI), developed by FEMA, captures all levee data (USACE and non-USACE) but primarily focuses on levees that provide 1% annual-chance flood protection on FEMA Flood Insurance Rate Maps (FIRMs).

It is likely that agricultural levees and other non-regulated levees within the planning area exist that are not inventoried or inspected. These levees that are not designed to provide protection from the 1-percent annual chance flood would overtop or fail in the 1-percent annual chance flood scenario. Therefore, any associated losses would be considered in the loss estimates provided in the Flood Hazard Section.

Figure 3.20. County Levees Shown on DFIRM as Providing Protection from the 1-Percent Annual Chance Flood



Source: https://levees.sec.usace.army.mil/#/

There are 10 levee systems, 56 miles of levees, and the average age is 47 years. Only 5 systems are screened, please see the information below on them.

The Brevator Levee System has prevented the Lincoln County properties from flooding during numerous flood events, however erosion and overtopping have occurred in the past. Erosion is common along the levee system, and erosion remains a primary concern with the system. There is a possibility that in any given year floodwaters could overtop or breach the levee system. A levee failure could result in flooding of depths of up to 8 feet, loss of life, and significant economic damage.

The Elsberry-Kings Lake Levee System has prevented Pike and Lincoln County properties from flooding during numerous flood events, however overtopping with subsequent breaches has occurred in the past. In recent high water events, the agricultural levee has been overtopped, experienced erosion, and seepage has been observed, and these items remain a primary concern with the system. There is a possibility that in any given year floodwaters could overtop or breach the levee system. A levee failure could result in flooding of depths of up to 10 feet, loss of life, and significant economic damage.

Though the Foley, Cap au Gris, Winfield Main Levee System has prevented Lincoln County communities from flooding during numerous major flood events, the levee has been overtopped by floodwaters during multiple events, which has led to levee failure. There is a possibility that in any given year floodwaters could overtop or breach the levee system. A levee failure could result in flooding of depths of 9 feet, loss of life, and significant economic damage.

The Sandy Creek Levee System has prevented Lincoln County agricultural properties from flooding during numerous flood events, however overtopping with subsequent breach has occurred in the past. In recent high water events, the agricultural levee has been overtopped and experienced erosion, and these items remain a primary concern with the system. There is a possibility that in any given year floodwaters could overtop or breach the levee system. A levee failure could result in flooding of depths of up to 10 feet, loss of life, and significant economic damage.

The Winfield Pin Oaks Levee System has prevented Lincoln County property from flooding during numerous flood events, however overtopping with subsequent breaches have occurred in the past. In 2008 the levee failed due to seepage, however significant flood fighting delayed the breach of the levee system. After the levee failed in 2008, volunteers then built an emergency berm around the town of Winfield that increased evacuation time and prevented wave damage to homes. Seepage, erosion, and slides have been observed in the past, and they remain a primary concern with the system. There is a possibility that in any given year floodwaters could overtop or breach the levee system. A levee failure could result in flooding of depths of up to 11 feet, loss of life, and significant economic damage.

Strength/Magnitude/Extent

Levee failure is typically an additional or secondary impact of another disaster such as flooding or earthquake. The main difference between levee failure and losses associated with riverine flooding is magnitude. Levee failure often occurs during a flood event, causing destruction in addition to what would have been caused by flooding alone. In addition, there would be an increased potential for loss of life due to the speed of onset and greater depth, extent, and velocity of flooding due to levee breach.

As previously mentioned, agricultural levees and levees that are not designed to provide flood protection from at least the 1-percent annual chance flood likely do exist in the planning area. However, none of these levees are shown on the Preliminary DFIRM, nor are they enrolled in the USACE Levee Safety Program. As a result, an inventory of these types of levees is not available for analysis. Additionally, since these types of levees do not provide protection from the 1-percent annual chance flood, losses associated with overtopping or failure are captured in the Flood Section of this plan.

Previous Occurrences

There were more than 1,000 Federal and non-Federal levee breaches during the Great Flood of 1993. From June to August 1993, rainfall totals surpassed greater than 24 inches of rain fell on northern and central Missouri. These amounts were approximately 200-350 percent greater than normal. The Missouri River crested at 48.87 feet at Kansas City on July 27. This crest moved down the Missouri River setting new records at Boonville, Jefferson City, Hermann, St. Charles, and other locations. The first levee was overtopped on June 7, but levee failures soon became common. Levee failures resulted in large amounts of sediments deposited in some inundated areas, and large quantities of sediments were scoured from other inundated areas. In Lincoln County, the Winfield/Pin Oak levee was breached in June of 2015 and in December, the Brevator and Old Monroe Public levees were breached. In St. Louis, out of 42 Federal levees, 12 of them failed or overtopped and out of 47 non-Federal levees, 39 failed (U. S. Geological Survey).

Towns along the Mississippi River from Illinois to Missouri were building barriers in an attempt to hold back rising floodwaters by mid-June. As many as 27 levees were in jeopardy of overflowing as the river was projected to rise (NCDC)

Heavy rains throughout Iowa and Missouri during June 2008 caused flooding along the Mississippi River drainage system within the USACE, St. Louis District in Missouri and Illinois. Heavy rainfall in April and May saturated the Midwest causing much of the additional heavy rains in June to develop directly into runoff. Rainfall totals over Missouri and Iowa ranged from 8-15 inches during the months of May and June. The saturated soil combined with the heavy rains created near record river levels throughout the northern portion of the St. Louis District.

The Mississippi overflowed 90 percent of the levees in eastern Lincoln County, rushing into Foley, and other towns around the county in June, 2008. The Army Corp of Engineers estimated that the river would have reached 39.2 feet, which is 13 to 14 feet above flood stage for many communities in Lincoln County. The average water level in Lincoln County was 34.3 feet, which is about eight feet above flood stage. On June 6, 2008 floodwaters opened a 150-foot breach in a primary levee along the Mississippi River in Winfield. The breach allowed floodwaters to claim dozens of homes and large tracts of farmland and put pressure on a secondary levee. The breach also prompted Lincoln County emergency officials to order the evacuation of residents east of Winfield.

Probability of Future Occurrence

Brevator Levee- The levee has four road crossing points, one railroad crossing point, two points where it ties into adjacent levee segments, and no closure structures. The leveed area contains several residential properties and associated outbuildings and farm related structures (implement storage sheds and grain storage bins); a large sand plant, Kimaterials Inc. LLC; and several small businesses such as Chantilly Cabinet and Ralph’s Auto Repair. There is also a series of waste water lagoons for the city of Old Monroe. The estimated structural value is $4,500,000. The population inside the leveed area is 27.

Elsberry/King’s Lake System- The Elsberry-Kings Lake Levee System reduces the risk of flooding from the Mississippi River to agricultural bottomland and a portion of the town of Elsberry, Missouri. The system was privately constructed and is locally operated and maintained by the nonfederal Sponsors: Elsberry Drainage and Levee District and Kings Lake Levee District, each responsible for individual segments that together comprise the 28 mile system. The levee system consists of earthen embankment along the Mississippi River, Lost Creek, and Bryants Creek. Within the 22,090-acre leveed area are MO HWY 79, agriculture, residential, commercial, and industrial properties including a grain elevator and agricultural service center. This system provides benefits to over 500 residents and employees and approximately $73.7 million in property value.

Foley, Cap Au Gris Levee & Winfield Main System- The Foley, Cap au Gris, Winfield Main Levee System reduces the risk of flooding from the Mississippi River to the Lincoln County, MO communities of Foley, Cap au Gris, and a portion of Winfield. The system consists of the three separate segments operated and maintained by the nonfederal Sponsors, Foley Drainage District, Cap au Gris Drainage and Levee District, and Winfield Levee and Drainage District. The levee system consists of over 12 miles of earthen embankment along the Mississippi River, Bobs Creek, and Sandy Creek, along with a section of railroad embankment maintained by Burlington Northern Santa Fe. Within the nearly 5,800-acre leveed area is primarily agriculture with multiple residential properties concentrated in the communities of Foley and Winfield, MO HWY 79, and the Foley Police Department. This system provides benefits to approximately over 300 residents and approximately $12.6 million in property value.

Sandy Creek levee system- The Sandy Creek Levee System reduces the risk of flooding from the Mississippi River to agricultural bottomland and a portion of the town of Elsberry, Missouri. The system is privately owned and operated the nonfederal Sponsor: Sandy Creek Levee District. The levee system was completed around 1921 and consists of 3.49 miles of earthen embankment along Kings Lake, Mississippi River, and Sandy Creek. Within the 930-acre leveed area are agriculture and isolated farmsteads. This system provides benefits to nearly 10 residents and employees and nearly $700 thousand in property.

Winfield Pin Oaks levee system- The Winfield Pin Oaks levee makes up the Winfield Pin Oaks levee system. The Winfield Pin Oaks levee is located in Lincoln County on the West Bank of the Mississippi River near Winfield, Missouri. The Winfield Pin Oaks levee extends from about River Mile 245 - 239 above the Ohio River's confluence with the Mississippi River. The Winfield Pin Oaks levee is approximately 4.95 miles long and provides flood risk reduction to $1.1M in property value, 1,960 acres of agricultural land, 146 residents, and 105 structures. The Winfield Pin Oaks levee system has 5 gravity drains and 3 pump stations.

Changing Future Conditions Considerations

If we accept the climate change scenario that forecasts more dramatic periods of precipitation, we can then infer that more stress will be placed upon levees and that levees will be more prone to failure. Couple that with an infrastructure of aging, perhaps poorly maintained levees, and we have the makings of a serious problem.

Vulnerability

Vulnerability Overview

The USACE regularly inspects levees within its Levee Safety Program to monitor their overall condition, identify deficiencies, verify that maintenance is taking place, determine eligibility for federal rehabilitation assistance (in accordance with P.L. 84-99), and provide information about the levees on which the public relies. Inspection information also contributes to effective risk assessments and supports levee accreditation decisions for the National Flood Insurance Program administered by the Federal Emergency Management Agency (FEMA).

The USACE now conducts two types of levee inspections. Routine Inspection is a visual inspection to verify and rate levee system operation and maintenance. It is typically conducted each year for all levees in the USACE Levee Safety Program. Periodic Inspection is a comprehensive inspection led by a professional engineer and conducted by a USACE multidisciplinary team that includes the levee sponsor. The USACE typically conducts this inspection every five years on the federally authorized levees in the USACE Levee Safety Program.

Both Routine and Periodic Inspections result in a rating for operation and maintenance. Each levee segment receives an overall segment inspection rating of Acceptable, Minimally Acceptable, or Unacceptable. Both the levee segments in Lincoln County have been inspected and rated as Acceptable.

Figure 3.21 Levee System Inspection Ratings

Acceptable	All inspection items are rated as Acceptable.
Minimally Acceptable	One or more levee segment inspection items are rated as Minimally Acceptable or one or more items are rated as Unacceptable and an engineering determination concludes that the Unacceptable inspection items would not prevent the segment/system from performing as intended during the next flood event.
Unacceptable	One or more levee segment inspection items are rated as Unacceptable and would prevent the segment/system from performing as intended, or a serious deficiency noted in past inspections (previous Unacceptable items in a Minimally Acceptable overall rating) has not been corrected within the established timeframe, not to exceed two years.

Potential losses to existing development

Development upstream, in the form of additional levees, creates the greatest impact to Mississippi River flooding in Lincoln County due to channeling additional water into waterways. The county regulates development within incorporated areas located in the floodplain of the Mississippi River. Flash floods and levee failures will continue to impact residents choosing to live in rural areas where low water crossings are required to access their homes. There is anticipated to be little or no increase in run off created by potential development; however, that could change within 15 years due to the potential development of a multi-hub transportation center, including a port, along the Mississippi in Lincoln County.

Impact of previous and future development

Development upstream, in the form of additional levees, creates the greatest impact to Mississippi River flooding in Lincoln County due to channeling additional water into waterways. The county regulates development within unincorporated areas located in the floodplain of the Missouri River. Flash floods and levee failures will continue to impact residents choosing to live in rural areas where low water crossings are required to access their homes. There is anticipated to be little or no increase in run off created by potential development.

Hazard Summary by Jurisdiction

Lincoln County- the agricultural areas, along eastern Lincoln County (Elsberry, Foley, Winfield, and Old Monroe) depend on levees to hold back flood waters. An action plan has been included for Old Monroe to make levee repairs and to remove debris along the levee.

The other communities in the county are not impacted by levees.

Problem Statement

Levee failure poses a signature risk to residents, businesses, and transportation corridors in Lincoln County located along the Mississippi River and its associated levees. While flooding and associated levee failure in Lincoln County will continue, loss of life and property, outside of that of crops, will remain unlikely. Flooding, particularly flash flooding, and levee failure associated with the flooding in the planning area's rivers and creeks will continue to be an issue due the geography.

3.4.7 Sinkholes

Hazard Profile

Hazard Description

Sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that naturally can be dissolved by ground water circulating through them. As the rock dissolves, spaces and caverns develop underground. The sudden collapse of the land surface above them can be dramatic and range in size from broad, regional lowering of the land surface to localized collapse. However, the primary causes of most subsidence are human activities: underground mining of coal, groundwater or petroleum withdrawal, and drainage of organic soils. In addition, sinkholes can develop as a result of subsurface void spaces created over time due to the erosion of subsurface limestone (karst).

Land subsidence occurs slowly and continuously over time, as a general rule. On occasion, it can occur abruptly, as in the sudden formation of sinkholes. Sinkhole formation can be aggravated by flooding.

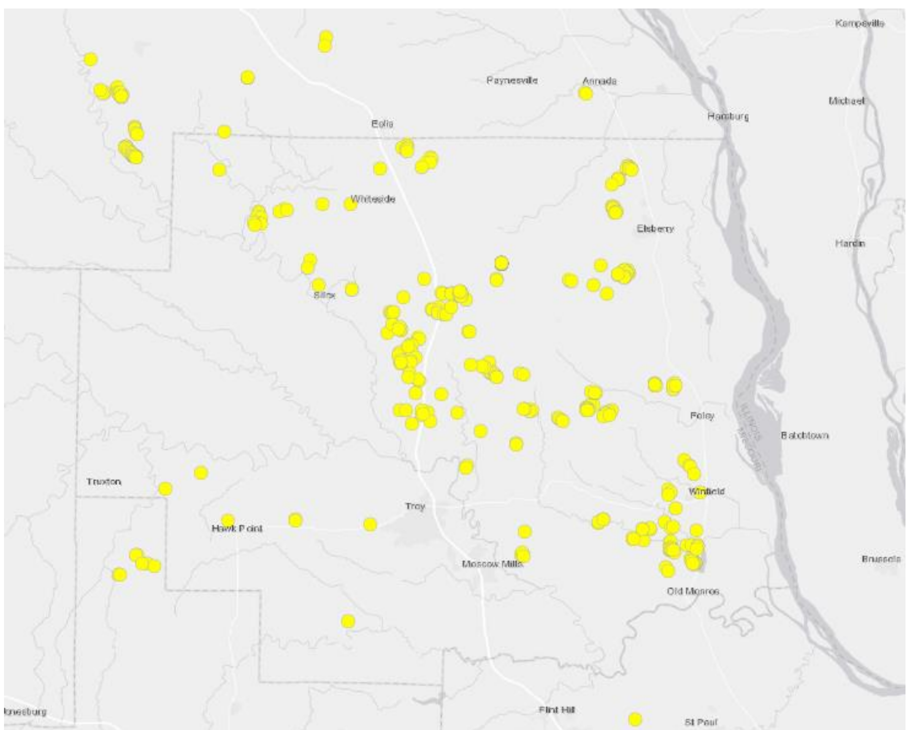
In the case of sinkholes, the rock below the surface is rock that has been dissolving by circulating groundwater. As the rock dissolves, spaces and caverns form, and ultimately the land above the spaces collapse. In Missouri, sinkhole problems are usually a result of surface materials above openings into bedrock caves eroding and collapsing into the cave opening. These collapses are called "cover collapses" and geologic information can be applied to predict the general regions where collapse will occur. Sinkholes range in size from several square yards to hundreds of acres and may be quite shallow or hundreds of feet deep.

According to the U.S. Geological Survey (USGS), the most damage from sinkholes tends to occur in Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. Fifty-nine percent of Missouri is underlain by thick, carbonate rock that makes Missouri vulnerable to sinkholes. Sinkholes occur in Missouri on a fairly frequent basis. Most of Missouri‘s sinkholes occur naturally in the State‘s karst regions (areas with soluble bedrock). They are a common geologic hazard in southern Missouri, but also occur in the central and northeastern parts of the State. Missouri sinkholes have varied from a few feet to hundreds of acres and from less than one to more than 100 feet deep. The largest known sinkhole in Missouri encompasses about 700 acres in western Boone County southeast of where Interstate 70 crosses the Missouri River. Sinkholes can also vary is shape like shallow bowls or saucers whereas other have vertical walls. Some hold water and form natural ponds.

Geographic Location

The figure below shows sink holes scattered across the county with a higher concentration in the center and northern portions of the county where there is a mix of limestone/shale and dolomite/limestone which contributes to the formation of sink holes. There is no recorded instance of damage caused by sink holes in Lincoln County. Most sink holes are in unincorporated areas.

Figure 3.22. Location of Sink Holes in Lincoln County



Source: Missouri Department of Natural Resources

Strength/Magnitude/Extent

Sinkholes vary in size and location, and these variances will determine the impact of the hazard. A sinkhole could result in the loss of a personal vehicle, a building collapse, or damage to infrastructure such as roads, water, or sewer lines. Groundwater contamination is also possible from a sinkhole. Because of the relationship of sinkholes to groundwater, pollutants captured or dumped in sinkholes could affect a community's groundwater system. Sinkhole collapse could be triggered by large earthquakes. Sinkholes located in floodplains can absorb floodwaters but make detailed flood hazard studies difficult to model.

To date, Missouri sinkholes have historically not had major impacts on development nor have they caused serious damage. Thus, the severity of future events is likely to be low.

Previous Occurrences

Sink holes occur naturally in Lincoln County and can develop nearly anywhere. There is no record of property damage or personal injuries due to sink holes in the county.

Probability of Future Occurrence

There are no records available in the planning area from which to derive quantifiable probabilities.

Changing Future Conditions Considerations

Direct effects from changing climate conditions such as an increase in droughts and could contribute to an increase in sinkholes. These changes raise the likelihood of extreme weather, meaning the torrential rain and flooding conditions which often lead to the exposure of sinkholes are likely to become increasingly common. Certain events such as a heavy precipitation following a period of drought can trigger a sinkhole due to low levels of groundwater combined with a heavy influx of rain. With potential growth areas located along major transportation network, it is important to consider best management practices during future projects in Lincoln County.

Vulnerability

Vulnerability Overview

As per the 2018 State Plan, Lincoln County is rated as "Low-Medium" and the total population potentially impacted is between 1 person to 106 people.

Potential Losses to Existing Development

The location of current sink holes and sink hole prone areas is well known to current property owners and developers who avoid construction in those areas. Potential losses are slight due to the rural locations of the sink holes.

Previous and Future Development

Builders avoid construction in known sink hole areas thereby avoiding potential risk.

Hazard Summary by Jurisdiction

No area of Lincoln County is at more risk than others, although, any growth areas near the sink holes will be impacted.

Problem Statement

There is potential risk to Lincoln County residents due to sink holes. However, most sink holes are found in uninhabited rural areas and construction in sink hole prone areas is avoided. Therefore, the risk is nearly non-existent.

3.4.8 Severe Thunderstorms including High Winds, Hail and Lightning

Hazard Profile

Hazard Description

Thunderstorms

A thunderstorm is defined as a storm that contains lightning and thunder which is caused by unstable atmospheric conditions. When cold upper air sinks and warm moist air rises, storm clouds or 'thunderheads' develop resulting in thunderstorms. This can occur singularly, as well as in clusters or lines. The National Weather Service defines a thunderstorm as "severe" if it includes hail that is one inch or more, or wind gusts that are at 58 miles per hour or higher. At any given moment across the world, there are about 1,800 thunderstorms occurring. Severe thunderstorms most often occur in Missouri in the spring and summer, during the afternoon and evenings, but can occur at any time. Other hazards associated with thunderstorms are heavy rains resulting in floods and flash floods, high winds, hail, and tornadoes. Each of these hazards is discussed separately elsewhere in this section.

High Winds

A severe thunderstorm can produce winds causing as much damage as a weak tornado. The damaging winds of thunderstorms include downbursts, microbursts, and straight-line winds. Downbursts are localized currents of air blasting down from a thunderstorm, which induce an outward burst of damaging wind on or near the ground. Microbursts are minimized downbursts covering an area of less than 2.5 miles across. They include a strong wind shear (a rapid change in the direction of wind over a short distance) near the surface. Microbursts may or may not include precipitation and can produce winds at speeds of more than 150 miles per hour. Damaging straight-line winds are high winds across a wide area that can reach speeds of 140 miles per hour.

Lightning

All thunderstorms produce lightning which can strike outside of the area where it is raining and is has been known to fall more than 10 miles away from the rainfall area. Thunder is simply the sound that lightning makes. Lightning is a huge discharge of electricity that shoots through the air causing vibrations and creating the sound of thunder.

Hail

According to the National Oceanic and Atmospheric Administration (NOAA), hail is precipitation that is formed when thunderstorm updrafts carry raindrops upward into extremely cold atmosphere causing them to freeze. The raindrops form into small frozen droplets. They continue to grow as they come into contact with super-cooled water which will freeze on contact with the frozen rain droplet. This frozen droplet can continue to grow and form hail. As long as the updraft forces can support or suspend the weight of the hailstone, hail can continue to grow before it hits the earth.

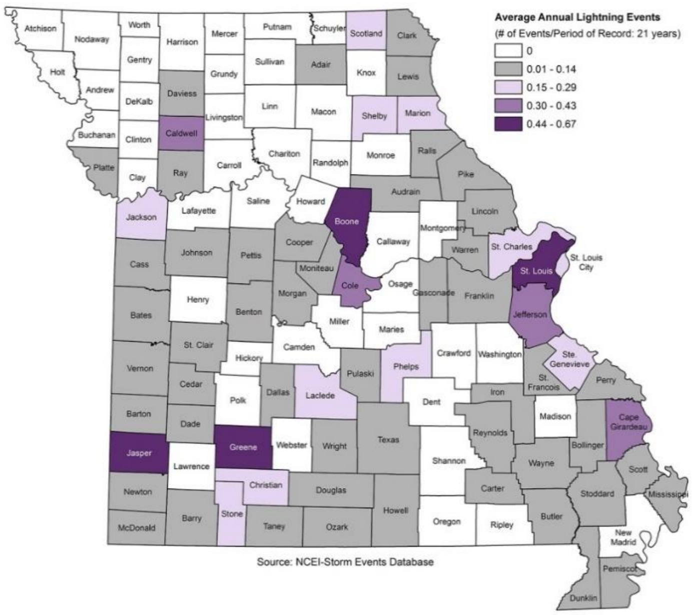
At the time when the updraft can no longer support the hailstone, it will fall down to the earth. For example, a ¼" diameter or pea sized hail requires updrafts of 24 miles per hour, while a 2 ¾" diameter or baseball sized hail requires an updraft of 81 miles per hour. According to the NOAA, the largest hailstone in diameter recorded in the United States was found in Vivian, South Dakota on July 23, 2010. It was eight inches in diameter, almost the size of a soccer ball. Soccer-ball-sized hail is the exception, but even small pea-sized hail can do damage.

Geographic Location

Thunderstorms, high winds, hail, and lightning are county-wide hazards and can occur anywhere in Lincoln County. Although these events occur similarly throughout the planning area, they are more frequently reported in more urbanized areas. In addition, damages are more likely to occur in more densely populated urban areas.

The figure below, taken from the 2018 Missouri State Plan, shows zero reported incidents of lightning in the planning area. That is not to say that lightning does not strike in Lincoln County, 0.01-0.14 events are reported.

Figure 3.23. Location and Frequency of Lightning in the U.S.A.



The figure below shows wind zones in the United States. The red zone, Zone IV, covers the entire State of Missouri which includes the planning area.

Figure 3.24. Wind Zones in the United States

Source: FEMA 320, Taking Shelter from the Storm, 3rd edition, http://www.weather.gov/media/bis/FEMA_SafeRoom.pdf

Strength/Magnitude/Extent

Based on information provided by the Tornado and Storm Research Organization (TORRO), the table below describes typical damage impacts of the various sizes of hail.

Table 3.29. Tornado and Storm Research Organization Hail Storm Intensity Scale

Intensity Category	Inches Diameter	Size Description	Typical Damage Impacts
Hard Hail	0.2-0.4	Pea	No damage
Potentially Damaging	0.4-0.6	Mothball	Slight general damage to plants, crops
Significant	0.6-0.8	Marble, grape	Significant damage to fruit, crops, vegetation
Severe	0.8-1.2	Walnut	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
Severe	1.2-1.6	Pigeon's egg	Wide spread glass damage, vehicle bodywork damage
Destructive	1.6-2.0	Golf ball	Whole sale destruction of glass, damage to tiled roofs, significant risk of injuries
Destructive	2.0-2.4	Hen's egg	Bodywork of grounded aircraft dented, brick walls pitted
Destructive	2.4-3.0	Tennis ball	Severe roof damage, risk of serious injuries
Destructive	3.0-3.5	Large orange	Severe damage to aircraft bodywork
Super Hailstorms	3.6-3.9	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
Super Hail Storms	4.0+	Melon	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open

Source :Tornado and Storm Research Organization (TORRO), Department of Geography, Oxford Brookes University

Notes: In addition to hail diameter, factors including number and density of hail stones, hail fall speed and surface wind speeds affect severity. http://www.torro.org.uk/site/hscale.php

Straight-line winds are defined as any thunderstorm wind that is not associated with rotation (i.e., is not a tornado). It is these winds, which can exceed 100 miles per hour, which represent the most common type of severe weather. They are responsible for most wind damage related to thunderstorms. Since thunderstorms do not have narrow tracks like tornadoes, the associated wind damage can be extensive and affect entire (and multiple) counties. Objects like trees, barns, outbuildings, high-profile vehicles, and power lines/poles can be toppled or destroyed, and roofs, windows, and homes can be damaged as wind speeds increase.

The onset of thunderstorms with lightning, high wind, and hail is generally rapid. Duration is less than six hours and warning time is generally six to twelve hours. Nationwide, lightning kills 75 to 100 people each year. Lightning strikes can also start structural and wildland fires, as well as damage electrical systems and equipment.

Previous Occurrences

Thunderstorms, high winds, lightning, and hail are common throughout the planning area. The NOAA National Centers for Environmental Information reports 99 Thunderstorm Wind Events over the 21-year period between 2000 and 2020, with no injury and damage. The USDA Risk Management Agency reports no Thunderstorm damage during the same period.

Table 3.30. Thunderstorm Wind Events, 2000 – 2020

Year	No. Events	Deaths	Injuries	Damage
2000	15	0	0	$ -
2001	4	0	0	$ 5000
2002	5	0	0	$ -
2003	1	0	0	$ -
2004	3	0	0	$ -
2005	7	0	0	$ -
2006	8	0	0	$ -
2007	4	0	0	$ 5000
2008	4	0	0	$ -
2009	3	0	0	$ 3000
2010	4	0	0	$ -
2011	6	0	0	$ -
2012	1	0	0	$ -
2013	6	0	0	$ -
2014	5	0	0	$ -
2015	1	0	0	$ -
2016	4	0	0	$ -
2017	4	0	0	$ -
2018	5	0	0	$ -
2019	6	0	0	$ -
2020	3	0	0	$ -
TOTAL	**99**	**0**	**0**	**$ 10,300**

Source: NOAA National Centers for Environmental Information

Subsequently, a search of the NOAA National Centers for Environmental Information and insurance claims from the USDA Risk Management Agency produced no record of damaging lightning for the past 21 years. This does not mean there was no lightning damage, just that damage was not sufficiently significant to attract enough attention to be reported.

Both the NOAA National Centers for Environmental Information and USDA Risk Management Agency insurance claims from 1999 through 2018 report Hail Events. The NOAA National Centers for Environmental Information lists 80 incidents of hail greater than ½" in diameter, some reaching nearly three inches. No injuries or damage were recorded.

Table 3.31. Hail Events, 2000 – 2020

Year	No. Events	Hail Size Range(Inches)
2000	1	.88
2001	2	3/4 - 1
2002	5	3/4 - 1
2003	2	1-1-1/4
2004	2	.88 - 1
2005	6	3/4 - 1-3/4
2006	10	3/4 - 1-3/4
2007	0	0
2008	18	3/4 - 1-3/4
2009	1	1
2010	4	.88 - 2
2011	8	.88 – 1-3/4
2012	7	.88 – 1-3/4
2013	1	.88
2014	4	3/4 – 2
2015	3	.88 – 1-3/4
2016	2	.88 – 3/4
2017	2	3/4 - 1
2018	1	1 1/4
2019	0	0
2020	3	1 - 2 1/2
TOTAL	69	

Source: NOAA National Centers for Environmental Information

USDA Risk Management Agency insurance claims for the corresponding period shows $423,675 of crop damage.

Table 3.32. Crop Insurance Claims Paid from Hail, 2000-2020

Crop Year	Acres	Damage ($)
2000	0.00	0.00
2001	34.01	6,076.00
2002	0.00	0.00
2003	0.00	0.00
2004	0.00	0.00
2005	0.00	0.00
2006	40.40	1,042.00
2007	0.00	0.00
2008	0.00	0.00
2009	255.37	15,319.00
2010	0.00	0.00
2011	1,200.29	393,376.15

Crop Year	Acres	Damage ($)
2012	7.47	273.00
2013	0.00	0.00
2014	0.00	0.00
2015	48.60	7,589.00
2016	0.00	0.00
2017	0.00	0.00
2018	0.00	0.00
2019	0.00	0.00
2020	0.00	0.00
Total	1,586.14	423,675.15

USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/data/cause

The NOAA National Centers for Environmental Information reports just three High Wind events, two during 2001 and one in 2002. The winds ranged in speeds of 40-43 knots. There were no injuries or damages included in the report. However, USDA Risk Management Agency insurance claims for the corresponding period show nearly $201,493 in crop damage claims.

Table 3.33. Insurance Claims paid from High Winds, 2000-2020

Crop Year		Dollars
2000	0.00	0.00
2001	0.00	0.00
2002	0.00	0.00
2003	0.00	0.00
2004	150.73	6,116.00
2005	35.71	768.00
2006	0.00	0.00
2007	0.00	0.00
2008	0.00	0.00
2009	134.30	13,417.00
2010	0.00	0.00
2011	850.77	124,559.80
2012	0.00	0.00
2013	0.00	0.00
2014	0.00	0.00
2015	0.00	0.00
2016	0.00	0.00
2017	0.00	0.00
2018	376.81	46,896.84
2019	36.68	8,543.50
2020	38.40	1,192.00
Total	1,623.40	201,493.14

Probability of Future Occurrence

The annual probability of future occurrence for Thunderstorm Wind is 323% in any given year, considering 68 events occurred during a 21-year period. The annual probability of occurrence for Hail events is even higher at 261%, given 55 events over a 21-year period. High Wind events are less likely with a probability of 14.2% during any given year. Lightning is more difficult to judge but there is one recorded event with a probability of 4% in any given year.

Changing Future Conditions Considerations

NASA's Earth Observatory provides an analysis on how climate change could, theoretically, increase potential storm energy by warming the surface and putting more moisture in the air through evaporation. The presence of warm, moist air near the surface is a key ingredient for summer storms that meteorologists have termed "convective available potential energy," or CAPE. With an increase in CAPE, there is greater potential for cumulus clouds to form. The study also counters this with the theory that warming in the Arctic could lead to less wind shear in the mid-latitude areas prone to summer storms, making the storms less likely.

Predicted increases in temperature could help create atmospheric conditions that are fertile breeding grounds for severe thunderstorms and tornadoes in Missouri. Possible impacts include an increased risk to life and property in both the public and private sectors. Public utilities and manufactured housing developments will be especially prone to damages. Jurisdictions already affected should be prepared for more of these events, and should thus prioritize mitigation actions such as construction of safe rooms for vulnerable populations, retrofitting and/or hardening existing structures, improving warning systems and public education, and reinforcing utilities and additional critical infrastructure

Vulnerability

Vulnerability Overview Severe thunderstorm losses are usually attributed to the associated hazards of hail, downburst winds, lightning and heavy rains. Losses due to hail and high wind are typically insured losses that are localized and do not result in presidential disaster declarations. However, in some cases, impacts are severe and widespread and assistance outside state capabilities is necessary. Hail and wind also can have devastating impacts on crops. Severe thunderstorms/heavy rains that lead to flooding are discussed in the flooding hazard profile. Hailstorms cause damage to property, crops, and the environment, and can injure and even kill livestock. In the United States, hail causes more than $1 billion in damage to property and crops each year. Even relatively small hail can shred plants to ribbons in a matter of minutes. Vehicles, roofs of buildings and homes, and landscaping are also commonly damaged by hail. Hail has been known to cause injury to humans, occasionally fatal injury.

In general, assets in the County vulnerable to thunderstorms with lightning, high winds, and hail include people, crops, vehicles, and built structures. Although this hazard results in high annual losses, private property insurance and crop insurance usually cover the majority of losses. Considering insurance coverage as a recovery capability, the overall impact on jurisdictions is reduced.

Most lightning damages occur to electronic equipment located inside buildings. But structural damage can also occur when a lightning strike causes a building fire. In addition, lightning strikes can cause damages to crops, if fields or forested lands are set on fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes. http://www.vaisala.com/en/products/thunderstormandlightningdetectionsystems/Pages/NLDN.aspx and http://www.lightningsafety.noaa.gov/

The 2018 State Plan lists Severe Thunderstorm Building Exposure for Lincoln County at $4.72B.

Previous Losses to Existing Development

Based on past loss trends and growth trends in Lincoln County, we anticipate losses to remain about where they are currently; totaling to average just under $90K per year in property and crop losses due to high wind, thunderstorms, hail, and lightning.

Previous and Future Development

Development trends are not anticipated to have an impact on potential losses.

Hazard Summary by Jurisdiction

Although this hazard poses the same risk across the county, the special needs, vulnerable populations are at more risk. Although the school districts are considered as vulnerable population, they do have an emergency plan and emergency alert system in case of any thunderstorm events.

Problem Statement

Severe thunderstorms, high wind, hail, and lightning will continue to strike Lincoln County. The 2018 State Plan forecasts the county to be exposed to up to $4.72B in losses. Possible solutions include review of local ordinance and building codes to address high winds and/or construction techniques to include structural bracing, straps and clips, or anchor bolts.

3.4.9 Tornado

Hazard Profile

Hazard Description

Essentially, tornadoes are a vortex storm with two components of winds. The first is the rotational winds that can measure up to 500 miles per hour, and the second is an uplifting current of great strength. The dynamic strength of both these currents can cause vacuums that can overpressure structures from the inside.

Although tornadoes have been documented in all 50 states, most of them occur in the central United States. The unique geography of the central United States allows for the development of thunderstorms that spawn tornadoes. The jet stream, which is a high-velocity stream of air, determines which area of the central United States will be prone to tornado development. The jet stream normally separates the cold air of the north from the warm air of the south. During the winter, the jet stream flows west to east from Texas to the Carolina coast. As the sun “moves” north, so does the jet stream, which at summer solstice flows from Canada across Lake Superior to Maine. During its move northward in the spring and its recession south during the fall, the jet stream crosses Missouri, causing the large thunderstorms that breed tornadoes.

Tornadoes spawn from the largest thunderstorms. The associated cumulonimbus clouds can reach heights of up to 55,000 feet above ground level and are commonly formed when Gulf air is warmed by solar heating. The moist, warm air is overridden by the dry cool air provided by the jet stream. This cold air presses down on the warm air, preventing it from rising, but only temporarily. Soon, the warm air forces its way through the cool air and the cool air moves downward past the rising warm air. This air movement, along with the deflection of the earth's surface, can cause the air masses to start rotating. This rotational movement around the location of the breakthrough forms a vortex, or funnel. If the newly created funnel stays in the sky, it is referred to as a funnel cloud. However, if it touches the ground, the funnel officially becomes a tornado.

A typical tornado can be described as a funnel-shaped cloud that is “anchored” to a cloud, usually a cumulonimbus that is also in contact with the earth's surface. This contact on average lasts 30 minutes and covers an average distance of 15 miles. The width of the tornado (and its path of destruction) is usually about 300 yards. However, tornadoes can stay on the ground for upward of 300 miles and can be up to a mile wide. The National Weather Service, in reviewing tornadoes occurring in Missouri between 1950 and 1996, calculated the mean path length at 2.27 miles and the mean path area at 0.14 square mile.

The average forward speed of a tornado is 30 miles per hour but may vary from nearly stationary to 70 miles per hour. The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. Tornadoes are most likely to occur in the afternoon and evening, but have been known to occur at all hours of the day and night.

Geographic Location

Tornados can occur anywhere in Lincoln County.

Strength/Magnitude/Extent

Tornadoes are the most violent of all atmospheric storms and are capable of tremendous destruction. Wind speeds can exceed 250 miles per hour and damage paths can be more than one mile wide and 50 miles long. Tornadoes have been known to lift and move objects weighing more than 300 tons a distance of 30 feet, toss homes more than 300 feet from their foundations, and siphon millions of tons of water from water bodies. Tornadoes also can generate a tremendous amount of flying debris or “missiles,” which often become airborne shrapnel that causes additional damage. If wind speeds are high enough, missiles can be thrown at a building with enough force to penetrate windows, roofs, and walls. However, the less spectacular damage is much more common.

Tornado magnitude is classified according to the EF-Scale; or the Enhanced Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renown severe storm researcher. The EF-Scale; shown below, attempts to rank tornadoes according to wind speed based on the damage caused. This update to the original EF-Scale was implemented in the U.S. on February1,2007.

Table 3.34. Enhanced Fujita Scale for Tornado Damage

FUJITASCALE			DERIVED EF SCALE		OPERATIONAL EF SCALE	
F Number	Fastest¼-mile (mph)	3 Second Gust (mph)	EF Nu	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85