Section 4: Risk Assessment

Requirement §201.6(c)(2)(i):	***[The risk assessment shall include a] description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.***
Requirement §201.6(c)(2)(ii):	***[The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2009 must also address NFIP insured structures that have been repetitively damaged by floods.***
Requirement §201.6(c)(2)(iii):	***For multi-jurisdictional plans, the risk assessment must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.***

Risk assessment is a process of estimating the potential for injury, death, property damage, or economic loss that may result from a hazard. A risk assessment is only as valuable as the thoroughness and accuracy of the information on which it is based. As will be seen, there is a great variation between hazards in the amount and reliability of the data available for analysis.

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Identification of Hazards

The following natural hazards have been identified as posing potential risk in the planning area*:*

- Severe Winter Weather (Snow, Ice, and Extreme Cold)
- Severe Thunderstorms (includes Damaging Winds, Hail, and Lightning)
- Tornado
- Flood (includes riverine flooding, flash flooding, and storm water flooding)
- Levee Failure
- Dam Failure
- Extreme Heat
- Drought
- Wildfire
- Earthquake
- Land Subsidence/Sinkhole

The Missouri State Hazard Mitigation Plan (2013) indicates that expansive soils, landslides, and rockfalls are recognized as hazards in Missouri, but occur infrequently and with minimal impact. For this reason, those hazards were not profiled in the state plan nor will they be profiled in the Cooper County plan.

There are certain other natural hazards that FEMA requires to be addressed in hazard mitigation plans if they are applicable to the planning area. Avalanches and volcanoes have not been included in this plan as they do not pose a threat due to Cooper County's topography and geology. Coastal erosion, coastal storms, hurricanes, and tsunamis do not pose a threat to the county due to its inland location.

Technological hazards and human hazards will not be addressed in this plan.

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Risk Assessments for Identified Hazards

A risk assessment has been conducted for each hazard identified as affecting the planning area. The remainder of this section includes these risk assessments, which are organized according to the following outline:

DESCRIPTION OF HAZARD

Location

Extent - The extent of the hazard refers to the expected strength or magnitude of that hazard on the planning area; extent is an attribute of the hazard alone and does not include its effect on humans or the built environment.

Previous Occurrences

Probability of Future Events (Natural Hazards) - The probability of future events is, for the most part, based on historical data while also taking into account the expected impact of climate change. It is assigned based on the following scale, which was slightly modified from that found in the *Missouri State Hazard Mitigation Plan (2013)*:

- Low – The hazard has little or no chance of happening (less than 1 percent chance of occurrence in any given year).
- Moderate – The hazard has a reasonable probability of occurring (between 1 and 10 percent chance of occurrence in any given year).
- High – The probability is considered sufficiently high to assume that the event will occur (between 10 and 100 percent chance of occurrence in any given year).

In the case of earthquakes, projections made by the USGS have also been taken into account in assessing the probability.

IDENTIFICATION OF COMMUNITY ASSETS potentially affected by or helping to mitigate the effects of the hazard in each participating jurisdiction. This is covered in Section 2 of the plan.

ANALYSIS OF RISK presented by the hazard, including a **measure of severity** for each participating jurisdiction. The **measure of severity** is an estimate of the deaths, injuries, or damage (property or environmental) that could result from the hazard. It is also broadly based on the scale found in the Missouri State Hazard Mitigation Plan (2013):

Low – Few or minor damage or injuries are likely.

Moderate – Personal injuries and/or damage to property or the environment are expected.

High – Major injuries and/or death and/or major damage will likely occur.

SUMMARY OF VULNERABILITY

A jurisdiction's vulnerability to a hazard is connected to the extent of that hazard, the probability of future events, the estimated measure of severity, and mitigation measures already in place for that hazard.

In many cases, the potential severity of the hazard event contributes the greatest weight to the vulnerability rating. In some cases, however, a low severity event with high frequency can cause economic strain, which translates into a higher vulnerability.

Existing Mitigation/Operating Assumptions: Both the measure of severity and overall vulnerability are greatly impacted by the mitigation already in place in the planning area; this existing mitigation is taken as an operating assumption when evaluating the vulnerability to a particular hazard. The following mitigation activities are applicable to many or all hazards:

- [Cooper County and any other jurisdictions?] have alternate methods/locations in place for fueling emergency vehicles.
- Interconnections are in place between Missouri American Water and PWDS #1 and PWSD #2. [From Cole County plan. Is this accurate for Cooper County?]
- Buses in all school districts have two-way radios on board. [From Cole County plan. Is this accurate for Cooper County?]
- Agreements are in place with local shelters in the planning area.
- General evacuation procedures are included in the Office of Emergency Management's (OEM) Emergency Operation Plan. [From Cole County plan. Is this accurate for Cooper County?]

Other current mitigation activities are aimed at mitigating the effects of a specific hazard and are described under the specific hazard profile. Cooper County does not currently have a planning and zoning commission or building codes.

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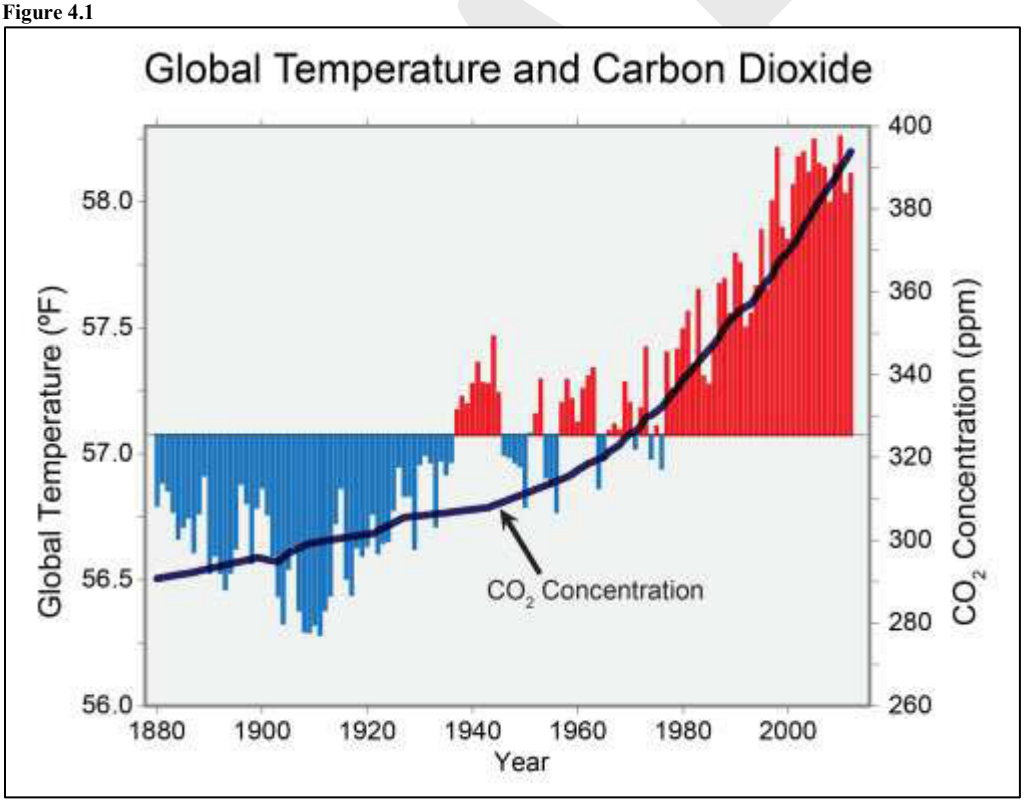
THE EFFECTS OF CLIMATE CHANGE ON HAZARDS

While climate change remains a contentious political issue in the United States, the scientific data is overwhelmingly clear: the climate is changing. The Cooper County Hazard Mitigation Planning Committee deemed it important to include a consideration of the effect of climate change on the hazards profiled. This is not required for county-level plans but, as of March 2016, will be required for state hazard mitigation plans.

The information for this section is taken primarily from *The National Climate Assessment 2014*. The 2014 assessment was put together by a team of 300 experts under the guidance of a 60-member Federal Advisory Committee. The assessment was reviewed by the public and other experts in the field, including the federal agencies and a panel from the National Academy of Sciences. The full report can be accessed at GlobalChange.gov. A number of charts from *The National Climate Assessment 2014* have been included to indicate just some of the scientific data supporting the conclusion that the climate is changing.

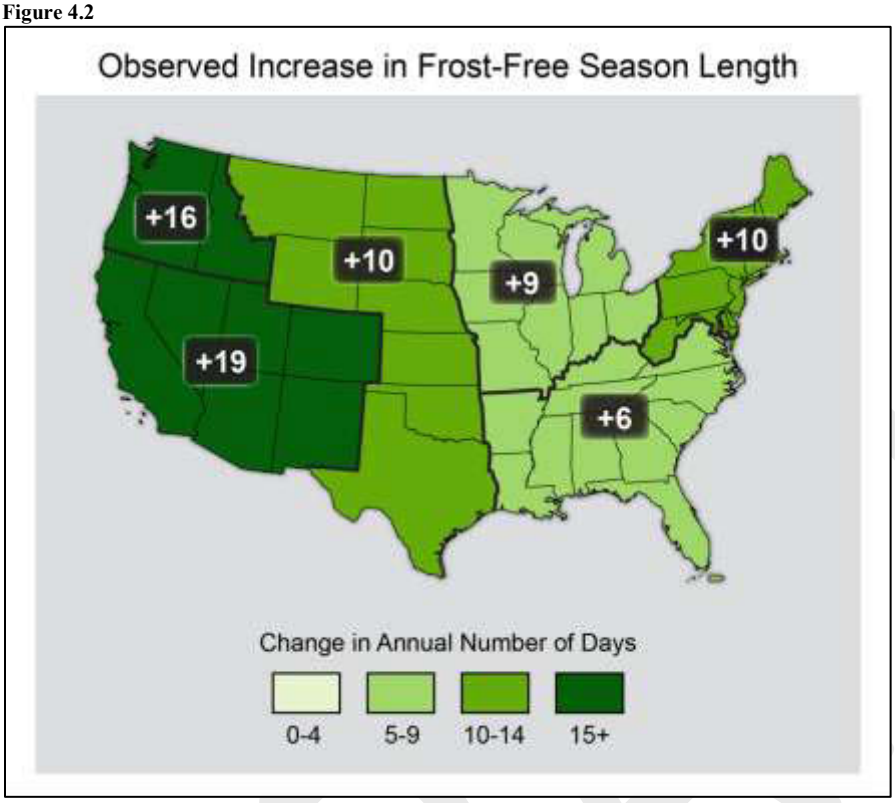
Global temperatures show a sharp increase which correlates with the increasing CO2 concentration in the atmosphere (Figure 4.1).

Figure 4.1



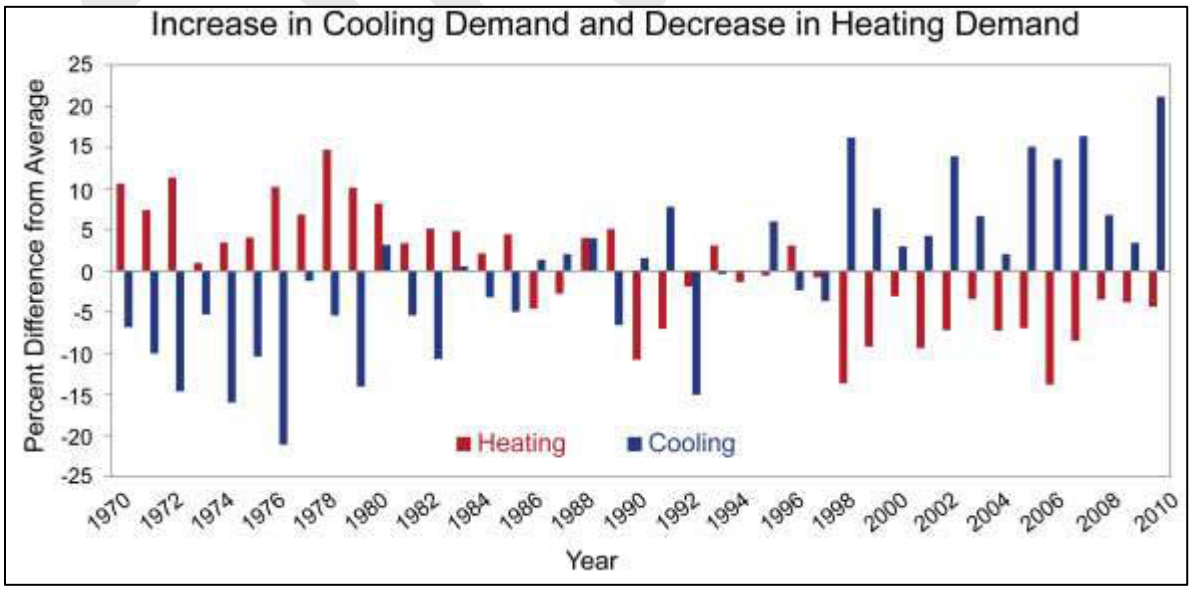
There has been a significant increase in frost-free days across the continental U.S. in the past two decades when compared with the average for the period 1901-1961 (Figure 4.2).

Figure 4.2



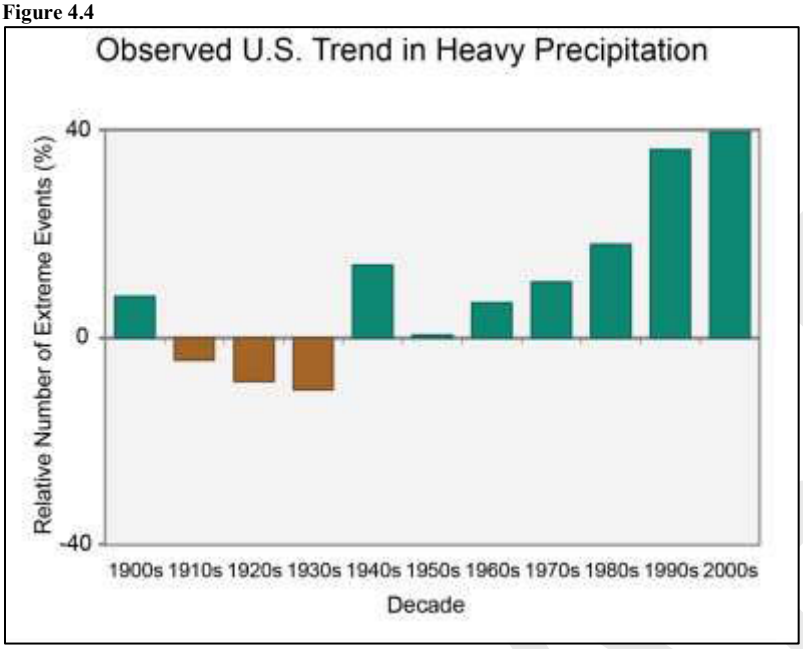
Likewise, there has been a trend of increased cooling demand in the past two decades (Figure 4.3).

Figure 4.3



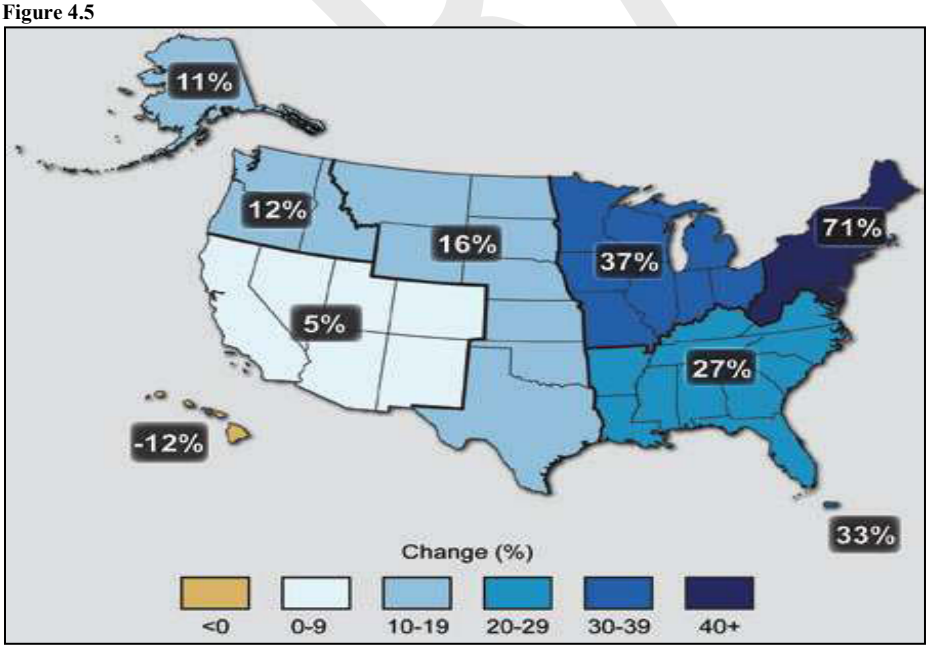
There is a strong upward trend in heavy precipitation for the U.S. as a whole, beginning in the 1940s (Figure 4.4). (The horizontal line at zero represents the average precipitation for the period 1901-1960.)

Figure 4.4



However, this heavier precipitation is affecting different regions of the country to varying degrees; the Northeast and the Midwest are experiencing the largest increase in sudden torrential downpours (Figure 4.5).

Figure 4.5



The National Climate Assessment 2014 states that the current data indicates observed increases in the following: winter storms, extreme heat, heavy downpours, and the intensity, frequency, and duration of hurricanes. All of these have potential effects on hazards profiled for Cooper County and its jurisdictions:

- Cooper County has been included in five Presidential Disaster Declarations for severe winter weather since 2002. It would be expected that severe winter weather events will continue to be of greater importance in the planning area.

- Extreme heat is already the number one weather-related killer in the United States. The increase in extreme heat makes it even more urgent that all jurisdictions ensure their citizens, especially the most vulnerable, are both aware of the dangers of extreme heat and have cooling resources/locations available.

- Heavy downpours are a causative factor for flash flooding and small stream flooding. It would be expected that flash flooding may become a larger problem in areas already prone to it and a problem in some areas previously unaffected.

- The increase in hurricane intensity can affect the planning area both directly and indirectly. The remnants of Hurricane Ike spread over the Midwest (and the planning area) in September 2008, causing flash flooding and road closures in the Mid-Missouri region. In June 2015, the planning area received heavy rains from the remnants of Hurricane Bill; numerous roads were closed because of flooding, and the Missouri River, already moderately high, rose even further. [from Cole plan. Accurate for Cooper plan?]

  Indirectly, the high cost of huge disasters, such as those caused by hurricanes, further strains the FEMA budget; pre-disaster mitigation project funding has become increasingly difficult to obtain. This has an indirect, but very real and problematic, impact on the planning area.

This list of the probable effects of climate change on the hazards profiled is conservative by design and not intended to be exhaustive. There are some natural hazards for which the effects of climate change are still unclear. *The National Climate Assessment 2014* indicates that the trends for tornadoes, hail, and damaging thunderstorm winds are still uncertain at this point.

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NATURAL HAZARDS AFFECTING THE PLANNING AREA

A summary of the probability and severity ratings for natural hazards in each of the participating jurisdictions is shown in Figure 4.6.

Figure 4.6

Natural Hazard Probability and Severity Ratings by Participating Jurisdiction [add more jurisdictions if necessary]

		Cooper County (uninc.)	Boonville	Bunceton	Otterville	Pilot Grove	Wooldridge	Linneman-Weekley Levee District	Overton-Wooldridge Levee District	Prairie Home R-V Schools		
Severe Winter Weather	P	H	H	H	H	H	H	na	na	H		
	S	M	M	M	M	M	M	na	na	L		
Severe Thunderstorm	P	H	H	H	H	H	H	na	na	H		
	S	M-H	M-H	M-H	M-H	M-H	M-H	na	na	M-H		
Tornado	P	H	H	H	H	H	H	na	na	H		
	S	H	H	H	H	H	H	na	na	H		
Flood	P	H	H	L	L	L	H	H	H	L		
	S	M	M	L	L	L	H	H	H	L		
Levee Failure	P	M	na	na	na	na	M	M	M	na		
	S	H	na	na	na	na	H	H	H	na		
Dam Failure	P	L	L	na	na	na	na	na	na	na		
	S	L	L	na	na	na	na	na	na	na		
Extreme Heat	P	M	M	M	M	M	M	na	na	M		
	S	M	M	M	M	M	M	na	na	M		
Drought	P	L	L	L	L	L	L	na	na	na		
	S	L	L	L	L	L	L	na	na	na		
Wildfire	P	L	L	L	L	L	L	na	na	L		
	S	L	L	L	L	L	L	na	na	L		
Earthquake	P	H	H	H	H	H	H	na	na	H		
	S	M	M	M	M	M	M	na	na	M		
Land Subsidence/ Sinkhole	P	M	na	na	na	na	na	na	na	na		
	S	L	na	na	na	na	na	na	na	na		

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4.1 SEVERE WINTER WEATHER (INCLUDING ICE, SNOW, AND SEVERE COLD)

Description of Hazard

Cooper County generally experiences severe winter weather at least every other year; certain years are particularly notable for their storm frequency and/or intensity. Winter storms in central Missouri contain ice, snow, severe cold, sleet, and wind; each of these has the potential to disrupt life in the region by making normal activity difficult and/or dangerous.

Winter storms pose a threat to central Missouri by creating disruptions in electricity, telephone, and other critical infrastructures. Employees may be unable to get to work due to icy conditions, unplowed roadways, and disruptions in transportation services, or facility damage. A shortage of supplies may ensue with a longer stretch of severe winter weather.

Snowstorms do not generally impact the region for long periods of time, but ice storms have shut down schools and businesses for extended periods. Ice is also the biggest threat to reliable power and phone service.

Location

The entire planning area is at risk from severe winter weather.

Extent

The historical data for the planning area (Figure 4.7) provides information regarding both the duration and severity of winter weather events.

Duration: Severe winter weather events involving some type of precipitation (freezing rain, sleet, ice, or snow) have an average duration of over a day and a half.

Severity: Cooper County experienced 29 officially recorded winter storms or periods of extreme cold during the period from January 14, 1994, through February 6, 2011, according to data from NOAA and FEMA. Figure 4.7 shows available data for these storms including additional information from SEMA Situation Reports.

Winter storms typically move through a large area. The deaths, injuries, and estimated costs reflect all counties in Missouri affected by the storm. The death associated with one of the periods of extreme cold did not occur in Cooper County; information on the locations of the injuries was not available. While it can be seen from the data that severe winter weather can result in great financial cost, the exact cost of these storms to Cooper County was not available in the data.

In some cases, more cost information is available for storms for which Presidential Disaster Declarations were made. After a Presidential Disaster Declaration, Public Assistance (PA) and/or Individual Assistance (IA) is made available through FEMA. The PA can be further specified as a specific category; the categories relevant to this data are Category A for debris removal and Category B for emergency protective measures.

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Since 2006, there have been five Presidential Disaster Declarations for severe winter weather in Missouri, three of these included Cooper County (#1673, #1676, #1736, and #1961). In all of these disasters, Public Assistance (PA) was made available to Cooper County through FEMA. There have also been two Presidential Emergency Declarations due to severe winter weather for the entire state of Missouri since 2006 (#3281 and #3303). Public Assistance (PA), limited to direct Federal Assistance, was made available during these Emergencies.

The Governor of Missouri declared a State of Emergency in the State for the winter storm of November 30 through December 1, 2006; this declaration allowed state funds to be used in disaster response. SEMA Situation Reports indicate a dairy farmer lost 23 head of cattle and other facilities valued at more than $1 million in damage from this storm; other individuals in Cooper County reported roofs collapsing on barns and greenhouses.

The severe winter weather in the first two weeks of December 2007 resulted in a Presidential Emergency Declaration (#3281) for the ice storm beginning on December 8, 2007. Neighboring counties received a Presidential Disaster Declaration (#1736) for the entire 10-day period of severe winter weather. SEMA activated the State Emergency Operations Center, and the Governor of Missouri declared a State Emergency which made state resources available to assist local governments.

According to the National Climate Data Center, the February 2011 blizzard was the first to strike central Missouri in several years. Over 20 inches of snow fell over a 24-hour period coupled with 40-mile-per-hour winds, which resulted in both a Presidential Emergency Declaration (#3317) and a Presidential Disaster Declaration (#1961). Interstate 70 was shut down from Warren County to just east of Kansas City. The National Guard was called to clear county roads and assist with emergency transportation. The region was brought to a standstill for several days. A Federal disaster declaration was obtained for many counties in order to assist with the cost of snow removal. Light freezing rain and sleet started on January 31 with an inch of sleet accumulating by the early morning hours of February 1. By midday, the precipitation had changed to snow and the wind began increasing. By late afternoon, travel became extremely dangerous. SEMA activated the State Emergency Operations Center, and the Governor of Missouri declared a State Emergency, which made state resources available to assist local governments.

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Previous Occurrences

Figure 4.7 Severe Winter Weather Events in Cooper County (1996 – May 2016)			
Date	**Storm Type**	**Duration (days)**	**Description**
1/9/1997	Heavy Snow	1	Up to 7 inches of snow in Boonville.
1/10/1997	Cold/Wind Chill	4	Very cold arctic air settled over Northwest and West Central Missouri from the 10th through the 13th.
1/12/1998	Ice Storm	1	A light freezing drizzle began late on the evening of January 11, then blossomed into a steady light freezing rain. Icy roads and walkways resulted in numerous problems during the morning commute on January 12.
3/11/2000	Heavy Snow	1	6 inches of heavy snow fell along and south of a line from Clinton through Sedalia to Boonville.
10/6/2000	Extreme Cold	5	Lows dropped below freezing for 5 consecutive days.
12/10/2000	Extreme Cold	22	Arctic air gripped the region from around December 10 through the end of the month. Except for a few hours on December 15 and 16, temperatures remained below freezing through the entire period. Snow cover persisted from December 13 through the end of the month.
12/11/2000	Ice Storm	1	Ice accumulations of up to 3/8 of an inch were reported from Marshall and Sedalia into the Boonville area.
12/13/2000	Heavy Snow	1	Snow overspread west-central Missouri during the overnight hours on December 12 and 13. The snow fell heavily at times, and accumulations reached 6 inches by early afternoon.
1/28/2001	Winter Storm	1	A storm system brought a mixed bag of wintry precipitation to northern Missouri on January 28 and 29.
2/9/2001	Winter Storm	1	The area reported 1/4 to 1/2 inch of ice accumulation, with snowfalls of 1 to 5 inches on top of the ice.

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1/30/2002	Ice Storm	2	A long-lived major ice and snow storm blasted much of northwest, northern, and central Missouri from late Tuesday, January 29, until Thursday, January 31.
3/1/2002	Heavy Snow	2	2 to 6 inches of snow. Strong gusty northwest winds caused considerable blowing and drifting of the snow.
1/2/2003	Winter Storm	1	A storm system on January 2 brought a band of heavy snows across southern portions of Pettis and Cooper counties. Snowfall amounts ranged from 5 to 8 inches.
12/10/2003	Winter Storm	1	The first winter storm of the season produced a general 2 to 5 inches of snow across the area.
1/25/2004	Winter Storm	1	A widespread freezing rain event left a general 1/4" of ice, with 3 to 4 tenths reported from Cass County eastward through Cooper County.
11/30/2006	Heavy Snow	1	10 to 16 inches of snow was common from Butler to Harrisonville, extending northeast through Clinton, Warrensburg, Sedalia, Boonville, and Moberly.
12/1/2006	Heavy Snow	1	10 to 16 inches of snow was common from Butler to Harrisonville, extending northeast through Clinton, Warrensburg, Sedalia, Boonville, and Moberly.
12/9/2007	Ice Storm	3	Up to a half inch of ice was reported across the county. Several tree branches and power lines were reported down.
1/12/2007	Winter Storm	3	One to two inches of sleet and freezing rain across the county.
2/28/2009	Heavy Snow	1	The extreme southwest portion of the county had as much as 6 inches of snow in Otterville and 4 miles west of Bunceton.
1/10/2011	Winter Weather	2	Four to six inches of snow was reported across the county.
1/19/2011	Winter Storm	2	The emergency manager measured 10.5 inches of snow in Boonville.
2/1/2011	Blizzard	1	Blizzard conditions were observed across the county, with frequent wind gusts up to 45 miles per hour, visibility less than 1/4 of a mile, and heavy snow of up to 19 inches reported in Boonville.
3/14/2011	Winter	1	There was up to 5.5 inches of snow observed in Boonville.

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	Weather		
2/13/2012	Winter Weather	1	Three to four inches of snow was measured across the county.
12/21/2013	Ice Storm	2	Trained weather spotters from across the area reported between .20 and .50 of freezing rain on December 21. Once the freezing rain ended, light snow accumulated throughout the area during the overnight hours. Between 1 and 3 inches of snow fell on top of the ice accumulation.
2/4/2013	Heavy Snow	2	6 to 10 inches of snow. Many areas reported drifts of 2 to 3 feet.
2/21/2013	Winter Storm	2	Boonville measured 9.5 inches of snow.
2/25/2013	Winter Storm	3	Ten and a half inches of snow was measured near Boonville.
3/23/2013	Winter Storm	2	Eight inches of snow was measured in Boonville.
1/6/2014	Cold/Wind Chill	1	Wind chill values were around 30 degrees below zero for the morning of January 6.
3/1/2014	Winter Storm	2	Trained spotters across the area reported about a half inch to an inch of sleet. Snowfall approaching 3 to 6 inches also accumulated.
Source: www.ncdc.noaa.gov/stormevents			

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Probability of Future Events – High for all participating jurisdictions

Several years witnessed multiple winter-weather events. Based on this historical data, there is a high probability that winter-weather events will occur in the future.

ANALYSIS OF RISK

Measure of Severity - Moderate for all participating jurisdictions, except for Prairie Home R-V Schools (low).

Severe winter weather presents a risk to both life and property in the planning area. Some of the damage is direct, but some comes in the form of economic losses due to closed businesses and schools and slowed or halted transportation (Figure 4.8).

Figure 4.8

Reported Damages - Severe Winter Weather Events in Cooper County (1996 – May 2016)

Date	Storm Type	Duration (days)	Description
1/9/1997	Heavy Snow	1	Many school districts canceled classes on January 9, and there were several reports of minor traffic accidents.
1/10/1997	Cold/Wind Chill	4	There were reports of frostbite and hypothermia, but no serious injuries or fatalities.
1/12/1998	Ice Storm	1	Icy roads and walkways resulted in numerous problems during the morning commute on January 12. Numerous traffic accidents were reported; some involved minor injuries, and there were several minor injuries as a result of pedestrians falling on icy walkways. Many schools in West Central Missouri closed due to the hazardous conditions.
12/10/2000	Extreme Cold	22	Numerous broken water pipes and water mains were reported.
12/11/2000	Ice Storm	1	Numerous traffic accidents were reported. Most schools in the area were closed, and many remained closed the next day.
12/13/2000	Heavy Snow	1	Schools were closed for up to 3 days in many locations, and there were numerous reports of traffic accidents.

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1/28/2001	Winter Storm	1	Numerous traffic accidents were reported and some schools were closed the following Monday.
2/9/2001	Winter Storm	1	Numerous traffic accidents were reported along with school closings.
1/30/2002	Ice Storm	2	At one point, 409,504 customers were without electrical power in the CWA, with some residents without power up to two weeks.
3/1/2002	Heavy Snow	2	Driving was hazardous and numerous accidents were reported. Interstate 70 closed for a time.
11/30/2006	Heavy Snow	1	Travel was extremely dangerous, and Interstate 70 had to be closed for a time.
12/1/2006	Heavy Snow	1	Travel was extremely dangerous, and Interstate 70 had to be closed for a time.
12/9/2007	Ice Storm	3	Several tree branches and power lines were reported down.
1/12/2007	Winter Storm	3	Numerous traffic accidents across the area were reported.
2/1/2011	Blizzard	1	Travel was nearly impossible, with the blowing and drifting snow and the very low visibilities.
3/14/2011	Winter Weather	1	Hazardous driving conditions were reported.
12/21/2013	Ice Storm	2	Some power outages occurred.
2/21/2013	Winter Storm	2	The very heavy snowfall created havoc on area roadways, and many travelers became stuck and stranded. Many roads became clogged with stalled vehicles, essentially closing down the roads. Many motorists abandoned their cars, leaving roadways littered with snow-covered vehicles.
Source: www.ncdc.noaa.gov/stormevents			

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Potential Impact - Life

Many deaths and injuries from winter storms are a result of traffic accidents caused by a combination of poor driving surfaces and speeds too fast for the conditions. Accidents during winter storms can be particularly devastating because of multiple car involvement. Response times for emergency vehicles may also be slowed by poor road conditions.

Strenuous outdoor activity in extreme cold can also be life threatening. The elderly are especially vulnerable to excessive and/or prolonged cold (or heat). The 2010 Census recorded 2,702 citizens (15.3 percent of the population) as 65 years and older in Cooper County.

Severe winter weather may require that people without power be sheltered and fed.

Potential Impact - Existing Structures

Much of the property damage that occurs from severe winter weather is due to some type of utility failure:

> Power Lines - Ice storms often adversely impact consistent power supplies. Ice buildup on wires can cause them to fall; downed tree limbs can knock out power lines. Prolonged power outages can be a threat for those relying on electricity for heat. This is a particular concern for more vulnerable populations such as the elderly.
>
> Water Lines - Winter storms and the associated cold weather can be problematic for water lines, especially if a rapid freeze/thaw cycle is involved. As the ground freezes and thaws, pipes can shift and sometimes break, causing a lack of potable water. Broken pipes can cause extensive and expensive damage to property. Frozen and burst water pipes are a real concern for the homeowner.

Severe winter weather can be expected in Cooper County nearly every year. The county has been included in five disaster declarations for severe winter weather since 2002. A winter storm that brought up to three-fourths of an inch of ice in December 2007 caused widespread power outages, leaving an estimated 165,000 residents without power in Cooper County and the surrounding counties of Bates, Chariton, Howard, Johnson, Pettis, and Saline. Most recently, in 2011, a series of storms blanketed the region in near record amounts of snow and created blizzard conditions across a large portion of the state. Snow fall on February 1, 2011, caused the closure of Interstate 70 from Kansas City to St. Louis. Expenses from these storms are in excess of $14 million, according to SEMA.

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Figure 4.9

Federal Emergency and Disaster Declarations for Severe Winter Weather
Cooper County, Missouri, 2002-2015

Emergency (EM) or Disaster (DR) Declaration	Incident Period	Event Type	# of Counties	Public Assistance (PA) Grants*		Type of Assistance Provided in Cooper County
				Emergency Work Categories A-B	Permanent Work Categories C-G	
DR-1403	1/29/02-2/13/02	Ice Storm	43	$34,013,640.27	$9,715,546.90	IA
EM-3281	12/8/07-12/15/07	Severe Winter Storms	entire state	Not available	Not available	PA (A,B)
EM-3303	1/26/09-1/28/09	Severe Winter Storm	entire state	Not available	Not available	PA (B)
EM-3317	1/31/11-2/5/11	Severe Winter Storm	115 counties	Not available	Not available	PA (B)
DR-1961	1/31/11-2/5/11	Severe Winter Storm and Snowstorm	64 counties	$7,036,419.52	$2,451,128.68	PA

*Money obligated for all counties in disaster declaration

Source: http://www.fema.gov/disasters

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Missouri State Hazard Mitigation Plan (2013) Analysis:

The *Missouri State Hazard Mitigation Plan (2013)* analyzed data for all counties in the state to develop vulnerability ratings for Severe Winter Weather.

The following data was analyzed:

- National Climatic Data Center (NCDC) storm event data (1993 to December 2012)
- U.S. Census Data (2000)
- Total building exposure from HAZUS-MR4
- FEMA Public Assistance (PA) funds from Disasters #1672, #1736, #1748, #1822, and #1961
- Census of Agriculture 2007 (USDA)
- Crop Insurance Claims data (1998-2012) from the Risk Management Agency of the USDA
- Calculated Social Vulnerability Index (SoVI™) for Missouri Counties from the Hazards and Vulnerability Research Institute of the Geography Department at the University of South Carolina

The results for Cooper County and its communities as a whole (the planning area) are shown in Figure 4.10.

Figure 4.10

Impact Assessment - Severe Winter Weather - Cooper County

Total Incidents 1993-2012	Housing Units/ sq. mile	Total Building Exposure ($)	Total Property Loss ($)	2007 Crop Exposure ($)	Total Crop Insurance Paid ($)
26	13.2	$1,698,351,000	$32,650,000	$42,447,000	$827,470

Source: *Missouri State Hazard Mitigation Plan (2013)*

Each factor analyzed was given a vulnerability rating from 1 to 5 with 1 indicating Low Vulnerability and 5 indicating High Vulnerability, and an overall Vulnerability Rating for Severe Winter Weather was determined. The results for Cooper County are shown in Figure 4.11.

Figure 4.11

Vulnerability Analysis - Severe Winter Weather - Cooper County

Incident Likelihood Rating	Housing Density Rating	Property Loss Ratio Rating	Crop Exposure Rating	Crop Loss Ratio Rating	Social Vulnerability Index	Total Score and Vulnerability	Vulnerability Rating
2	1	4	3	4	1	17	Medium-High

Source: *Missouri State Hazard Mitigation Plan (2013)*

The *Missouri State Hazard Mitigation Plan (2013)* analysis determined an overall Medium-High Vulnerability rating for Cooper County in regards to severe winter weather.

The actual cost of structural damage associated with winter storm events is probably higher than the data indicates. The data is a combination of the Public Assistance for Presidential Disaster Declaration events and NCDC data for undeclared events. It should be remembered that PA only covers uninsured losses; any individual private losses due to these winter storm events would not be recorded in this data. In addition, the NCDC data is based on early estimates, and local knowledge indicates that the NCDC data does not contain significant losses associated with many events.

Potential Impact - Future Development

There is no known future development that will have a particular impact on the vulnerability to severe weather. However, as with many non-locale specific hazards, growth and development increase the size of the population and the assets at risk.

Existing Mitigation Activities

Shelters: The planning area is well prepared with Red Cross certified shelters (Figure 3.7).

Cooper County and Boonville Public Works Departments both have snowplowing plans which prioritize critical roads and streets for plowing. Jefferson City also maintains a GIS-based online road conditions map which is updated regularly. Both Public Works Departments maintain stocks of chemicals and fuel at appropriate levels for responding to severe winter weather events; the two jurisdictions work together on some purchasing to maximize cost effectiveness.

Utility Companies

Utility companies in Cooper County have policies regarding tree trimming and brush removal around power lines. Consistent maintenance of trees and brush around utility lines limits the possibility of power outages during a severe winter storm. Maintenance also makes financial sense because repairing fallen utility lines and poles is costly and dangerous.

National Weather Service and Local Media

The Kansas City Office of the National Weather Service coordinates with local jurisdictions and media outlets to disperse information regarding severe winter storm watches and warnings. Early warning allows the public to prepare for a severe storm. If a storm reaches catastrophic proportions and officials need to communicate directly with the public, the Emergency Alert System exists to spread that information.

The National Weather Service sets up winter weather warnings in stages of severity. These stages are shown in Figure 4.12.

Figure 4.12 **National Weather Service Winter Warnings**	
Winter Weather Advisory	Winter weather conditions are expected to cause significant inconveniences and may be hazardous. If caution is exercised, these situations should not become life-threatening. The greatest hazard is often to motorists.
Winter Storm Watch	Severe winter conditions, such as heavy snow and/or ice, are possible within the next day or two.
Winter Storm Warning	Severe winter conditions have begun or are about to begin in your area.
Blizzard Warning	Snow and strong winds will combine to produce a blinding snow (near zero visibility), deep drifts, and life-threatening wind chill. Seek refuge immediately.
Frost/Freeze Warning	Below freezing temperatures are expected and may cause significant damage to plants, crops, or fruit trees. In areas unaccustomed to freezing temperatures, people who have homes without heat need to take added precautions.

SUMMARY OF VULNERABILITY

Severe winter weather is one of the most common and costly natural hazards to affect the planning area; it has been responsible for three federal Emergency Disaster Declarations and two Presidential Disaster Declarations for Cooper County since 2002. In addition, climate data indicates that winter storms are increasing due to changes in the climate. All participating jurisdictions are vulnerable to this hazard.

Some of the worst problems from severe winter weather occur when ice storms affect the area; widespread and lengthy power outages can occur. In addition, traffic accidents are a major source of injuries during severe winter weather.

The planning area has numerous mitigation activities in place that help mitigate the hazards associated with severe winter weather: active tree-trimming programs to protect power lines; excellent media coverage of winter weather advisories/warnings and preparedness information; two-way radio communication on all schools buses; maintenance of chemical and fuel stocks in both Cooper County and Boonville for event response; snowplowing plans in the County and Boonville that prioritize routes; an online GIS-based road conditions map for Boonville; backup power at many government facilities in Cooper County and Boonville; and abundant Red Cross certified shelters.

However, there is still a need for more backup generators and transfer switches in the planning area. This is a difficult issue as the expense is great and the funding possibilities are limited. In addition, there is a need to find reliable transportation for vulnerable populations in need of transfer to shelters.

4.2 SEVERE THUNDERSTORMS (INCLUDING DAMAGING WINDS, HAIL, AND LIGHTNING)

DESCRIPTION OF HAZARD

A thunderstorm is a rainstorm with thunder and lightning present. Warm, humid climates, such as that in mid-Missouri, are favorable for the formation of thunderstorms. Thunderstorms can occur during any season in Missouri, but they are more frequent in the spring and summer.

The average Missourian is well aware of the hazards of the thunderstorm season; these could include heavy rains, strong winds, tornadoes, hail, and lightning strikes. The effects of heavy rains will be considered in the section on flood (Section 4.4), and tornadoes are covered in Section 4.3.

Thunderstorms can range in complexity from single cell storms through multicell cluster storms, multicell line storms (squall lines), and on to supercell storms. A single cell thunderstorm typically lasts 20 to 30 minutes, but when numerous cells are generated, as in a multicell storm, the thunderstorm can last for hours. Supercell storms include rotation and are responsible for the generation of severe tornadoes.

Severe and damaging winds in the planning area are usually, but not always, associated with thunderstorms. Thunderstorm winds can reach speeds up to 100 miles per hour and produce damage paths for hundreds of miles. According to the National Oceanic and Atmospheric Administration (NOAA), property and crop damage from thunderstorm winds is more common, and can be more severe, than damage from tornadoes. Thunderstorm wind damage accounts for half of all the NOAA reports of severe weather events in the lower 48 states.

Thunderstorm winds are often called "straight-line" winds to distinguish them from tornadoes, which have a rotational element. The following are the distinctions made between different thunderstorm winds:

- Gust front – Gusty winds out ahead of a thunderstorm, characterized by a wind shift and temperature drop.

- Downburst – A strong downdraft with a width of greater than 2.5 miles, which results in an outward burst of damaging winds near the ground, may possibly produce damage similar to that of a strong tornado.

- Microbursts – A small concentrated downburst with a width less than 2.5 miles, generally short-lived, lasting only 5 to 10 minutes with maximum wind speeds up to 168 miles per hour.

Much of the damage caused by high winds occurs because of falling trees; people, buildings, and vehicles may be damaged by falling trunks and branches. Power lines may be blown or knocked

down and people left without electricity. In some cases, roofs are directly blown off buildings, and windows are shattered.

Hail is formed when updrafts in thunderstorms carry raindrops up to very high and cold areas where they freeze into ice. Hail, especially large-sized hail, can cause severe damage and presents a threat to automobiles, airplanes, roofs, crops, livestock, and even humans.

Lightning, a massive electrical discharge, is produced by all thunderstorms. The electrical discharge can be within a cloud, between clouds, or between a cloud and the ground.

Location

The entire planning area is at risk from severe thunderstorms and all the related threats accompanying them.

Extent

The National Weather Service considers a thunderstorm "severe" when it includes one or more of the following: winds gusting in excess of 57.5 miles per hour, hail at least 0.75 inch in diameter, or a tornado. The NOAA database records thunderstorm events that fall into this severe classification.

For the 10-year period from May 31, 2006, through May 31, 2016, the average estimated wind gust for damaging winds reported in Cooper County (Figure 4.13) was 54 knots.

For the same period, the average measured diameter of severe hail reported in Cooper County was over 1 inch in size. The largest hail reported measured 4.25 inches in diameter (Boonville, June 17, 2009). In total, there were 34 reports of hail of 0.75-inch diameter or larger during the 10-year period (Figure 4.14).

According to information from NOAA, a lightning bolt can contain 100 million to 1 billion volts of electricity and billions of watts of energy. This energy can heat the air around the lightning 18,000 to 60,000 °F.

Previous Occurrences

Historical data from NOAA for damaging winds (thunderstorm winds), hail, and lightning are shown in Figures 4.13, 4.14, and 4.15.

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Damaging Winds

According to NOAA, there were 17 thunderstorm wind events in Cooper County in the 10-year period ending on May 31, 2016 (see Figure 4.13).

Figure 4.13

Thunderstorm Wind Events, Cooper County, 5/31/2006 - 5/31/2016

Location	Date	Mag (knots)
Boonville	7/13/06	52 EG
Boonville Airport	10/17/07	52 EG
Boonville	10/17/07	52 EG
Otterville	08/28/08	52 EG
Pisgah	08/28/08	52 EG
Boonville	6/27/09	52 EG
Boonville Airport	6/27/09	52 EG
Boonville	10/1/2009	61 EG
Boonville Viertel Airport	7/30/2010	61 EG
Boonville Viertel Airport	5/22/2011	52 EG
Boonville	8/7/2011	61 EG
Prairie Home	6/4/2014	61 EG
Otterville	7/4/2014	52 EG
Otterville	10/1/2014	50 EG
Bunceton	7/24/2015	52 EG
Lick	7/26/2015	52 EG
Boonville	3/30/2016	52 EG

EG = Estimated Gust

Source: http://www.ncdc.noaa.gov/stormevents/

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Hail

NOAA lists 34 separate reports of hail (of at least 0.75 inch in diameter) in the planning area in the 10-year period from May 31, 2006, through May 31, 2016 (Figure 4.14). These reports occurred on 16 different days. There was a report of 4.25-inch diameter hail with a 2009 storm and numerous storms that spawned hail of 1-inch diameter or larger.

Figure 4.14

Hail Events in Cooper County, 5/31/2006 - 5/31/2016

Location	Date	Size	Location	Date	Size
Boonville	6/10/2006	0.88 in.	Bunceton	4/17/2013	0.75 in.
Boonville	6/10/2006	0.75 in.	Otterville	3/27/2014	1.75 in.
Bunceton	6/10/2006	1.00 in.	Pisgah	3/27/2014	1.25 in.
Otterville	1/7/2008	0.88 in.	Boonville	4/3/2014	1.00 in.
Bunceton	1/7/2008	0.75 in.	Pleasant Green	4/3/2014	0.88 in.
Boonville	4/3/2008	0.75 in.	Pilot Grove	4/3/2014	0.75 in.
Clifton City	4/23/2008	1.00 in.			
Pilot Grove	5/7/2009	0.75 in.			
Boonville	6/10/2009	1.00 in.			
Boonville	6/17/2009	1.00 in.			
Boonville Viertel Airport	6/17/2009	1.75 in.			
Boonville	6/17/2009	2.5 in.			
Boonville	6/17/2009	4.25 in.			
Overton	6/17/2009	1.00 in.			
Boonville	4/4/2010	1.00 in.			
Lone Elm	5/11/2010	0.88 in.			
Pilot Grove	5/22/2011	1.00 in.			
Boonville	5/22/2011	1.00 in.			
Clarks Fork	5/22/2011	2.75 in.			
Boonville	5/22/2011	1.50 in.			
Boonville	5/22/2011	1.00 in.			
Lick	5/22/2011	1.75 in.			
Boonville	6/10/2011	1.00 in.			
Boonville	6/13/2011	1.00 in.			
Boonville	6/13/2011	1.75 in.			
Boonville	6/13/2011	1.50 in.			
Boonville	3/28/2012	0.75 in.			
Boonville	9/7/2012	1.50 in.			

Source: http://www.ncdc.noaa.gov/stormevents/

Lightning

According to data from the NWS, lightning ranked as the third leading cause of weather-related fatalities over the 30-year period of 1983-2012, causing an average of 52 fatalities in the U.S. each year. According to the *Missouri State Hazard Mitigation Plan (2013)*, lightning was responsible for eight deaths in Missouri during the period 2006-2012 and caused over $2.37 million in property damages in Missouri over that same period.

Figure 4.15

Lightning Events in Cooper County, 1/1/2000 - 5/31/2016

Location	Date	Deaths	Injuries	Damage		Incident Details
				Property	Crops	
Boonville	5/24/2000	0	0	5K	0	A house in Boonville was damaged by a lightning strike.
Totals:		**0**	**0**	**5K**	**0**	

Source: http://www.ncdc.noaa.gov/stormevents/

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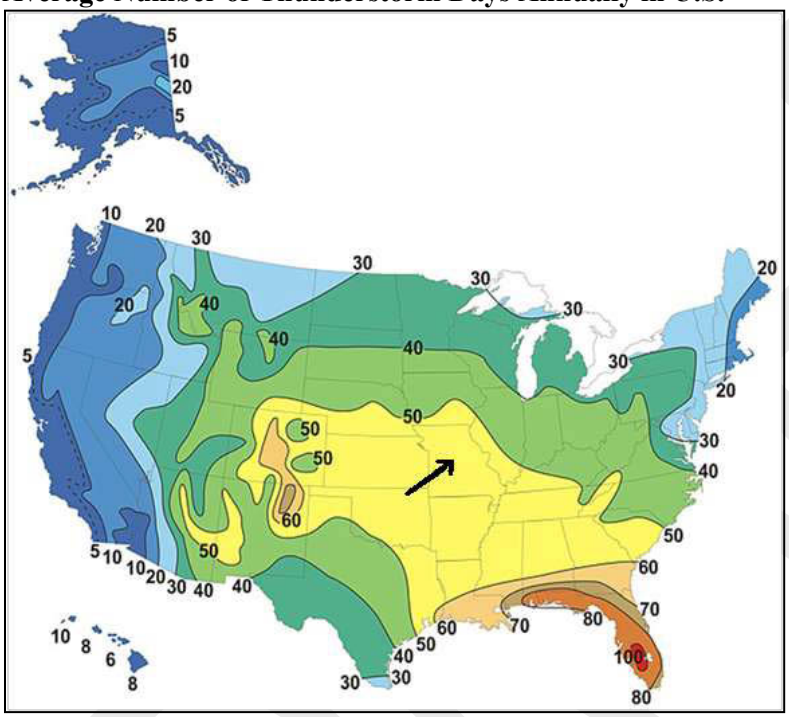
Probability of Future Events

High for damaging winds and hail – all participating jurisdictions.
Low for lightning – all participating jurisdictions.

National Weather Service data indicates an average of 50 to 60 thunderstorm days per year in Missouri (Figure 4.16).

Figure 4.16
Average Number of Thunderstorm Days Annually in U.S.



Source: NOAA

Data from NOAA for the recent 10-year period (5/31/2006-5/31/2016) indicates 17 thunderstorm wind events in Cooper County (Figure 4.13). There were two years in this period when an event was not reported. Based on this data, the calculated probability of a future severe thunderstorm wind event in any given year is 80 percent.

Data from NOAA for the same 10-year period indicates 34 reported severe hail events in the planning area (Figure 4.14). There were two years without severe hail events in the planning area during this period. Based on this data, the calculated probability of a future severe hail event in any given year is 80 percent.

Data from NOAA shows that since the year 2000, only one lightning event that caused property damage or injury has occurred in the planning area (Figure 4.15). Based on this data, the probability of a future lightning event causing property damage, injury, or death in any given year is low.

ANALYSIS OF RISK

Measure of Severity –

Moderate to high for damaging winds, hail, and lightning – all participating jurisdictions.

Potential Impact - Life

Severe thunderstorms and their related hazards pose a threat to people and animals. Windblown debris, falling trees, falling branches, and lightning are very dangerous to those who are exposed. Excessive damage to utilities can leave people without electricity for long periods – an especially dangerous situation for vulnerable populations.

Hail also presents a potential bodily threat. In 2000, a man in Texas died from softball-size hail. According to NOAA's National Severe Storms Laboratory, a 3.25-inch hailstone weighing 1.5 pounds has an estimated falling velocity of about 106 miles per hour.

The only injury from thunderstorm-related events reported in the recent 10-year period for the planning area was a man struck by lightning in June of 2008.

Potential Impact - Existing Structures

There is a wide range of possible impact from severe thunderstorms. Non-permanent and wood-framed structures are very vulnerable to destruction. While high winds are the force behind damage, it is the windblown debris and falling trees and branches that cause the most damage. Lightning can cause costly disruptions to electrical systems.

The annualized losses calculated for the planning area in the *Missouri State Hazard Mitigation Plan (2013)* are shown in Figure 4.17. The annualized losses were calculated by combining historical loss data from the NOAA database and paid crop insurance claims from USDA's Risk Management Agency (RMA) for the period 1993 to July 2013.

Figure 4.17

Annualized Property Loss and Crop Claims
Severe Thunderstorm in Cooper County

Damaging Wind	$65,872
Hail	$8,943
Lightning	$333*
Total	**$75,148**

*Property damage alone

Source: *Missouri State Hazard Mitigation Plan (2013)*

NOAA data, from which the annualized losses are calculated, vastly underestimates the cost of these hazards in the planning area. Local information indicates that many instances of property damage are not reflected in the NOAA data.

While the NOAA data does not indicate damage from any hailstorm events in the period, common knowledge would indicate that this is not accurate. A huge storm in the spring of 2006

caused massive hail damage across the mid-Missouri region. Information from neighboring Boone County indicates that there was over $1 million in hail damage incurred by that county's buildings for the year 2006. Many private homes throughout the region received new roofs because of hailstorm damage that year.

While hailstorms of the magnitude that caused such damage in 2006 do not occur every year in Cooper County, hail is a costly hazard for the planning area.

Potential Impact - Future Development

A larger population and more extensive built environment increase the risk of injury, loss of life, and damage from severe thunderstorms.

There has been growth in population and housing in certain parts of the planning area in recent years. While Census figures indicate an overall population growth rate of 6 percent in the planning area (Cooper County) between 2000 and 2010, the population growth in Prairie Home and Windsor Place was 27 percent and 44 percent, respectively. Housing units in the planning area increased by 12 percent during this period (Figure 2.11).

It would be wise to consider mitigation strategies for severe thunderstorms during the planning phase of any new development. The type of construction affects vulnerability to damaging winds, hail, lightning, and tornadoes. Design and construction choices and the inclusion of hardened areas for safe rooms can save lives.

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Existing Mitigation Activities

There are a variety of strategies in place in the planning area by which the public can be informed of severe weather conditions resulting from thunderstorms.

Cooper County has been recognized by the National Weather Service as a StormReady® Community. In order to become recognized as StormReady®, the Emergency Management Agency is evaluated on its abilities to do the following:

- receive real-time weather information from the NWS
- disseminate the information to the public
- transmit real-time information to the NWS
- educate the public regarding weather hazards/protection

Warning Systems The following warning systems are used in the county:

- Local television weather reports
- Local radio weather reports
- 9-1-1 call center and Public Emergency Broadcast Center
- Outdoor warning sirens

Safe Rooms [Are there any safe rooms in Cooper County?]

Mobile Homes The State of Missouri regulates manufactured housing and modular units through the Missouri Public Service Commission. This includes enforcing tie down and anchoring requirements.

Shelters There are numerous Red Cross Certified Shelters in the planning area should sheltering become necessary (Figure 3.7).

Insurance Industry The insurance industry is heavily invested in finding mitigation strategies for hail damage as it is one of the most costly hazards for the industry. The fifth largest payout made by State Farm Insurance ($245 million) was for a 1992 hailstorm in Texas. (The only higher payouts were for Hurricane Andrew in 1992, an earthquake in Los Angeles in 1994, Hurricane Hugo in 1989, and wildfires in Oakland, California, in 1991.)

High insurance claims for hail damage, especially in the Midwestern states, are one reason for an increase in insurance premiums. The type of roofing material used in construction can greatly affect vulnerability to hail. In an effort to have a multifaceted approach to the problem of high damages and increasing premiums, the industry has supported research and testing standards in roofing materials.

In 1996, a testing standard (UL2218) was developed to grade the impact resistance of roofing materials. There are four rated classes of resistant materials with Class IV shingles providing the most resistance against both hail and high winds.

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In the past, impact-resistant roofing (mostly made of aluminum, copper, plastic, and resin) was not affordable for most homeowners. Recent research has resulted in "modified asphalt" shingles, which are much more affordable; some of these achieve the Class IV rating.

Installing impact-resistant roofing can have an added benefit on insurance rates. In Texas, all insurers subject to Texas rate regulations were required in 1998 to begin offering premium discounts for customers who have installed impact-resistant roofs. In Missouri, some insurers offer these discounts on a voluntary basis.

SUMMARY OF VULNERABILITY

Severe thunderstorms with damaging winds, hail, and lightning are common, dangerous, and often costly occurrences in the planning area. These weather events can be expected almost every year, and every jurisdiction is vulnerable to these hazards.

Both human life and the built environment are at risk; the impact on the built environment has been quite costly in the past, and this can be expected to continue into the future.

Public awareness education, excellent weather coverage by the local media, an excellent outdoor warning system, and regular emergency exercises in the schools help mitigate the risk to human life. However, there is a great need throughout the planning area for more safe rooms to protect from high wind events; this is especially true in the schools. Additional generators and power transfer hookups are needed in case of widespread and/or lengthy power outages. These identified needs have been targeted for action in the mitigation strategy, but funding remains an issue for the costly safe rooms and generators/power transfer hookups. [Is this true for Cooper County?]

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4.3 TORNADO

DESCRIPTION OF HAZARD

A tornado is a violently rotating column of air that is usually generated by a supercell thunderstorm. The movement speed of a tornado is typically around 10 to 20 miles per hour but can range from almost stationary to more than 60 miles per hour, according to NOAA's National Severe Storms Laboratory. Tornadoes often travel from southwest to northeast but can move in any direction.

Tornadoes occur most frequently in late afternoon and early evening but can occur at any time; they tend to dissipate as fast as they form. Unlike a hurricane, which can last for multiple hours, tornadoes are often in one place for no more than a few minutes. The seasonal, temporal, and spatial uncertainties surrounding thunderstorms and tornadoes make widespread and year-round preparedness essential.

Location

The entire planning area is at risk from tornadoes.

Extent

The Enhanced Fujita or EF-Scale (Figure 4.18) is currently used in the United States to classify tornadoes. It is based on engineering studies of the wind effects on 28 different types of structures (buildings, towers, poles, trees). This indirect measurement of speed is used because it is currently not possible to measure ground-level speeds in strong tornadoes; the winds destroy the instruments needed for measurement.

In addition to estimated wind speeds, averaged data from tornadoes can give an idea of the length and width of tornadoes in the different classifications.

Figure 4.18

Tornado Extent

EF-Scale Number	Wind Speed* (mph)	Length** (miles)	Width** (feet)
EF0	65-85	0.9	93
EF1	86-110	2.9	210
EF2	111-135	6.6	413
EF3	136-165	14.0	865
EF4	166-200	27.1	1,511
EF5	Over 200	33.9	1,823

*3 second gust

**Source: FEMA Benefit-Cost Analysis Course, Student Manual Version 4.5

The EF-Scale has been in use since 2007. It uses the same ratings as the original Fujita Scale (F-Scale), which it replaced, but the wind speeds have been adjusted to reflect current knowledge

and give a more realistic estimate of wind speeds for all tornadoes, including historical ones in the NOAA database. The ratings of tornadoes prior to 2007 were not changed in the NOAA database with the adoption of the EF-Scale.

There continue to be limitations even with the EF-Scale since the scale is based on sustained damage. As noted on the NOAA website, "Damage rating is (at best) an exercise in educated guessing. Even experienced damage-survey meteorologists and wind engineers can and often do disagree among themselves on a tornado's strength."

Another issue with tornadoes is speed of onset. Technological advances—such as Doppler radar, computer modeling, and Emergency Warning Systems—have increased the amount of time the general public has to respond to a tornado. Despite these advances, tornadoes can still strike an area with little warning. Often, people have no more than a few minutes to get to safety. Being able to quickly get to a safe place is absolutely imperative in order to prevent loss of life.

Previous Occurrences

The planning area has experienced 17 tornado events since October 1966, as officially recorded by NOAA (Figure 4.19). This includes three "significant" F2 tornadoes.

The historical record in the planning area over this 50-year period indicates tornadoes in the EF0 to EF2 range. While history is informative, it is not necessarily predictive of the future; there is the possibility that the planning area could experience a tornado above the EF2 level in the future.

In addition, many historical tornadoes may have been stronger than the data indicates. According to the NOAA website, "Because the only way we can compare all tornadoes is by whatever damage they caused, and EF5/F5 damage is only possible when tornadoes hit well-built structures, the true 'violence' of most historical tornadoes is unknown—especially before the middle to late 20th century."

Figure 4.19

Tornado Events in Cooper County, 10/14/1966 - 5/31/2016

Location	Date	Time	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
County	6/11/1968	17:00	F0	0	0	0.03K	0
County	4/20/1973	13:50	F1	0	0	2.5K	0
County	4/20/1973	18:35	F2	0	0	25K	0
County	5/21/1973	16:50	F1	0	0	2.5K	0
County	7/19/1975	20:00	F0	0	0	2.5K	0
County	4/20/1976	19:30	F0	0	0	0	0
County	5/14/1982	20:20	F2	0	0	25K	0
County	5/14/1982	20:30	F1	0	0	25K	0
County	4/29/1984	16:40	F0	0	0	0	0
County	7/11/1992	16:15	F0	0	0	0	0
County	9/7/1992	18:40	F2	0	0	250K	0
Boonville	4/8/1999	16:30	F1	0	0	750K	50K
Pilot Grove	4/10/2001	17:11	F1	0	0	25K	0

Boonville	8/13/2005	14:53	F0	0	0	50K	0
Blackwater	3/12/2006	16:04	F0	0	0	5K	0
Otterville	3/12/2006	16:30	F0	0	0	0	0
Pleasant Green	5/25/2011	12:04	EF0	0	0	0	0
TOTALS:				0	0	1.163M	50K
Source: http://www.ncdc.noaa.gov/stormevents/							

Probability of Future Events

High - all participating jurisdictions

For the period from October 1966 through May 2016, a period of approximately 50 years, the NOAA database reports 12 years with at least one tornado event in the planning area. Based on this historical data, the calculated probability of a future tornado event of any magnitude in a year is about 24 percent.

The probabilities of occurrence of the different magnitudes of tornadoes in any given year, based on historical data, have also been calculated (Figure 4.20). While the calculated probabilities for an EF3, EF4, or EF5 tornado are 0 percent, this does not mean tornadoes of these magnitudes could not occur in the planning area; it just means they have not occurred in the historical record.

Figure 4.20

Probability of Future Tornado Events

EF-Scale	# of years with tornado event (1966-2016)	Probability	Probability Rating
All	12	24%	High
EF0	8	16%	High
EF1	4	8%	Moderate
EF2	3	6%	Moderate
EF3	0	0%	Low
EF4	0	0%	Low
EF5	0	0%	Low

ANALYSIS OF RISK

Measure of Severity
High - all participating jurisdictions

The destructive effects of a tornado depend on the strength of the winds, proximity to people and structures, the strength of structures, and how well a person is sheltered. They are obviously a hazard with the potential to cause both great loss of life and catastrophic destruction.

Potential Impact - Life

While tornadoes can strike anywhere, there is a greater chance of injury and loss of life (and destruction of property) in population centers. This is especially true of a tornado with a large path.

There have been no reported injuries associated with recorded tornadoes in the planning area.

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Potential Impact - Existing Structures

Tornadoes cause the most costly physical destruction when they touch ground in urban areas. High winds affect all structure types differently; non-permanent and wood-framed structures are especially vulnerable to destruction.

In addition to a direct hit on a building by a tornado, damage to trees poses a serious threat. People, buildings, power lines, and vehicles are all at risk from falling branches, uprooted trees, and windblown debris.

There has been $1.163 million in reported property damages associated with recorded tornadoes in the planning area.

The Enhanced Fujita Scale was developed by studying wind effects on various structures types (Figure 4.21). Inspection of this information gives an idea of the damage that might be expected with tornadoes of different magnitudes.

Figure 4.21

Tornado Strength and Damage

EF-Scale Number	Intensity Phrase	Wind Speed* (mph)	Type of Damage Done
F0	Gale tornado	65-85	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.
F1	Moderate tornado	86-110	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	Significant tornado	111-135	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	Severe tornado	136-165	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F4	Devastating tornado	166-200	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	Incredible tornado	Over 200	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through the air in excess of 100 meters; trees debarked; steel reinforced concrete structures badly damaged.

*3 second gust

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Impact Assessment on Total Property

An assessment has been developed for the impact of EF0 through EF3 tornadoes in each of the incorporated communities participating in the hazard mitigation plan (Figure 4.23).

The average area of the different magnitudes of tornadoes was calculated from the average length and width of tornado paths established from historical data (Figure 4.22).

Figure 4.22

Average Tornado Size

EF Class	Length (miles)	Width (feet)	Width (miles)	Area (square miles)
EF0	0.9	93	0.02	0.02
EF1	2.9	210	0.04	0.12
EF2	6.6	413	0.08	0.53
EF3	14.0	865	0.16	2.24
EF4	27.1	1,511	0.29	7.86
EF5	33.9	1,823	0.35	11.87

Source: FEMA Benefit-Cost Analysis Course, Student Manual Version 4.5

The following assumptions have been made in developing the assessment:

- The entire tornado path is within the given jurisdiction.
- The total property value in the jurisdiction is the sum of the real, personal, and government-owned property as reported in the jurisdictional profile charts in Section 3.2
- The total property value is evenly distributed in the tornado path.
- The damage factor is 25 percent. Information from FEMA indicates that damage in the path of an EF2 tornado will range from minimal to approximately 50 percent. From this information, an average damage factor of 25 percent was assumed. This assumption was applied to all magnitudes of tornadoes in the analysis.

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Figure 4.23

Tornado Vulnerability Analysis - Major Population Areas

Jurisdictional Data			Estimated Property Damage - Real and Personal (25% damage factor assumed)			
Jurisdiction	**Area (square miles)**	**Total Market Value of Property***	**EF0**	**EF1**	**EF2**	**EF3**
Blackwater	0.3					
Boonville	7.2					
Bunceton	0.9					
Otterville	0.5					
Pilot Grove	0.4					
Prairie Home	0.4					
Windsor Place	0.2					
Wooldridge	0.1					

*Total of Personal and Real Property Market Values plus Government-Owned Property Values (Section 3.2 - Property and Valuation Charts)

[Need the value of the government-owned property to fill out the table.]

There are some obvious limitations to this assessment. Some of these are listed below:

- The analysis is based on numerous assumptions and estimates.
- Property value is not distributed evenly in jurisdictions.
- Conversion of the length and width of a tornado path into area will cause an overestimation of damage in smaller jurisdictions.
- The analysis does not take into account the type of construction; this is a major factor in structure vulnerability.

Missouri State Hazard Mitigation Plan (2013) Analysis: The State Plan set the Total Building Exposure in the planning area at $1,698,351,000.

Potential Impact - Future Development

A larger population and more extensive built environment increase the risk of injury, loss of life, and damage from tornadoes.

There has been growth in population and housing in certain parts of the planning area in recent years. While Census figures indicate an overall population growth rate of 6 percent in the planning area (Cooper County) between 2000 and 2010, the population growth in Prairie Home

and Windsor Place was 27 percent and 44 percent, respectively. Housing units in the planning area increased by 12 percent during this period (Figure 2.11).

It would be wise to consider mitigation strategies for tornadoes and other high-wind situations during the planning phase of any new development. The type of construction greatly affects vulnerability to tornadoes and high winds. Design and construction choices and the inclusion of hardened areas for safe rooms can save lives.

Existing Mitigation Activities

There are a variety of strategies in place in the planning area by which the public can be informed of severe weather conditions resulting from tornadoes.

Cooper County has been recognized by the National Weather Service as a StormReady® Community. In order to become recognized as StormReady®, the Emergency Management Agency is evaluated on its abilities to do the following:

- receive real-time weather information from the NWS
- disseminate that information to the public
- transmit real-time information to the NWS
- educate the public regarding weather hazards/protection

Warning Systems The following warning systems are used in the county:

- Local television weather reports
- Local radio weather reports
- 9-1-1 call center and Public Emergency Broadcast Center
- Outdoor warning sirens

Safe Rooms [Are there any safe rooms in Cooper County?]

Mobile Homes The State of Missouri regulates manufactured housing and modular units through the Missouri Public Service Commission. This includes enforcing tie down and anchoring requirements.

Shelters There are numerous Red Cross Certified Shelters in the planning area should sheltering become necessary (Figures 3.7).

SUMMARY OF VULNERABILITY

The entire planning area is vulnerable to the potentially devastating impact of tornadoes. Their random nature and potentially quick speed of onset pose particular risks for human life. Tornadoes of the magnitude known to historically occur in the area can wreak extensive and costly structural damage.

Public awareness education, excellent weather coverage by the local media, an excellent outdoor warning system, and regular emergency exercises in the schools help mitigate the risk to human life. However, there is a great need throughout the planning area for more safe rooms to protect

from high wind events; this is especially true in the schools. Additional generators and power transfer hookups are needed in case of widespread and/or lengthy power outages. These identified needs have been targeted for action in the mitigation strategy, but funding remains an issue for the costly safe rooms and generators/power transfer hookups. [Is this true for Cooper County?]

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4.4 FLOOD

DESCRIPTION OF HAZARD

Flooding is defined as partial or complete inundation of usually dry areas. **Riverine flooding** refers to when a river or creek overflows its normal boundaries. The relatively flat areas adjacent to rivers and stream banks that are inundated at times of high water are called floodplains. The term base flood, or 100-year flood, is the area in the floodplain that is subject to a one percent or greater chance of flooding in any given year, based upon historical records.

Cooper County and its jurisdictions are at great risk for flooding because the northern border of the County is situated on the bank of the Missouri River, the longest river in the United States. The Missouri River drains approximately one-sixth of the area of the continental United States, according to the USGS. It drains over half the state of Missouri as it flows eastward to join the Mississippi River at St. Louis. Since Cooper County is located less than 200 miles upstream from the mouth of this 2,540 mile river, it is obvious that flooding is a major concern for the county. There are also numerous creeks throughout the county with year-round water flows draining into the Missouri River.

In addition to the threat of riverine flooding, when a river or creek overflows its normal boundaries, the planning area is also susceptible to **flash flooding**. NOAA defines a flash flood as "an event that occurs within 6 hours following the end of the causative event (such as rains, ice jams, or dam breaks)." Flash floods develop quickly and are responsible for more flood-related deaths than any other type of flooding. The textual descriptions for flash-flooding events in the NOAA database indicate that flash flooding in the planning area is usually triggered by 2 to 5 inches of rainfall within a "short period."

In some cases, however, flooding may not be directly attributable to a river, stream, or lake overflowing its banks. It may simply be the combination of excessive rainfall and/or snowmelt, saturated ground, and inadequate drainage. With no place else to go, water will find the lowest elevations, areas that are often not in a floodplain. This type of flooding, often referred to as **sheet flooding**, is becoming increasingly prevalent as development outstrips the ability of the drainage infrastructure to properly carry and disburse the water flow.

FEMA defines sheet flooding as "a type of flood hazard with flooding depths of 1 to 3 feet that occurs in areas of sloping land."

Local **storm water flooding** can result when tremendous flow of water occurs due to large rain events. Local flooding can create public safety issues due to flooded roadways and drainage structures.

Most flooding in Cooper County occurs in spring and summer, but floods can occur in any season.

Location

The entire planning area is at risk from some type of flooding. Boonville, Bunceton, Otterville, Pilot Grove, Wooldridge, and the unincorporated areas of Cooper County near the Missouri River, Lamine River, and Petite Saline Rive are at higher risk of riverine flooding than the rest of the county.

The current Flood Insurance Rate Map (FIRM) for Cooper County is dated May 3, 2011; it shows the flood zones for these jurisdictions at greater risk. Flood zones are geographic areas defined according to varying levels of flood risk; each zone reflects the severity or type of flooding in the area.

The FIRMs for the participating jurisdictions at greater risk are included (see figures 4.24 through 4.29).

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Figure 4.24 (reviewed by Beau Derque, September 2016)

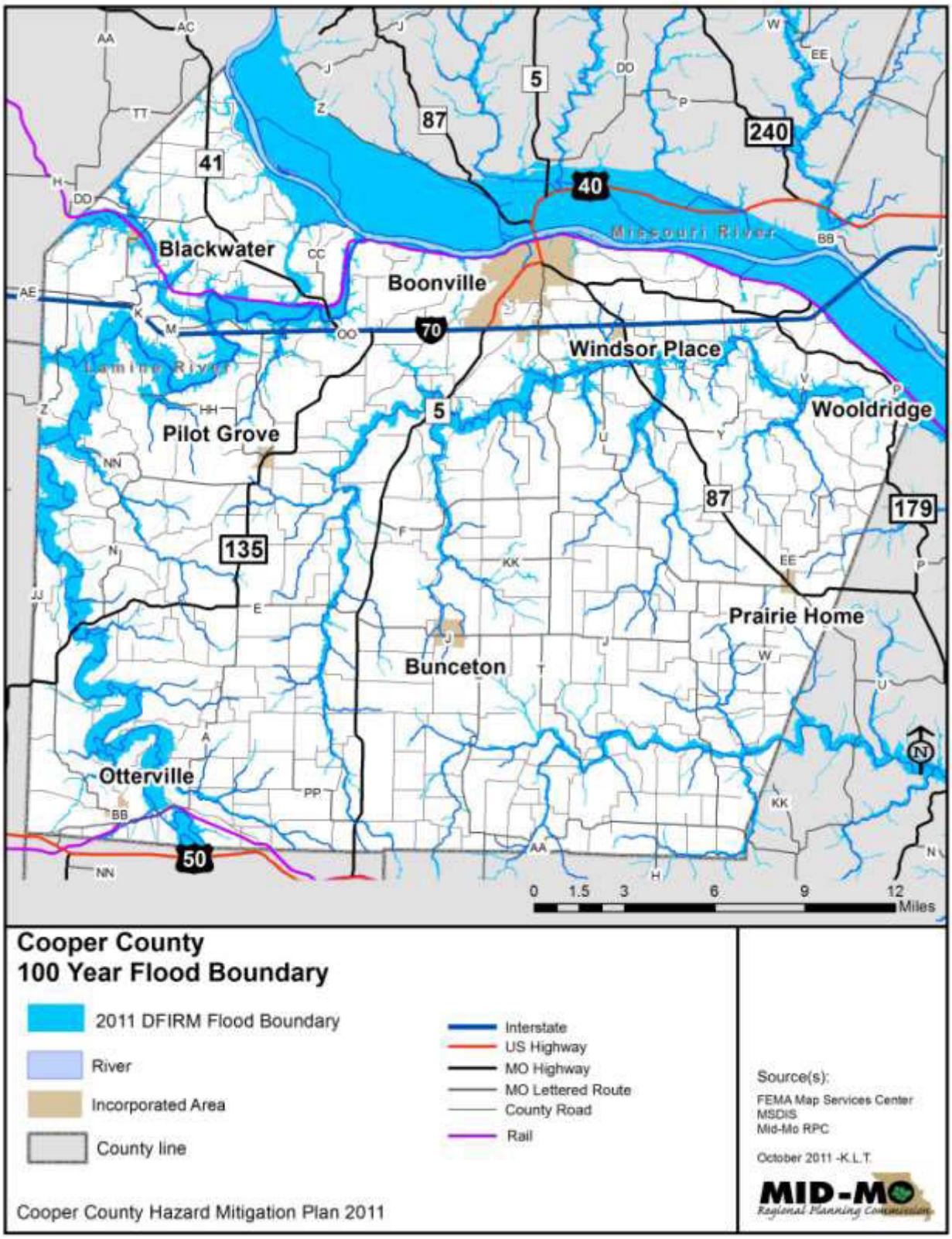


Figure 4.25 (reviewed by Beau Derque, September 2016)

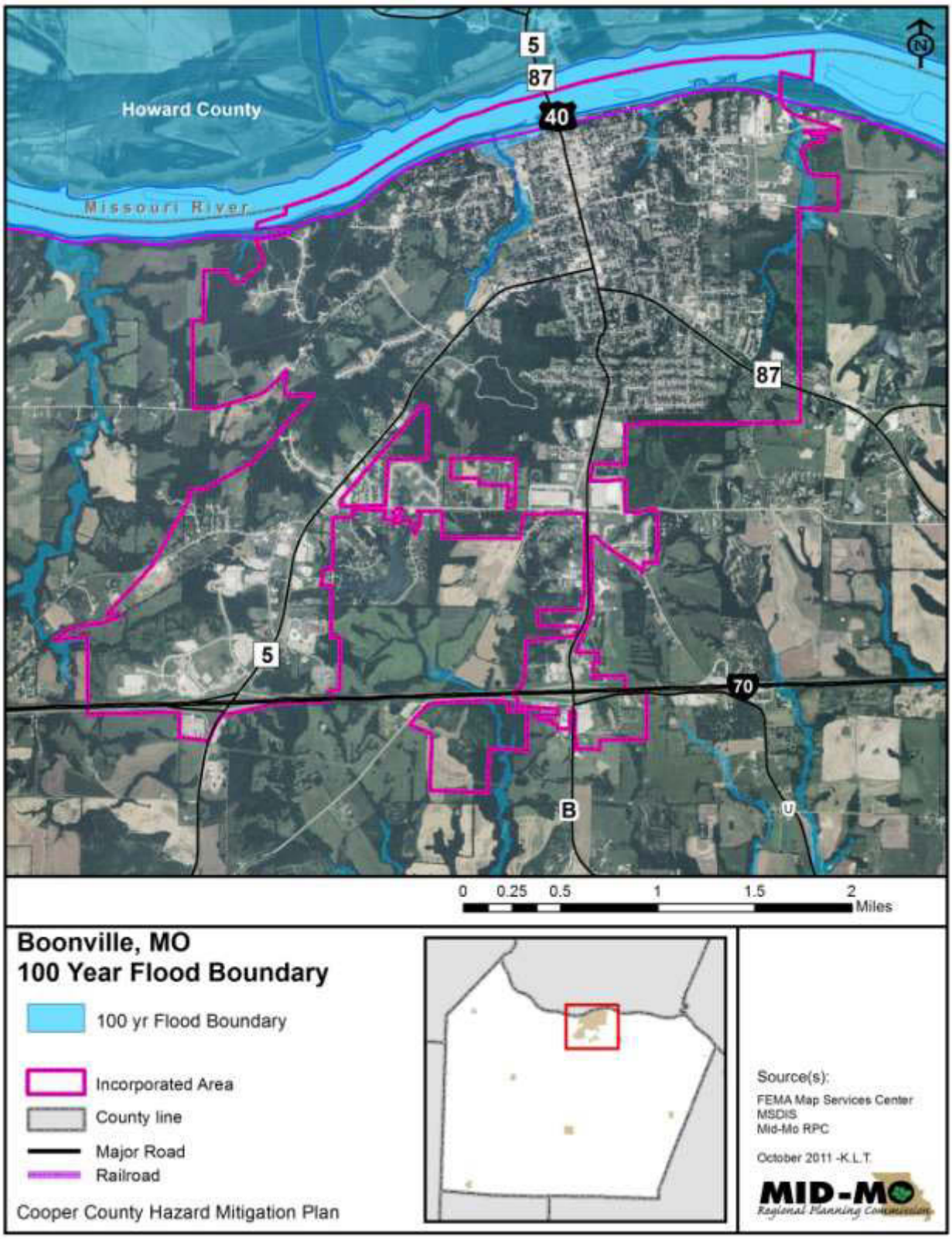


Figure 4.26 (reviewed by Beau Derque, September 2016)

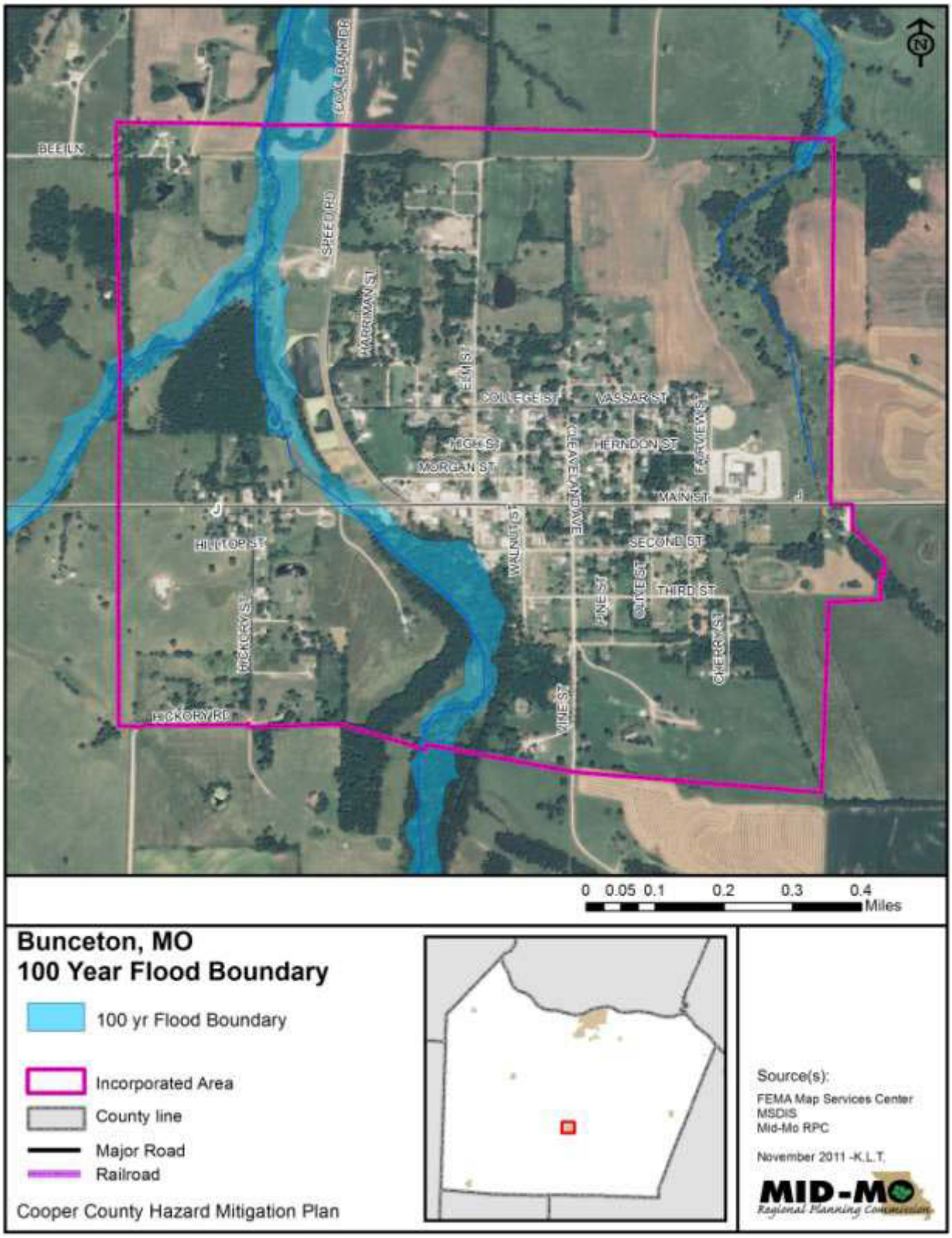


Figure 4.27 (reviewed by Beau Derque, September 2016)

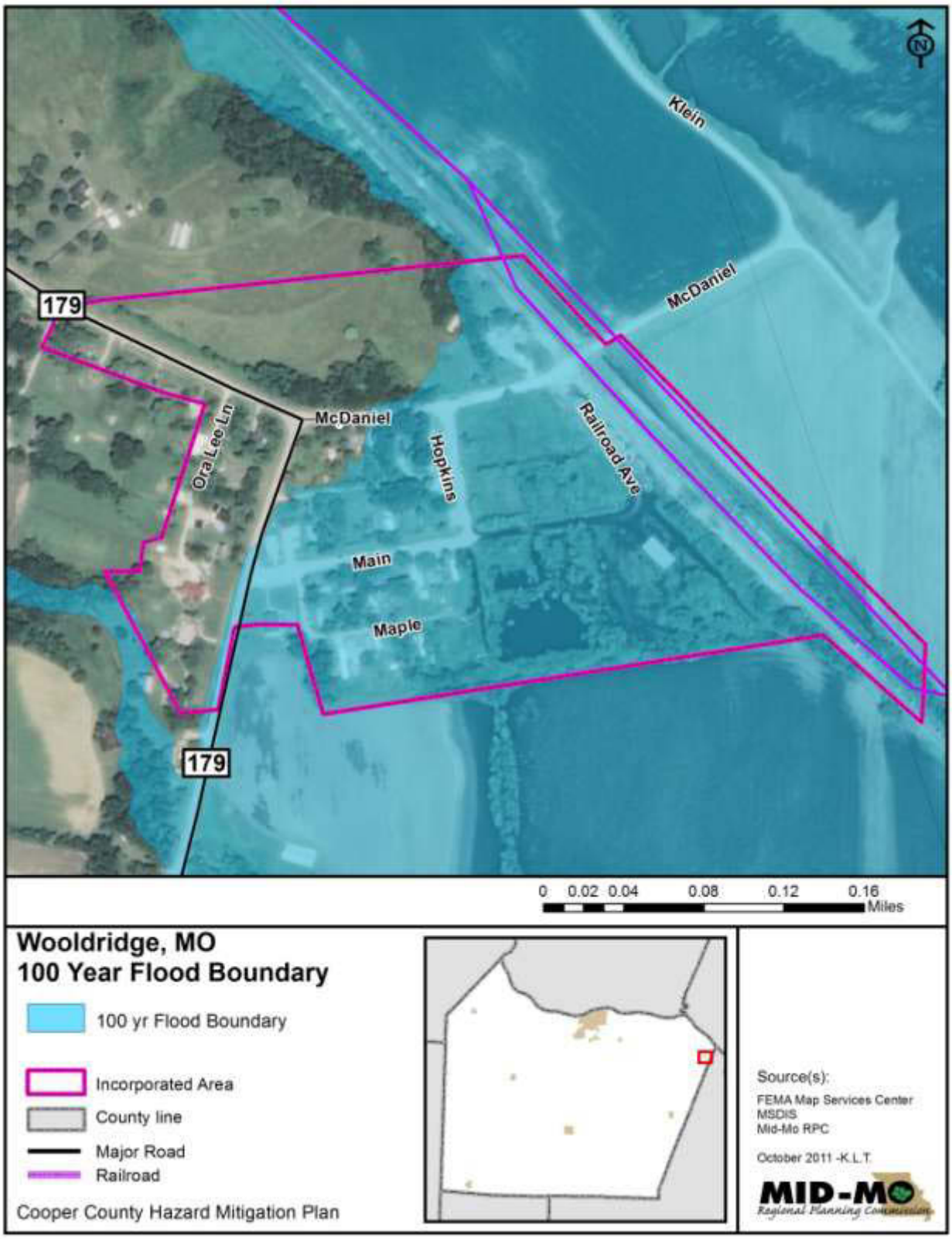


Figure 4.28 (reviewed by Beau Derque, September 2016)

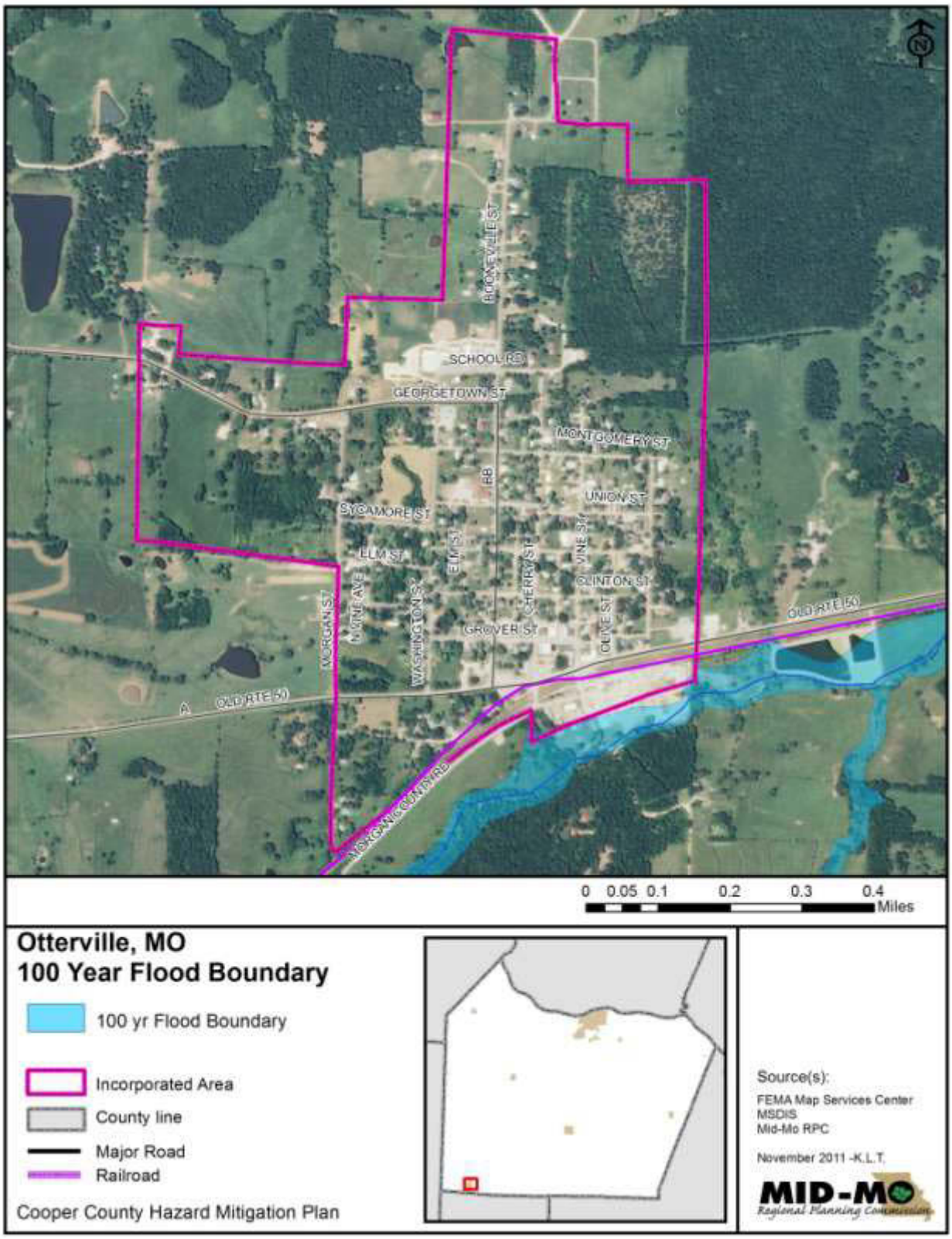
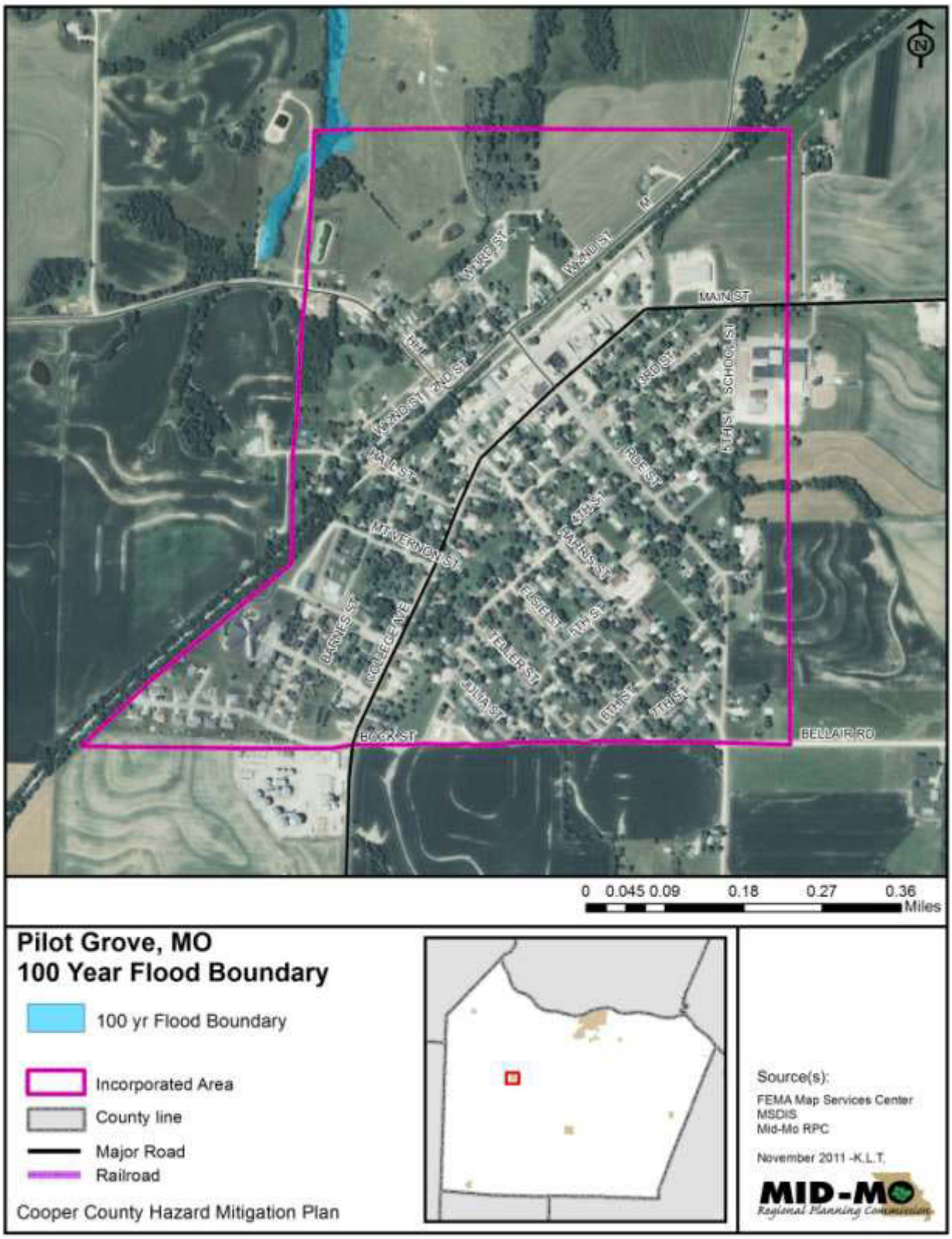


Figure 4.29 (reviewed by Beau Derque, September 2016)



Flash flooding areas are a concern for all jurisdictions in the planning area. Flash flooding occurs throughout the planning area; as a result, low water crossings can be potentially high-risk areas for accidents due to high water. Road closures in these areas are rare due to the quick rise and fall of water levels. Figure 4.30a depicts low water crossing locations.

Cole County Public Works collected GIS (and explanatory) data on county maintained low water crossings, low water bridges, culverts and pipes for the 2010 update of the hazard mitigation plan (Figures 4.27a-d). The information was reviewed and approved as current by County Public Works during the 2015 update. [Do we need similar data for Cooper County?]

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Figure 4.30a (reviewed by Beau Derque, September 2016)

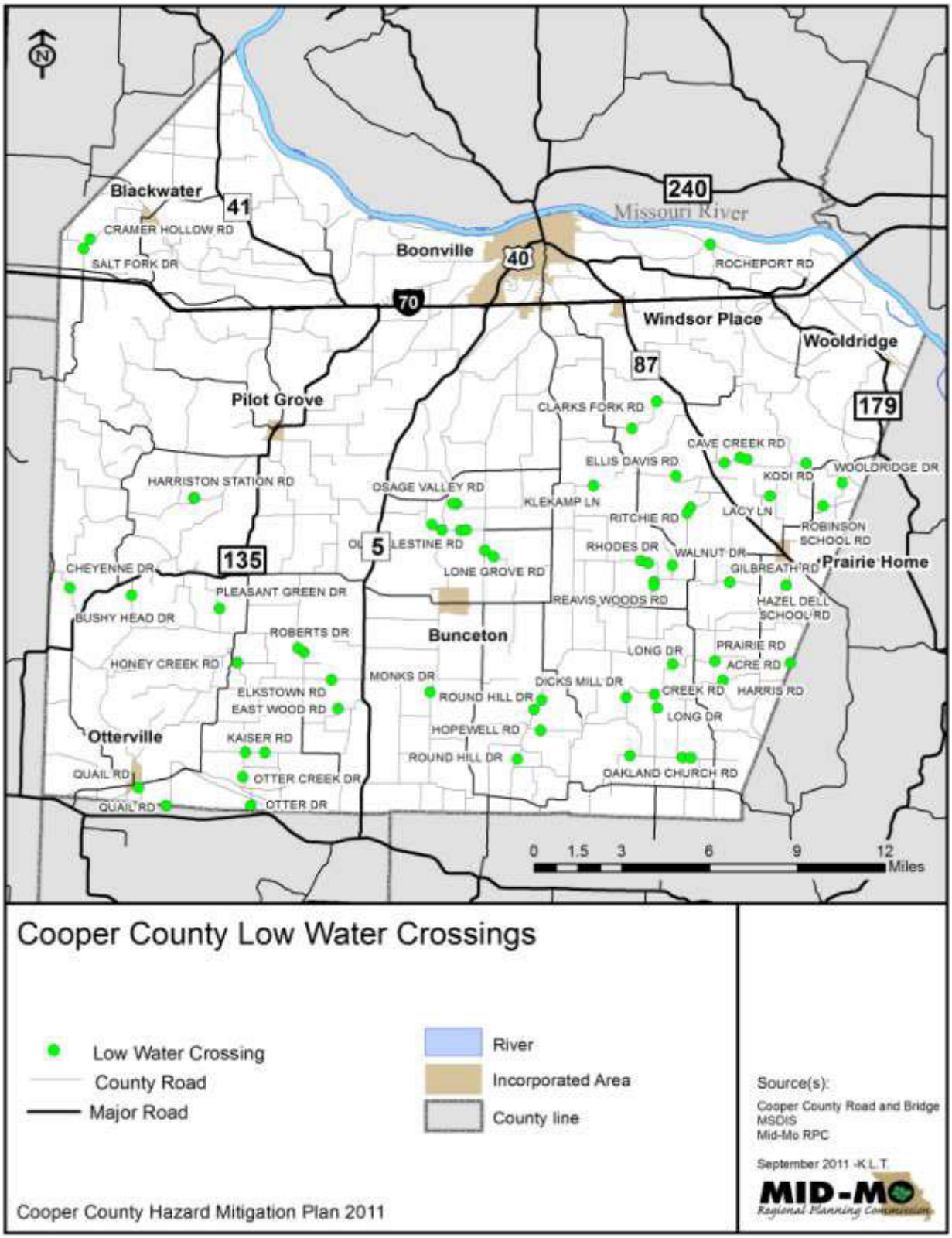

Figure 4.27b

Cole County Public Works Designated Flood Areas

Map ID	Road	Structure	Area Designation/Comments
1	Clark Fork Rd	Box Culvert	Flood Area
2	Binkley Rd	Low Water Crossing	Flood Area
3	Southwest Rd	Low Water Crossing	Not Signed For Flooding
4	Penny Hollow Rd	Bridge	Flood Area
5	Swift Rd	Low Water Crossing	Flood Area
6	Pit Rd	Box Culvert	Flood Area
7	Boise Brule Rd	Low Water Crossing	Not Signed For Flooding
8	Blue Ridge Rd	Low Water Crossing	Flood Area
9	Hickory Hill Rd	Box Culvert	Flood Area
10	Sandy Fork Rd	Low Water Crossing	Flood Area
11	Sandy Fork Rd	Low Water Crossing	Flood Area
12	Sandy Fork Rd	Low Water Crossing	Flood Area
13	Sandy Fork Rd	Low Water Crossing	Flood Area
14	Fall Hill Rd	Pipe	Flood Area
15	Fall Hill Rd	Box Culvert	Flood Area
16	S Teal Bottom Rd	Pipe	Flood Area, Slough Backs Up From Osage River
17	Scheuler Ferry Rd W	Box Culvert	Flood Area, Slough Backs Up From Osage River
18	Deer Run Rd	Pipe	Flood Area
19	Deer Run Rd	Bridge	Flood Area
20	Deer Run Rd	Box Culvert	Flood Area
21	Tanner Bridge Rd	Bridge	Flood Area
22	Tanner Bridge Rd	Pipe	Flood Area
23	Tanner Bridge Rd	Pipe	Flood Area
24	Tanner Bridge Rd	Pipe	Flood Area
25	Tanner Bridge Rd	Box Culvert	Flood Area
26	Buffalo Rd	Box Culvert	Flood Area
27	Upper Bottom Rd	Box Culvert	Flood Area
28	Upper Bottom Rd	Box Culvert	Flood Area
29	Scheuler Ferry Rd	Pipe	Flood Area, Slough Backs Up From Osage River
30	Profits Creek Rd	Box Culvert	Flood Area
31	Lake Rd	Box Culvert	Flood Area
32	Lake Rd	Box Culvert	Flood Area
33	Bode Ferry Rd	Bridge	Flood Area
34	Lock And Dam Rd	Pipe	Flood Area, Slough Backs Up From Osage River
35	Helias Spur	Box Culvert	Flood Area
36	S Liberty Rd	Low Water Crossing	Flood Area
37	Lisletown Rd	Pipe	Flood Area, Slough Backs Up From Osage River
38	Osage Water St	Flood Area	Flood Area, Road Next To Osage River
39	Engineers Rd	Flood Area	Flood Area, Slough Backs Up From Osage River
40	Engineers Rd	Flood Area	Flood Area, Slough Backs Up From Osage River
41	Stoney Gap Rd	Box Culvert	Flood Area
42	Bald Hill Rd	Bridge	Flood Area
43	Zion Rd	Box Culvert	Flood Area
44	Zion Rd	Bridge	Flood Area

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Figure 4.27c			
Cole County Public Works Designated Flood Areas			
Map ID	**Road**	**Structure**	**Area Designation/Comments**
41	Stoney Gap Rd	Box Culvert	Flood Area
42	Bald Hill Rd	Bridge	Flood Area
43	Zion Rd	Box Culvert	Flood Area
44	Zion Rd	Bridge	Flood Area
45	Beck Rd	Box Culvert	Flood Area
46	Bainer Rd	Box Culvert	Flood Area
47	Loesch Rd	Bridge	Flood Area
48	Walnut Acres Rd	Bridge	Flood Area
49	Walnut Acres Rd	Box Culvert	Flood Area
50	Walnut Acres Rd	Bridge	Flood Area
51	Stringtown Rd	Box Culvert	Flood Area
52	Vaughn Ford Rd	Low Water Crossing	Flood Area
53	Oakland Rd	Box Culvert	Flood Area
54	Oakland Rd	Low Water Crossing	Flood Area
55	Old Bass Rd	Bridge	Flood Area
56	Jones Rd	Low Water Crossing	Not Signed For Flooding
57	Hemstreet Rd	Bridge	Flood Area
58	Kautsch Rd	Box Culvert	Flood Area
59	Kautsch Rd	Box Culvert	Flood Area
60	Scrivner Rd	Box Culvert	Flood Area
61	Gully Rd	Low Water Crossing	Flood Area
62	Dawson Rd	Low Water Crossing	Not Signed For Flooding
63	S Branch Rd	Low Water Crossing	Flood Area
64	N Branch Rd	Low Water Crossing	Flood Area
65	N Branch Rd	Low Water Crossing	Flood Area
66	Scrivner Rd	Bridge	Flood Area
67	Scrivner Rd	Bridge	Flood Area
68	Scott Rd	Low Water Crossing	Not Signed For Flooding
69	Claywell Rd	Box Culvert	Flood Area
70	Curtman Rd	Box Culvert	Flood Area
71	Curtman Rd	Box Culvert	Flood Area
72	Clearwater Rd	Bridge	Flood Area
73	Enon Rd	Box Culvert	Flood Area
74	Settlen Rd	Pipe	Flood Area
75	Settlen Rd	Pipe	Flood Area
76	Campbell Rd	Low Water Crossing	Flood Area
77	Campbell Rd	Bridge	Flood Area
78	Payne Rd	Low Water Crossing	Flood Area
79	Payne Rd	Bridge	Flood Area
80	W Alexander Rd	Box Culvert	Flood Area
81	Alexander Rd	Box Culvert	Flood Area
82	County Line Rd	Bridge	Flood Area
83	County Line Rd	Box Culvert	Flood Area

Figure 4.27d

Cole County Public Works Designated Flood Areas

Map ID	Road	Structure	Area Designation/Comments
84	County Line Rd	Box Culvert	Flood Area
85	E Cole Junction Rd	Flood Area	Flood Area, Road Is Next To Greys Creek Which Backs Up From Missouri River
86	E Cole Junction Rd	Pipe	Flood Area, Slough Backs Up From Missouri River
87	E Cole Junction Rd	Pipe	Flood Area, Slough Backs Up From Missouri River
88	W Cole Junction Rd	Pipe	Flood Area, Slough Backs Up From Missouri River
89	Claysville Rd	Pipe	Flood Area, Slough Backs Up From Missouri River
90	Claysville Rd	Pipe	Flood Aera, Slough Backs Up From Missouri River
91	Scott Station Rd	Bridge	Flood Area North Of Bridge
93	High Point Rd	Box Culvert	Flood Area
94	High Point Rd	Box Culvert	Flood Area
95	Old Stage Rd	Pipe	Flood Area
99	Bryant Rd	Flood Area	Flood Area, Road Next To Unnamed Creek
100	Mud Creek Rd	Low Water Crossing	Flood Area
101	Mud Creek Rd	Low Water Crossing	Flood Area
102	Mud Creek Rd	Box Culvert	Flood Area
103	Mud Creek Rd	Box Culvert	Flood Area
104	Mud Creek Rd	Pipe	Flood Area
105	Moniteau Creek Rd	Bridge	Not Signed For Flooding, Moniteau Creek Backs Up From Missouri River
106	Kings Chapel Rd W	Low Water Crossing	Flood Area
107	Rainbow Dr	Box Culvert	Flood Area
108	E Lohman Rd	Low Water Crossing	Flood Area
109	Meadows Ford Rd	Low Water Crossing	Flood Area
110	Rockhouse Spur	Low Water Crossing	Flood Area
111	Waterford Rd	Low Water Crossing	Flood Area
112	Waterford Rd	Box Culvert	Flood Area
113	Kaylor Bridge	Bridge	Flood Area
114	Wayside Rd	Box Culvert	Flood Area
115	Wayside Rd	Box Culvert	Flood Area
116	Wayside Rd	Pipe	Flood Area
117	Murphy Ford Rd	Low Water Crossing	Flood Area
118	Tellman Rd	Box Culvert	Flood Area
119	Tellman Rd	Box Culvert	Flood Area

Source: Cole County Public Works - Collected September 2010

Extent

There are characteristic differences between riverine flooding and small stream/flash flooding in the planning area; these differences involve both the speed of onset and duration of flooding events.

Riverine flooding –

- Speed of onset - Riverine flooding is a hazard that allows for mitigation, preparation, and potential evacuation because of the relatively long speed of onset.

- Duration - An examination of the NOAA data for riverine flooding from January 1, 1996, through May 31, 2016, indicates an average duration of approximately 3.9 days per event (Figure 4.28).

Figure 4.28

Cooper County Historic Data
River Flooding
January 1, 1996 - May 31, 2016

Location	Date	River	Duration (days)
Otterville	1996: 5/6/96-5/8/96	Lamine	3
Boonville	1996: 5/8/96-5/16/96	Missouri	9
Boonville	1996: 5/25/96-5/31/96	Missouri	7
Boonville	1996: 6/1/96-6/11/96	Missouri	11
Boonville	1996: 6/18/96-6/20/96	Missouri	3
Boonville	1996: 6/25/96-6/30/96	Missouri	6
Otterville	1996: 7/21/96-7/23/96	Lamine	3
Boonville	1996: 7/21/96-7/24/96	Missouri	4
13 counties	1997: 2/21/97-2/28/97	Missouri	8
5 counties	1997: 2/26/97-2/27/97	Lamine	2
6 counties	1997: 4/11/97-4/27/97	Missouri	17
6 counties	1997: 5/3/97-5/11/97	Missouri	9
7 counties	1997: 5/26/97-5/28/97	Lamine	3
7 counties	1998: 3/8/98-3/9/98	Lamine	2
14 counties	1998: 3/31/98-3/31/98	Missouri	1
12 counties	1998: 4/1/98-4/6/98	Missouri	6
10 counties	1998: 4/10/98-4/16/98	Missouri	7
Otterville	1998: 6/4/98-6/5/98	Lamine	2
3 counties	1998: 6/8/98-6/9/98	Lamine	2
6 counties	1998: 6/15/98-6/25/98	Missouri	11
10 counties	1998: 6/20/98-6/23/98	Lamine	4
2 counties	1998: 7/1/98-7/1/98	Missouri	1
2 counties	1998: 7/26/98-7/27/98	Lamine	2
Otterville	1998: 7/29/98-7/29/98	Lamine	1
6 counties	1998: 7/30/98-7/31/98	Lamine	2
4 counties	1998: 8/1/98-8/1/98	Missouri	1
9 counties	1998: 9/15/98-9/16/98	Missouri	2

15 counties	1998: 10/5/98-10/11/98	Missouri	7
9 counties	1998: 10/19/98-10/21/98	Missouri	3
14 counties	1998: 11/2/98-11/14/98	Missouri	13
6 counties	1999: 1/31/99-1/31/99	Lamine	1
5 counties	1999: 2/1/99-2/1/99	Lamine	1
5 counties	1999: 2/7/99-2/7/99	Lamine	1
6 counties	1999: 3/8/99-3/9/99	Lamine	2
16 counties	1999: 4/16/99-4/21/99	Lamine	6
12 counties	1999: 4/23/99-4/30/99	Missouri	8
6 counties	1999: 5/1/99-5/2/99	Missouri	2
12 counties	1999: 5/4/99-5/8/99	Missouri	5
6 counties	1999: 5/14/99-5/27/99	Missouri	14
2 counties	1999: 6/3/99-6/3/99	Missouri	1
12 counties	1999: 6/28/99-6/30/99	Missouri and Lamine	3
8 counties	1999: 7/1/99-7/5/99	Missouri	5
3 counties	2000: 2/18/00-2/19/00	Lamine	2
2 counties	2000: 5/26/00-5/29/00	Lamine	4
3 counties	2001: 1/29/01-1/30/01	Lamine	2
16 counties	2001: 2/24/01-2/25/01	Lamine	2
4 counties	2001: 4/3/01-4/5/01	Lamine	3
5 counties	2001: 5/7/01-5/9/01	Missouri	3
Otterville	2002: 1/31/02-1/31/02	Lamine	1
4 counties	2002: 5/8/02-5/17/02	Missouri	10
4 counties	2002: 5/8/02-5/10/02	Lamine	3
Otterville	2003: 12/23/03-12/23/03	Lamine	1
Otterville	2004: 7/24/04-7/25/04	Lamine	2
Otterville	2004: 8/25/04-8/25/04	Lamine	1
Otterville	2004: 11/1/04-11/3/04	Lamine	3
Otterville	2004: 11/24/04-11/24/04	Lamine	1
Otterville	2004: 11/27/04-11/28/04	Lamine	2
Otterville	2005: 1/5/05-1/6/05	Lamine	2
Otterville	2005: 1/13/05-1/14/05	Lamine	2
Otterville	2005: 2/13/05-2/14/05	Lamine	1
Boonville	2005: 6/13/05-6/15/05	Missouri	3
Otterville	2005: 8/26/05-8/27/05	Lamine	2
Otterville	2007: 4/14/07-4/15/07	Lamine	2
Boonville	2007: 5/7/07-5/19/07	Missouri	13
Otterville	2007: 6/30/07-6/30/07	Lamine	1
5 counties	2007: 7/1/07-7/1/07	Lamine	1
6 counties	2008: 2/17/08-2/18/08	Lamine	2
9 counties	2008: 3/18/08-3/19/08	Lamine	2
Otterville	2008: 4/10/08-4/11/08	Lamine	2
7 counties	2008: 4/24/08-4/25/08	Lamine	2
Otterville	2008: 5/8/08-5/8/08	Lamine	1

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Average duration of river flooding in planning area (days)	3.9
Source: http://www.ncdc.noaa.gov/stormevents	

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Small Stream and Flash Flooding –

- Speed of onset - In contrast to riverine flooding, small stream flooding and flash flooding occur very quickly with heavy rains.

- Duration - Flash flooding in the planning area usually takes place within the span of one day, according to the NOAA data (Figure 4.29). The data of reported events in the NOAA database indicates an average duration of 4.4 hours.

Figure 4.29

Cooper County Historic Data
Flash Flooding
January 1, 1996 – May 31, 2016

Location	Date	Duration (hours)
South portion of Cooper County	5/26/2000	8
Bunceton	4/10/2001	1
Boonville	5/7/2002	3
Boonville	5/8/2002	3
Pilot Grove	5/19/2004	3
Wooldridge	5/25/2004	3
Wooldridge	5/25/2004	3
Boonville	5/30/2004	3
Boonville	8/4/2004	6
Pilot Grove	1/12/2005	5
Prairie Home	6/8/2005	5
Boonville	8/18/2005	4
Boonville	8/26/2005	3
Bunceton	6/10/2007	4
Otterville	6/10/2007	4
Blackwater	6/29/2007	4
Prairie Home	9/12/2008	6
Bunceton	9/12/2008	6
Boonville Viertel Airport	9/12/2008	6
Blackwater	6/15/2009	6
Bunceton	4/29/2012	6
Bunceton	5/20/2013	6
Boonville	5/31/2013	6
Boonville	9/1/2014	1
Average duration of flash flooding in planning area (hours)		4.4

Source: http://www.ncdc.noaa.gov/stormevents

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Previous Occurrences

The floods of 1993 and 1995 were the worst repetitive flood events in Missouri history, according to the Missouri State Hazard Mitigation Plan (2007). There was also severe flooding in the state in 1994. There were five presidential disaster declarations for flooding during this period; Cooper County was included in Disaster Declaration 995 (July 9, 1993) and Disaster Declaration 1054 (June 2, 1995). Figure 3.5.8 depicts the extent of the 1993 flood waters. Figures 4.28 and 4.29 give a list of documented flooding events in the county.

After a Presidential Disaster Declaration, Public Assistance (PA) and/or Individual Assistance (IA) is made available through FEMA. Cooper County was eligible for both PA and IA from each of these disaster declarations.

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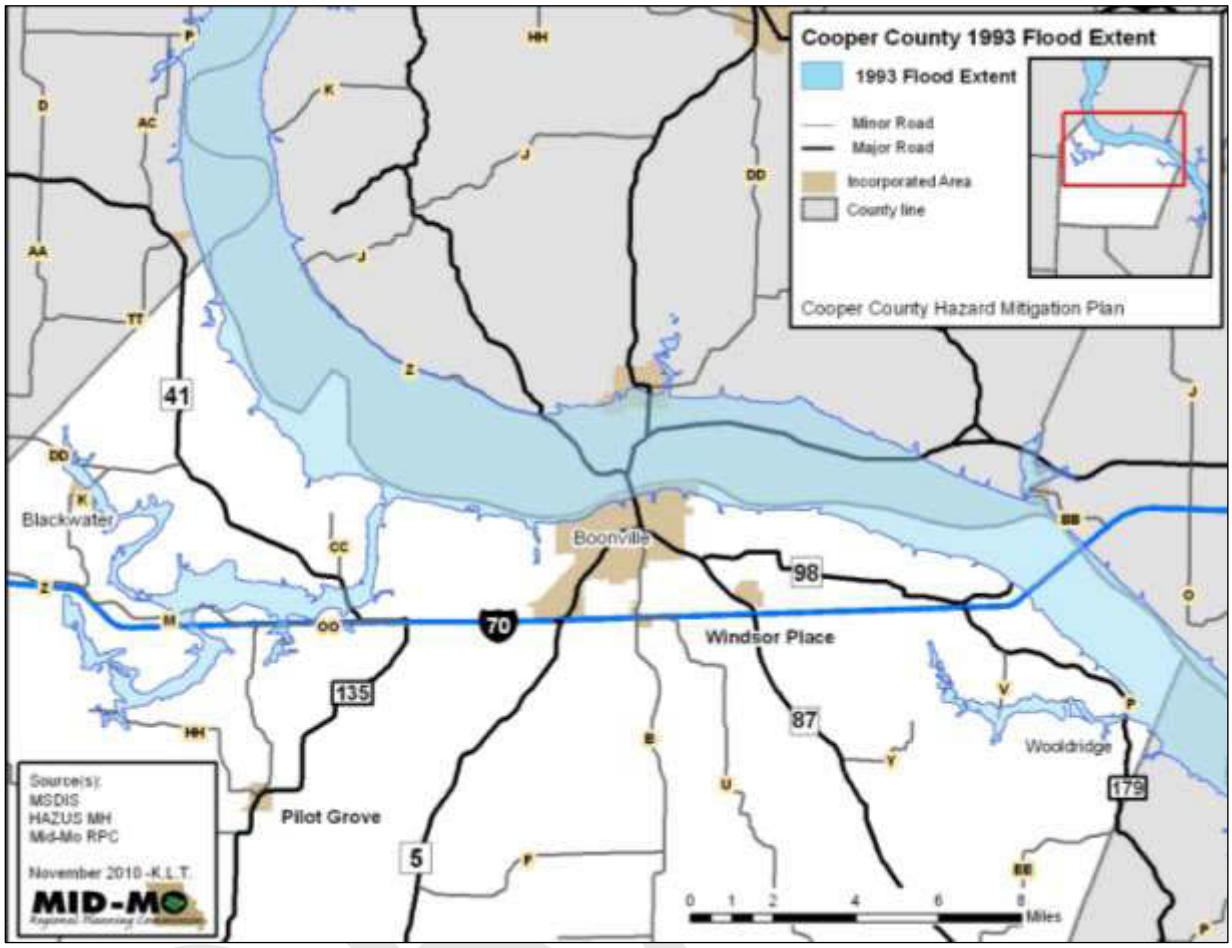
Figure 3.5.8 (reviewed by Beau Derque, September 2016)



In the summer of 2011, the Missouri River flooded again, this time stemming not from significant precipitation in the Mid-Missouri Region but from high precipitation and snow melt in Montana and North Dakota. Higher than normal rain and snow in the winter and spring of 2011 caused wide scale flooding in several states, including North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri. According to the National Weather Service, the Upper Missouri River Valley received more rainfall in the month of May than it does in an entire year.

While Cooper County was spared from incurring damage to residences or businesses, unlike upriver neighbors, it was not spared from seepage through levee walls. All levee districts in Cooper County had to pump water from inside levee walls during the months of June and July. Cooper County was part of both the Emergency Declaration 3325 and the Presidential Disaster Declaration 1980 and eligible for PA and IA. Significant pumping was needed in all levee districts as well as sandbagging and maintenance of the levee in the Village of Wooldridge. The levee that protects a portion of Wooldridge had been in serious disrepair. As flood waters were rising, volunteers, county workers, and the National Guard worked to clear debris on the levee and then placed sandbags to add extra protection. Thankfully, the river crested without reaching the levee.

In addition to the river floods of 1993, 1995, and 2011, data from NOAA indicates numerous other flooding events in Cooper County since 1993. The Missouri River flood in April 1994 caused $5 million in property damage and $5 million in crop damage across 79 Missouri counties; the portion of this reported loss that occurred in Cooper County is not indicated in the NOAA data.

Flash flooding can be particularly hazardous in that there may be very little warning for travelers. The NOAA data contains specific information about two flash flooding events where travelers were endangered in Cooper County. Two cars were swept off Highway 5 near Bunceton in the flash flood on June 10, 2007. In the other incident, a car was stalled on Highway W near Prairie Home with floodwaters reaching the door of the vehicle (September 12, 2008). No indication of injury was given in the data for these incidents.

There have been 24 reported flash flooding events since 1996 (Figure 4.29.)

The death reported from the flooding in June 1999 did not occur in Cooper County.

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Probability of Future Events

Figure 4.30 Probability of Future Flooding Events			
EF-Scale	**# of years with flood event (1996-2016)**	**Probability**	**Probability Rating**
River flood	12	57%	High
Flash flood	11	52%	High

Probability: High – Cooper County, Boonville, Wooldridge, Linneman-Weekley Levee District, and the Overton-Wooldridge Levee District

Low – Bunceton, Otterville, Pilot Grove

ANALYSIS OF RISK

Severity: High – Wooldridge, Linneman-Weekley Levee District, and the Overton-Wooldridge Levee District

Moderate – Cooper County

Low – Bunceton, Otterville, Pilot Grove

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National Flood Insurance Program Repetitive Loss Properties

Requirement §201.6(c)(2)(ii):	***[The risk assessment] must also address National Flood Insurance Program (NFIP) insured structures that have been repetitively damaged by floods.***

The NFIP defines a **Repetitive Loss Property** as "any insurable building for which two or more claims of more than $1,000 were paid by the National Flood Insurance Program (NFIP) within any rolling ten-year period, since 1978." A repetitive loss property may or may not currently be insured by the NFIP. There are no Repetitive Loss Properties in Cooper County, according to the Missouri State Hazard Mitigation Plan (2013).

A Severe Repetitive Loss (SRL) property is defined as a **residential property** that is covered under an NFIP flood insurance policy and:

> (a) Has at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amount of such claims payments exceeds $20,000; or
>
> (b) For which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building.
>
> For both (a) and (b) above, at least two of the referenced claims must have occurred within any 10-year period, and must be greater than 10 days apart.

There are no Severe Repetitive Loss Properties in Cooper County, according to the Missouri State Hazard Mitigation Plan (2013).

Potential Impact – Life

All types of flooding present a threat to human life. Small stream/urban stream flooding and flash flooding are particularly hazardous due to their quick onset. It is an ongoing struggle to educate the public concerning the very real hazard presented by flooded low water crossings and other flash flooding situations.

In addition to the risk of drowning, exposure to flood waters can result in infection or injury from sewage, agricultural runoff, and industrial chemicals. Flooded buildings present health risks from mold, chemicals, and electrical hazards.

Flooding also poses a threat to the livelihood of those farming in low lands; this is especially a problem near the Missouri River. When the river level is high for an extended period, water will seep up through the soil and cause additional flooding to that already caused by heavy rains. Standing water in fields may prevent planting at the optimal time for a successful harvest or damage/destroy crops during the growing season.

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Potential Impact on Existing Structures

Cooper County residents, structures, and infrastructure lying in or near the Missouri River Floodplain or Lamine River Floodplain are all vulnerable to the effects of a major flood. Other structures not within designated floodplains are also vulnerable to the effects of flash flooding brought on by storm water or sheet flooding. Figures 4.24 through 4.29 depict the 100-year flood plain for Cooper County. Through the use of high resolution 2007 aerial imagery from the Missouri Spatial Data Service at the University of Missouri, a GIS Specialist for the Mid-Missouri Regional Planning Commission was able to see and count structures in the floodplain. It was found that only Cooper County (unincorporated area), Boonville, Bunceton, and Wooldridge had structures in the floodplain. There were 359 structures in all of Cooper County, with 24 of those in Boonville, one in Bunceton, and 36 in Wooldridge. These structures may consist of businesses, residences, towers, outbuildings, or other manmade structures. Further analysis of the data may give a more precise categorization of the structures.

It can be said with certainty that there are not fire stations, schools, nursing homes, hospitals, prisons, government centers, or police stations in the 100-year floodplain.

Both the City of Bunceton and the City of Otterville have their wastewater lagoons located partially within the 100-year floodplain. This has not posed a significant problem for either community.

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Existing Mitigation Activities

The Missouri River floods of 1993 and 1995 were devastating events for many parts of the Midwest United States. Changes in river management, including major wetland restoration projects along the river's long course and the buyout of properties in the river floodplain have all helped to mitigate risk associated with riverine flooding in the planning area.

National Flood Insurance Program (NFIP)

The National Flood Insurance Act of 1968 established the National Flood Insurance Program (NFIP) to help encourage wise development and reduce losses from flood. Communities participating in the NFIP agree to adopt and enforce floodplain management ordinances to reduce risks to new and improved structures in Special Flood Hazard Areas. (A Special Flood Hazard Area (SFHA) is an area of land that has a 1-percent chance of being inundated by a flood in any given year; this area is also called the "base flood" or commonly referred to as the "100-year flood" area.)

A county or community's membership in the NFIP enables property owners to purchase flood insurance at a more affordable cost than market-based insurance. This also helps reduce the post-disaster assistance required in flood damage situations.

Participation in the National Flood Insurance Program is a critical aspect of hazard mitigation planning because it provides communities with direct resources that can be used for controlling the potentially devastating impacts of floods. Furthermore, participation in the program helps communities more easily recover from flood impacts.

The NFIP statuses of jurisdictions in the planning area are shown in Figure 4.32.

Figure 4.32

Cooper County Jurisdictions - NFIP Status

Participating			
Jurisdiction	**Entry into Program**	**Date of Current FIRM**	**Community ID (CID)**
Cooper County	9/1/1989	5/3/2011	290794
Blackwater	12/7/1984	5/3/2011	290109
Boonville	10/16/1984	5/3/2011	290110
Bunceton	1/7/2016	5/3/2011	290111A
Pilot Grove	11/24/2008	5/3/2011	290678
Wooldridge	12/4/1984	5/3/2011	290112
Not Participating			
Jurisdiction	**Sanction Date***	**Date of Current FIRM**	**Community ID (CID)**
Otterville	4/25/1976	5/3/2011	290556

*Sanction Date indicates the date that a community decided not to participate in the NFIP (or was suspended for noncompliance).

Source: NFIP Community Status Book

A comparison of NFIP insurance policies in effect in the planning area in 2011 and 2016 indicates an overall increase of only one policy (Figure 4.33). While the amount of property insured decreased, the premiums being paid increased by 14.48 percent. This reflects the increase in the price of flood insurance, even when purchasing it through the NFIP.

Figure 4.33

NFIP Policies in Cooper County

Community	Policies In-Force		Insurance In-Force Whole		Written Premium In-Force	
	11/7/2011	7/31/2016	11/7/2011	7/31/2016	11/7/2011	7/31/2016
Cooper County*	3	3	$388,000	$148,000	$1,244	$1,540
Blackwater	NA	1	NA	$30,000	NA	$521
Boonville	1	1	$1,000,000	$1,000,000	$1,457	$1,552

*Unincorporated areas of county only

Source: bsa.nfipstat.fema.gov/reports/1011.htm#MOT

Risk MAP

Risk MAP is a FEMA program focused on flood risk reduction. According to FEMA, the program "provides communities with flood information and tools they can use to enhance their mitigation plans and better protect their citizens. Through more accurate flood maps, risk assessment tools, and outreach support, Risk MAP builds on Map Modernization and strengthens local ability to make informed decisions about reducing risk."

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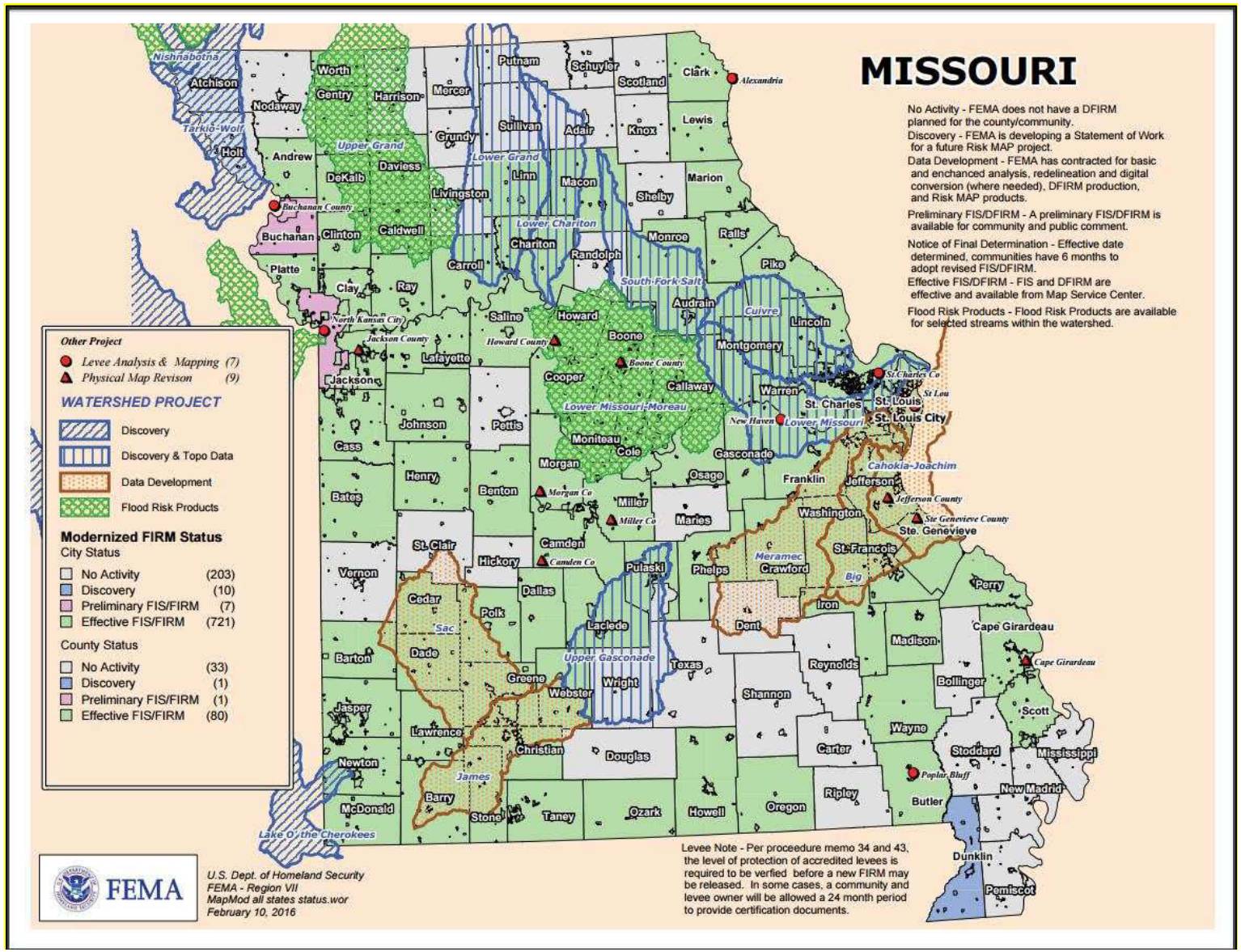
Figure 4.34


MISSOURI
No Activity - FEMA does not have a DFIRM planned for the county/community.
Discovery - FEMA is developing a Statement of Work for a future Risk MAP project.
Data Development - FEMA has contracted for basic and enchanced analysis, redelineation and digital conversion (where needed), DFIRM production, and Risk MAP products.
Preliminary FIS/DFIRM - A preliminary FIS/DFIRM is available for community and public comment.
Notice of Final Determination - Effective date determined, communities have 6 months to adopt revised FIS/DFIRM.
Effective FIS/DFIRM - FIS and DFIRM are effective and available from Map Service Center.
Flood Risk Products - Flood Risk Products are available for selected streams within the watershed.
Other Project
Levee Analysis & Mapping (7)
Physical Map Revison (9)
WATERSHED PROJECT
Discovery
Discovery & Topo Data
Data Development
Flood Risk Products
Modernized FIRM Status
City Status
No Activity (203)
Discovery (10)
Preliminary FIS/FIRM (7)
Effective FIS/FIRM (721)
County Status
No Activity (33)
Discovery (1)
Preliminary FIS/FIRM (1)
Effective FIS/FIRM (80)
Levee Note - Per proceedure memo 34 and 43, the level of protection of accredited levees is required to be verfied before a new FIRM may be released. In some cases, a community and levee owner will be allowed a 24 month period to provide certification documents.
FEMA
U.S. Dept. of Homeland Security
FEMA - Region VII
MapMod all states status.wor
February 10, 2016

County

Cooper County posts signs at some of their low-water crossing to warn of flooding. Also, many state routes in the county have flood warning signs.

Boonville

Boonville enforces floodplain ordinances; building codes and zoning contribute to this enforcement.

Pilot Grove

Pilot Grove enforces floodplain ordinances.

Wooldridge

The village has performed extensive maintenance to their levee and flood gate to prepare for future events that may occur.

Other

The National Weather Service issues flooding hazard alerts according to three response levels (Figure 4.35). These alerts are broadcast through local media.

Figure 4.35

Flood Response Levels

Level	Description
Flood Watch	Flash flooding or flooding is possible within a designated area
Flood Warning	Flash flooding or flooding has been reported or is imminent
Flood Advisory	Flooding of small streams, streets, and low lying areas—such as railroad underpasses and some urban drains—is occurring

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Potential Impact - Future Development
Impact on future development is directly related to floodplain management and regulations set forth by the county and individual communities.

There is a high level of awareness in the planning area regarding the dangers and potential of flooding. Participation in the NFIP means that floodplain ordinances are in place that regulate development in the floodplains of those jurisdictions.

It is now known that climate change is causing an increase in the type of heavy downpours that trigger flash flooding; it is reasonable to expect that flash flooding will become even more of a problem in the planning area than it has been in the past. Any increase in impervious surface means an increase in runoff. It is important that development projects are closely monitored to ensure compliance with all applicable storm water regulations in order to minimize the negative effects of flash flooding.

SUMMARY OF VULNERABILITY

Large-scale floods, such as the 1993 flood, are devastating events for entire regions of the country. Not only was Mid-Missouri impacted, but the entire Midwest suffered large losses in life, property, and crop damage, which carried over to the rest of the United States. Transit routes were disrupted, people lost jobs, and crops never made it to market. Small-scale floods or flash flooding can impact a neighborhood or a city but are limited in their spatial extent.

The entire planning area is at risk from some type of flooding. The most common types of flooding in the area are flash and sheet flooding associated with heavy downpours. This type of flooding can impact a neighborhood or a city but are limited in their spatial extent. Flash flooding is of particular concern in the unincorporated parts of Cooper County, where roads can become impassable. Climate change is causing an increase in heavy downpours, and this will, in turn, most likely increase the frequency and/or severity of flash flooding.

Flooding of the Missouri River and the Lamine River (and their branches) is a potential problem for the areas near those rivers and branches.

NFIP membership, floodplain regulations, and a high awareness of the threat of potential flooding all act to help mitigate the vulnerability to this hazard.

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4.5 LEVEE FAILURE

DESCRIPTION OF HAZARD

A levee is defined by the National Flood Insurance Program as "a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding."

Federally authorized levees are typically designed and built by the US Army Corps of Engineers in cooperation with a local sponsor then turned over to a local sponsor to operate and maintain.

Non-federal levees are designed, built, and managed by a non-federal entity.

There is no single agency with responsibility for levee oversight. The Corps of Engineers has specific and limited responsibilities for approximately 2,000 levees nationwide through their Levee Program.

The responsibilities of local levee owners or sponsors are broad and may include levee safety; land use planning and development; building codes; and operations, maintenance, repair, rehabilitation, and replacement of the levee. The certification of levees for FEMA's National Flood Insurance Program is also the responsibility of the local levee owners or sponsors.

Federally authorized and some non-federal levees may be eligible for Corps of Engineers rehabilitation assistance funding. It is important to note that current levees in the planning area are agricultural levees and as such are built to withstand only 50-year floods.

This assessment discusses the major levees in the planning area; these levees are owned and operated by levee districts. There are also several privately owned levees, which are maintained by their owners; official data on the locations of these private levees is not available.

The USACE notes that there is a "large universe of private and other non-Corps levees that have not been inventoried or inspected/assessed. We don't know the size of this universe, where the levees are located, their condition, or the consequences of failure, loss of life being of paramount concern."

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Location

The levee districts in Cooper County are found along the Missouri River on the northern and northeastern boundaries of Cooper County (see Figures 4.36 and 4.37). The levee that protects a portion of the Village of Wooldridge is located in northeastern Cooper County and protects the community from riverine flooding stemming from the Petite Saline Creek (see Figure 4.38). The Petite Saline Creek floods a large area of Cooper County when the Missouri River rises and backs up into this tributary.

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Figure 4.36 (reviewed by Beau Derque, September 2016)

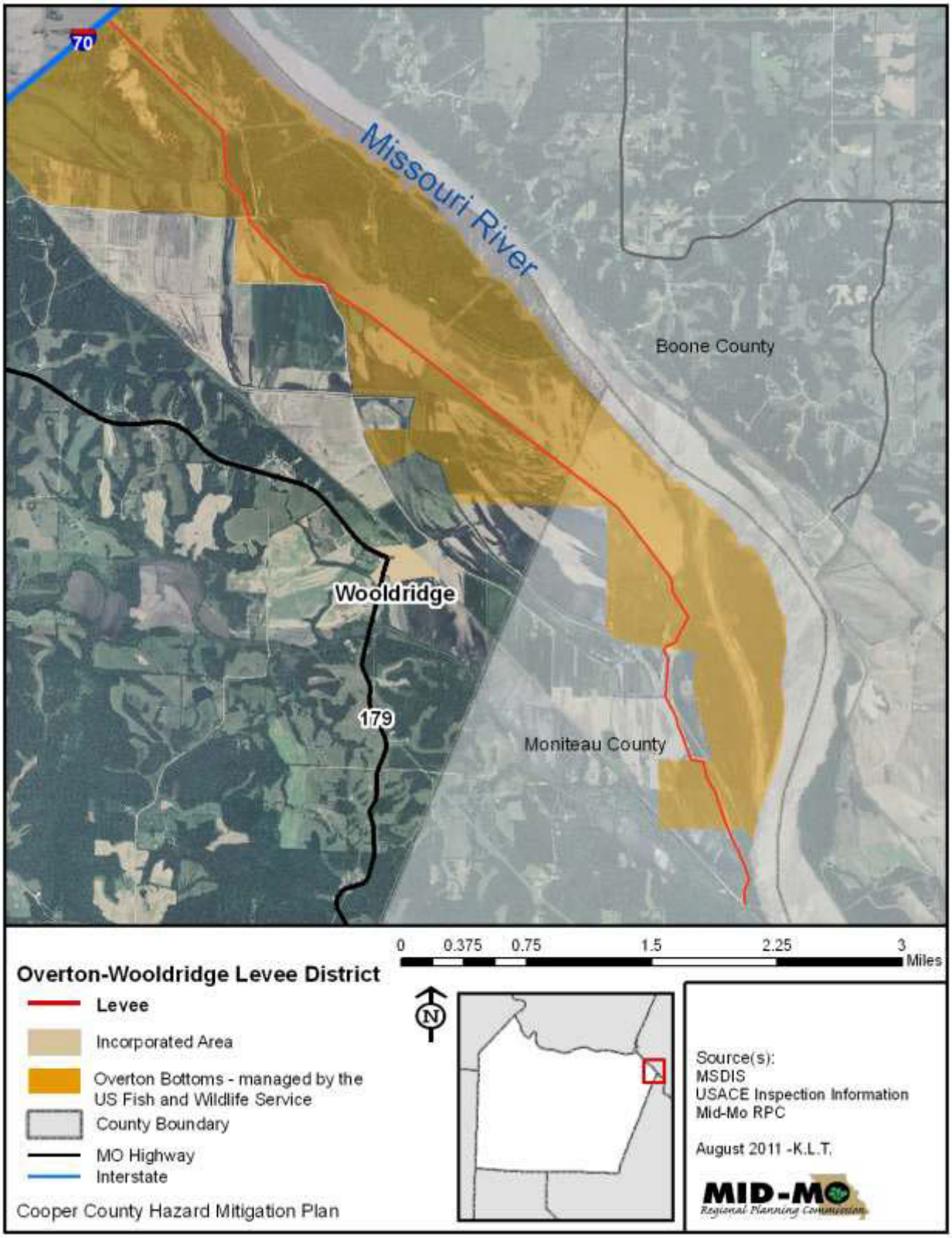


Figure 4.37 (reviewed by Beau Derque, September 2016)

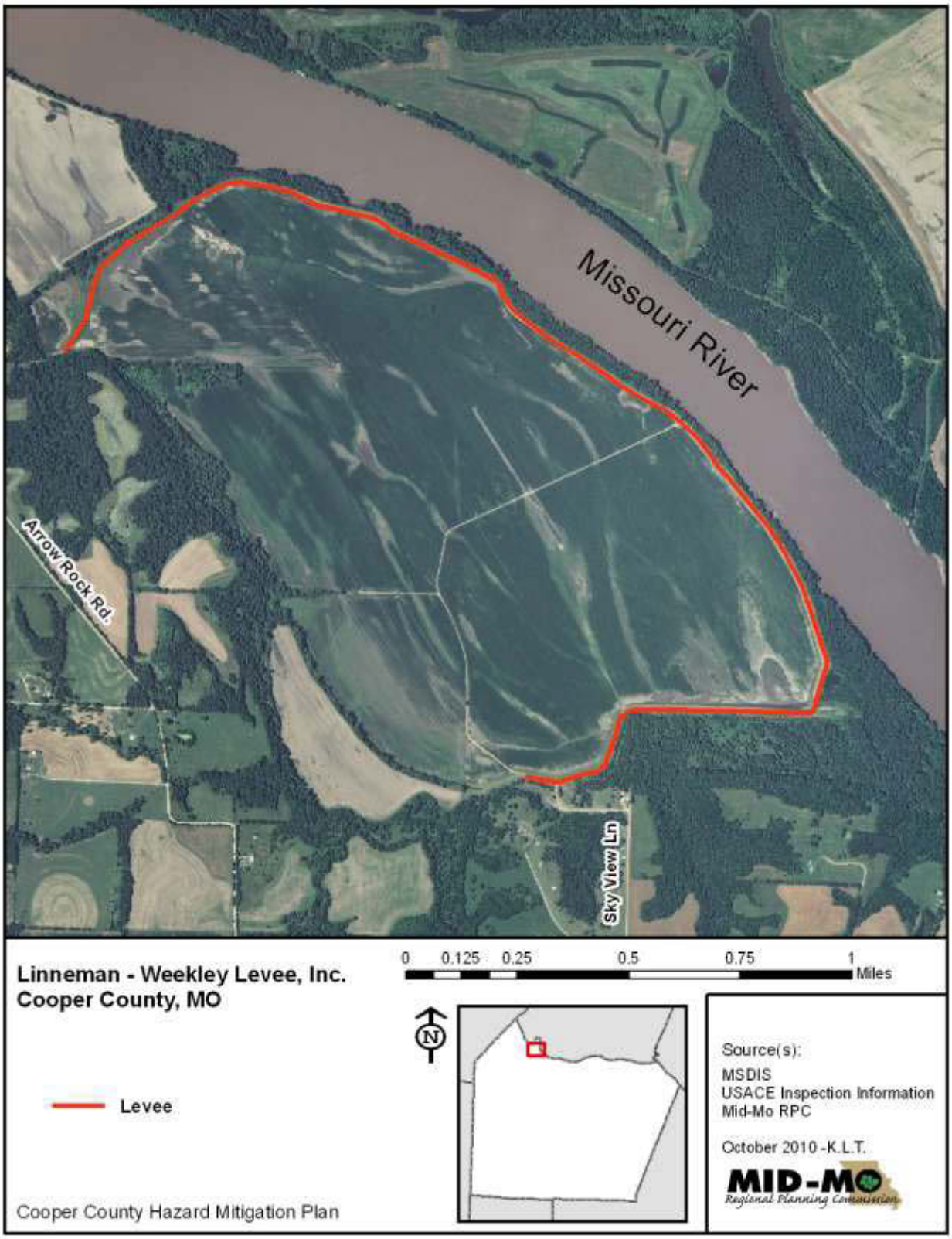
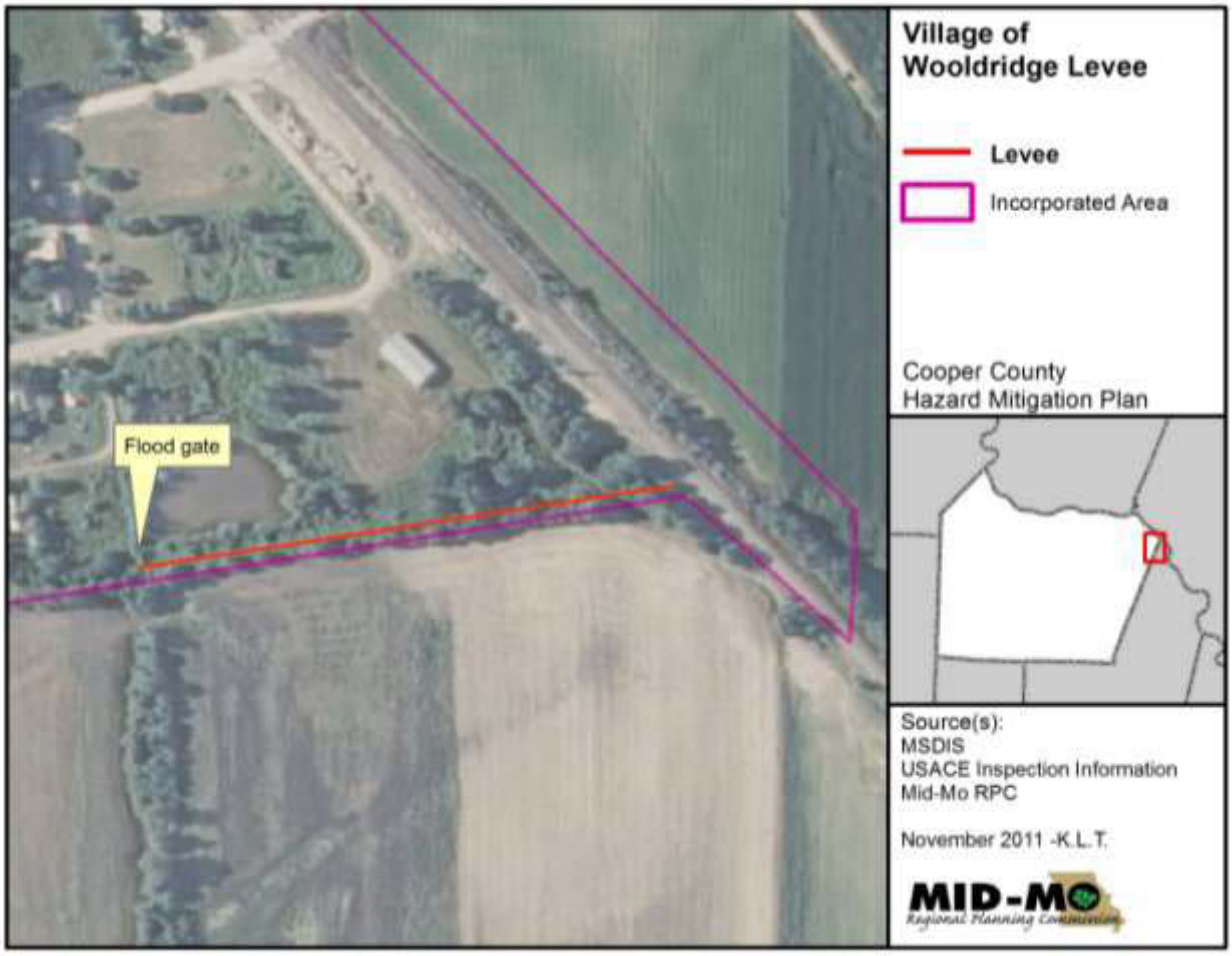


Figure 4.38 (reviewed by Beau Derque, September 2016)



The levees are part of the U.S. Army Corps of Engineers (USACE) Rehabilitation Program. As part of this program, a levee district is eligible for USACE levee rehabilitation assistance if its levee receives damage during a flood event. The levee must maintain a *minimally acceptable* standard to remain eligible for the assistance. According to the USACE, "The rating is based on the levee inspection checklist, which includes 125 specific items dealing with operation and maintenance of levee embankments, floodwalls, interior drainage, pump stations, and channels."

Levee System Inspection Ratings	
Acceptable	All inspection items are rated as Acceptable.
Minimally Acceptable	One or more 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 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.

The levee ratings from the most recent inspections in [year], along with other information, are shown in Figure 4.37.

Figure 4.37

Major Levees in the Planning Area

Levee Name	Segment Length (miles)	Leveed Area Acreage	Inspection Date	Inspection Rating
Linneman-Weekley Levee	3.75	888.11	5/13/2013	Minimally acceptable
Overton-Wooldridge Levee District	x	x	x	x
Village of Wooldridge Levee	x	x	x	x

Sources: USACE National Levee Database: USACE Levee Inspection Reports

There are other, privately owned levees in the planning area; official data on the locations of these private levees is not available. These privately owned levees are maintained by their owners and are not part of any federal rehabilitation program. Tracking of levee conditions is a point of concern, especially because there are so many of these privately owned levees.

Extent

Levee failure, according to FEMA, can occur by the following means:

- **Overtopping -** When a large flood occurs, water can flow over a levee. The stress exerted by the flowing water can cause rapid erosion.
- **Piping -** Levees are often built over old stream beds. Flood waters will follow these subgrade channels, causing a levee to erode internally, thereby allowing flood waters to rupture the levee structure.
- **Seepage and Saturation** - If flood waters sit up against a levee for a long period, the levee may become saturated and eventually collapse.
- **Erosion -** Most levees are constructed of sand or soil, which erodes easily under high-velocity flood waters.
- **Structural Failures -** Lack of regular maintenance is a key reason levees fail at gates, walls, or closure sites.

Regular maintenance and inspection of the levees is critical. For the major levees in the planning area, the potential of major failure is connected to flooding of the Missouri River, a hazard with a longer speed of onset than many other hazards. This longer speed of onset allows time to mitigate and prepare for potential failure as flooding threatens.

Previous Occurrences

According to the US Army Corps of Engineers, all levees in Cooper County and most of the surrounding counties failed during the 1993 Flood, resulting in the inundation of land and structures being protected.

Structures and communities that were affected by the levee breaches include the City of Boonville, Blackwater, the Blackwater Wastewater Facility, Wooldridge, and several residences and businesses. While the levees do not directly protect these areas, the breaches increased flooding in these locations.

In the summer of 2011, high levels of flooding occurred along the Missouri River, stemming from releases from the Gavin's Point Reservoir near Yankton, South Dakota. The water that was released from the reservoir and other reservoirs upstream resulted in large-scale flooding in the upper Missouri River Valley. These flooded areas included North Dakota, South Dakota, Nebraska, Iowa, Kansas, and Missouri. While flood waters from this event caused severe damage to levees in northwestern Missouri, the central portion of the state fared much better. There were no failures of levees in Cooper County.

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While levee failures did not occur, there were instances of seepage coming under levees and causing damage to agricultural fields and roadways. Both the Linneman-Weekley and Overton-Wooldridge levee districts incurred damage to agricultural fields and had to maintain pumps to keep water out of protected areas.

Wooldridge also took measures to mitigate the effects of the 2011 flooding. On July1, 2011, the Missouri National Guard arrived in Wooldridge to prepare sandbags for the levee. At that time, the Petite Saline Creek, which is a tributary to the Missouri River, was backing up into town. Soldiers, volunteers, and prisoners worked to clear vegetation, fill sandbags, and place the bags on the levee. Water levels did not overtop the levee.

In addition to major flooding events, smaller flooding events have caused damage for levee districts. The Overton-Wooldridge Levee District experiences periodic flooding stemming from seepage under their levee. Water from the adjoining wetland area seeps under the levee through sandy soil and causes pooling of water farther inland that should be protected by the levee. Levee district board members stated that this seepage did not occur until the creation of a side channel or chute in the wetland by the US Fish and Wildlife Service in 2001. According to the US Fish and Wildlife Service, the 1.5-mile chute at Overton Bottoms only receives water from the Missouri River at high river stages and is used for fish sampling.

Probability of Future Events

Probability: Moderate

ANALYSIS OF RISK

Severity: High

Impact – Life

Levee failure presents a flooding threat to life. The longer period of onset associated with failure of levees along the Missouri River would minimize the threat of actual drowning; however, drowning could still occur. The greater threat from levee failure would be exposure to flood waters with possible resulting infection or injury from sewage, agricultural runoff, and industrial chemicals. Flooded buildings present health risks from mold, chemicals, and electrical hazards.

Impact - Existing Structures

Structures in Cooper County that would be vulnerable to the effects of levee failure would include those that lie in areas in or near the Missouri River floodplain and its tributaries. Since the 1993 Flood, many structures have been relocated, bought out, abandoned, elevated, or remodeled; this has reduced the amount of vulnerable structures and people in areas where levees could potentially fail.

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Information on the agricultural land and built environment protected by the major levees in the planning area is shown in Figures 4.40-4.41.

Figure 4.40 **Linneman-Weekley Levee District Inc.**
Levee Embankment Data
LEVEE DESIGNED GAGE FUNCTION READING/STATION: 34.0 – Boonville Gage **LEVEL OF PROTECTION PROVIDED:** Exceeds a 10-year flood event. **AVERAGE HEIGHT OF LEVEE:** 6' to 12' **AVERAGE CROWN WIDTH:** 8' to 16' **AVERAGE SIDE SLOPE:** Landside slope 1 on 3 to 1 on 4 Riverside ranges from 1 on 3 to 1 on 6
Protected Features
TOTAL ACRES PROTECTED: 1,000 **TOTAL AGRICULTURAL PRODUCTION ACRES PROTECTED:** 1,000 **TOWNS:** 0 **BUSINESSES:** 0 **RESIDENCES:** 0 **ROADS:** Approximately 2 miles of unimproved farm to market roads. **UTILIITES:** 0 **BARNS:** 0 **MACHINE SHEDS:** 0 **OUTBUILDINGS:** 0 **IRRIGATION SYSTEMS:** 0 **GRAIN BINS:** 0 **OTHER FACILITIES:** 0 Source: USACE Inspection Report

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A levee system was established under the guidelines of a Not-For-Profit Corporation and was last inspected on January 24, 2005. Information about this Levee District can be obtained by contacting Jason Linneman at 660-846-2600.

Figure 4.41

Overton-Wooldridge Levee

Levee Embankment Data

LEVEE DESIGNED GAGE FUNCTION READING/STATION: 32.0 Boonville Gage

LEVEL OF PROTECTION PROVIDED: Exceeds a 10-year-flood event

AVERAGE HEIGHT OF LEVEE: Varies from a low of 8' to a high of 14' above the landside natural ground surface.

AVERAGE CROWN WIDTH: Varies from 10' to 12'

AVERAGE SIDE SLOPE: L/S: 1 on 3 **R/S:** 1 on 3

ANNUAL MAINTENANCE COSTS: Approximately $2,500.00

Protected Features

TOTAL ACRES PROTECTED: Approximately 3,500 (Approx. 1,435 acres of MO River Mitigation Project lands – known as Overton Bottoms Conservation Area South.)

TOTAL AGRICULTURAL PRODUCTION ACRES PROTECTED: Approximately 3,400 (Note: MO River Mitigation Project lands are agriculturally leased on a year-to-year basis.)

TOWNS: 0

BUSINESSES: 0

RESIDENCES: 0

ROADS: Approximately 5.20 miles of gravel surfaced County roads and approximately 5.00 miles of non-surface farm service roads.

UTILIITES: Approximately 4.50 miles of overhead power lines.

BARNS: 5

MACHINE SHEDS: 0

OUTBUILDINGS: 3

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IRRIGATION SYSTEMS: 0

GRAIN BINS: 1

OTHER FACILITIES: Limited protection afforded to approximately 6.00 miles of railroad embankment.

This levee is sponsored by the Cooper County Commission and was last inspected on January 19, 2006 [still accurate?]. Information about this Levee District can be obtained by contacting Art Schnuck at 660-882-2021 [still accurate?].

(The data in Figures 4.40 and 4.41 was provided by Engineer Cliff Sanders of the US Army Corps of Engineers in Glasgow, Missouri. The data includes protected area information from a "Supplemental Levee Inspection Information" form collected during the inspections in 2005 and 2006.)

Impact - Future Development

Impact on future development is directly related to floodplain management and regulations set forth by the county and individual communities through levee management and regulations which are not clearly defined. It is important to note that levees in Cooper County are located in designated floodplains. This means that all new construction in these areas fall under Cooper County's floodplain regulations and must adhere to that coding.

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Existing Mitigation Strategies

The US Army Corps of Engineers oversees the inspection of the Linneman-Weekley Levee District and the Overton-Wooldridge Levee District; it is up to the owner or sponsor to inspect and fix their levees. Both levee districts and the Village of Wooldridge have a maintenance plan in place.

Most areas behind the three levees in the planning area are in designated floodplains and new construction must meet floodplain regulations and/or NFIP guidelines.

SUMMARY OF VULNERABILITY

Jurisdictions: Cooper County, Wooldridge, Overton-Wooldridge Levee District, and Linneman-Weekley Levee District

The two main levees in the planning area (Overton-Wooldridge Levee District and Linneman-Weekley Levee District) are addressed in this plan. Vulnerability assessments are not being completed for the private levees in the planning area due to the lack of official data on their locations.

The Overton-Wooldridge Levee District and Linneman-Weekley Levee District levees in the planning area are agricultural levees. Agricultural levees are usually built to withstand a 50-year flood, but these three levees fall well below that protection level at 10- to 25-year flood event levels. The Village of Wooldridge Levee is not part of the USACE Levee Rehabilitation Program and does not have an inspection report. It has been estimated by the Wooldridge Board of Trustees that there are approximately 12 to 15 residences that are protected by the levee.

The risk of flooding from levee failure remains. The warning time afforded by a hazard such as levee failure, which has a long period of onset, will allow for preparations and evacuations to take place, should the need arise.

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4.6 DAM FAILURE

DESCRIPTION OF HAZARD

A dam is defined by the National Dam Safety Act as an artificial barrier which impounds or diverts water and is:

1. more than 6 feet high and stores 50 acre feet or more or
2. 25 feet or more high and stores more than 15 acre feet.

Based on this definition, there are over 80,000 dams in the United States. Over 95 percent are non-federal, with most being owned by state governments, municipalities, watershed districts, industries, lake associations, land developers, and private citizens.

Dam owners have primary responsibility for the safe design, operation, and maintenance of their dams. They also have responsibility for providing early warning of problems at the dam, for developing an effective emergency action plan, and for coordinating that plan with local officials. The State has ultimate responsibility for public safety, and many states regulate construction, modification, maintenance, and operation of dams. Many states also ensure a dam safety program.

Dam construction varies widely throughout the state. A majority of dams are of earthen construction. Missouri's mining industry has produced numerous tailing dams for the surface disposal of mine waste. These dams are made from mining material deposited in slurry form in an impoundment. Other types of earthen dams are reinforced with a core of concrete and/or asphalt. The largest dams in the state are built of reinforced concrete and are used for hydroelectric power.

Failure - Dams can fail for many reasons. The most common reasons are listed below:

> **Piping:** internal erosion caused by embankment leakage, foundation leakage, and deterioration of pertinent structures appended to the dam.
>
> **Erosion:** inadequate spillway capacity causing overtopping of the dam, flow erosion, and inadequate slope protection.
>
> **Structural Failure:** caused by an earthquake, slope instability, or faulty construction.

These three types of failures are often interrelated. For example, erosion, either on the surface or internal, may weaken the dam or lead to structural failure. Similarly, a structural failure may shorten the seepage path and lead to a piping failure.

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Dam Hazard Classification - Dams in Missouri have been classified according to both a federal and state system with regards to potential hazard posed.

The **federal classification system** is based upon the probable loss of human life and the impact on economic, environmental, and lifeline interests from dam failure. It should be noted that there is always the possibility of loss of human life when a dam fails; this classification system does not account for the possibility of people occasionally passing through an inundation area that is usually unoccupied (for example, occasional recreational users, daytime users of downstream lands, and so on).

The **state classification system** is based upon the type and number of structures downstream from a dam. An inventory of all the dams of the state was done in the late 1970s and early 1980s, according to Glenn Lloyd, Civil Engineer and Dam Safety Inspector with the Dam Safety Program of the Missouri Department of Natural Resources (DNR). All of the known dams were classified by the state at that time.

A summary of the federal and state classification systems, how the two systems relate to each other, and inspection requirements for regulated dams is shown in Figure 4.44.

Figure 4.44

Dam Hazard Classification Systems

Federal		State		
Classification	**Criterion**	**Classification**	**Downstream Environment**	**Inspection Requirement (Regulated Dams)**
High hazard	Probable loss of human life	Class 1	10 or more permanent dwellings; or any public building	Every 2 years
		Class 2	1-9 permanent dwellings; or 1 or more campgrounds with permanent water, sewer and electrical services; or one or more industrial buildings	Every 3 years
Significant hazard	No probable loss of human life but potential economic loss, environmental damage, disruption of lifeline facilities or other impact of concern	Class 3	Everything else	Every 5 years
Low hazard	No probable loss of human life; low economic and/or environmental loss; loss principally limited to owner's property			

Sources: Federal Guidelines for Dam Safety, Hazard Potential Classification System for Dams, April 2004, http://www.fema.gov/library/viewRecord.do?id=1830; http://www.sos.mo.gov/adrules/csr/current/10csr/10c22-2.pdf; Glenn Lloyd, Civil Engineer/Dam Safety Inspector, MO DNR, Water Resources Center, Dam Safety Program

Dam Regulation in Missouri

Pursuant to Chapter 236 of the Revised Statutes of Missouri, a dam must be 35 feet or higher to be state regulated; regulation makes a dam subject to permit and inspection requirements. For regulated dams, the state classification system dictates the required inspection cycle. According to the Association of State Dam Safety Officials, 5,206 dams in Missouri have been classified, and only 653 are regulated by the state.

The inspection cycle for regulated dams allows for a regulated dam's classification to be updated when appropriate. Classification is a dynamic system; development can easily change the situation downstream. A regulated dam in Missouri would have its classification appraised at least once every 5 years.

In addition, the DNR database of dams in Missouri reflects only the known dams; a dam less than 35 feet in height that was built since the inventory was taken over 30 years ago may not appear in the database.

There are currently 22 dams in Cooper County, according to the Department of Natural Resources database. Of these, only two are regulated by the state (see Figure 4.45).

Figure 4.45 **Hazard Categories of Cooper County Dams**

Hazard Category	Regulated Dams	Unregulated Dams	All County Dams	Percentage of Total Dams
High	0	2	2	9%
Significant	0	0	0	0%
Low	2	18	20	91%
Total	2	20	22	100%

Note that one of the unregulated high hazard dams is dry and thus not a threat at the present time.

One must use caution in assuming the classifications of non-regulated dams are currently accurate. It is very probable that, for most of the non-regulated dams, the classification does not take into account over 30 years of development and change in Cooper County.

Specific information for the 2 regulated dams and the 20 unregulated dams can be found in Figures 3.1.3 and 3.1.4. Again, it is important to note that, according to information from Missouri DNR, much of this data, perhaps most of it, for the unregulated dams has not been updated since the dam survey was first conducted in the late 1970s and early 1980s. The heights of the unregulated dams may be, in some cases, the only currently reliable information.

Location

The dams in the planning area are located in unincorporated Cooper County and Boonville (see Figure 4.46).

Dam failure is not an issue for Blackwater, Bunceton, Otterville, Pilot Grove, Prairie Home, Windsor Place, Wooldridge, Blackwater R-II Schools, Boonville R-I Schools, Cooper County R-IV Schools, Otterville R-VI Schools, Pilot Grove C-4 Schools, and Prairie Home R-V Schools. Even though the Boonville R-I School District is in Boonville where there are dams, the structures of these educational institutions are not within the estimated inundation areas of the dams.

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Figure 4.46

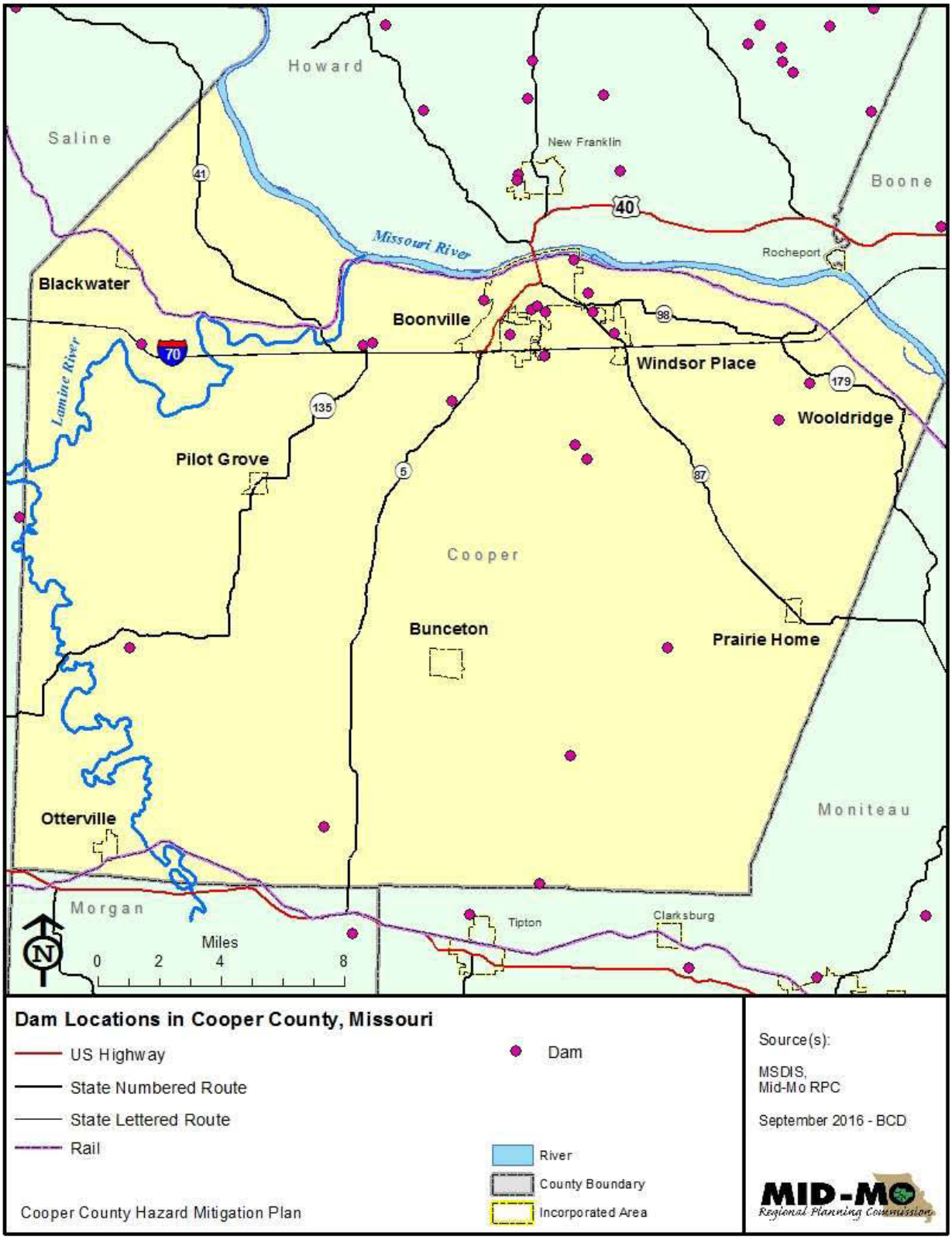
Howard
Saline
New Franklin
Boone
Missouri River
Rocheport
Blackwater
Boonville
Windsor Place
Wooldridge
Lamine River
Pilot Grove
Cooper
Bunceton
Prairie Home
Otterville
Moniteau
Morgan
Tipton
Clarksburg
Miles
0 2 4 8
Dam Locations in Cooper County, Missouri
US Highway
State Numbered Route
State Lettered Route
Rail
Dam
River
County Boundary
Incorporated Area
Cooper County Hazard Mitigation Plan
Source(s):
MSDIS,
Mid-Mo RPC
September 2016 - BCD
MID-MO
Regional Planning Commission

Figure 4.47

REGULATED Cooper County Dams									
Map ID #	Name	Year Built	Ht (feet)	Reservoir Area (Acres)	Drainage Area (Acres)	Latitude	Longitude	Federal Class	State Class
6	LAKE OF THE WOODS DAM	1968	39	28	328	38.9433516	-92.7600314	L	3
15	HAMMOND LAKE DAM	1985	48	9	34	38.745342	-92.724942	L	3
NON REGULATED Cooper County Dams									
12	BECKER-MILLER-MARCUM LAKE DAM	1974	25	5	60	38.6856804	-92.7434567	L	3
14	FENICAL LAKE DAM	1977	25	3	34	38.9391982	-92.9820874	L	3
19	FRIEDRICH LAKE DAM	1970	22	9	48	38.9123885	-92.7950688	H	2
5	HOLTZCLAW LAKE DAM	1961	34	9	30	38.938777	-92.8484423	L	3
20	LANGKOP LAKE DAM	1969	17	14	325	38.7121609	-92.8725471	L	3
11	LENZ LAKE DAM	1975	20	9	23	38.795856	-92.6663235	L	3
2	NORTHEAST DAM # 2	1970	25	3	60	38.956585	-92.7438654	L	3
13	PHILLIPS LAKE DAM	1976	30	5	15	38.7963794	-92.9895115	L	3
16	ROBINSON'S DAM	1959	20	5	33	38.9028635	-92.5988421	L	3
4	ROLFLING LAKE DAM SEC 6	1957	29	13	91	38.9628937	-92.7131784	L	3
3	ROLFLING LAKE DAM-SEC 36 (DRY)	1957	This lake is dry			38.9783333	-92.7213889		
22	SCHNUCK	1997	31	2	0	38.92	-92.58	L	
9	SCHNUCK LAKE DAM	1977	32	7	30	38.9439716	-92.6977937	L	3
21	SCHRADER LAKE DAM	1965	25	10	64	38.9397345	-92.8429927	L	3
10	SMITH LAKE DAM	1977	30	4	25	38.9539433	-92.7102226	L	3
1	SOUTHWEST DAM NUMBER 1	1969	21	2	30	38.9551489	-92.7471637	L	3
8	STOELTING DAM	1965	21	4	19	38.9537619	-92.7391235	L	3
7	TROUT DAM	1960	20	4	20	38.9595031	-92.7758811	L	3
0	WINDMILL CAMPGROUND DAM	1971	20	2	90	38.933468	-92.7394135	L	3
18	WINDSOR PLACE NUMBER 1	1951	22	6	62	38.8848699	-92.714099	L	3
17	WINDSOR PLACE NUMBER 2	1945	23	4	37	38.8912599	-92.7215193	L	3
Source: http://www.dnr.mo.gov/env/wrc/damsft/Crystal_Reports/cooper_dams.pdf									

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Figure 4.48 (reviewed by Beau Derque, September 2016)

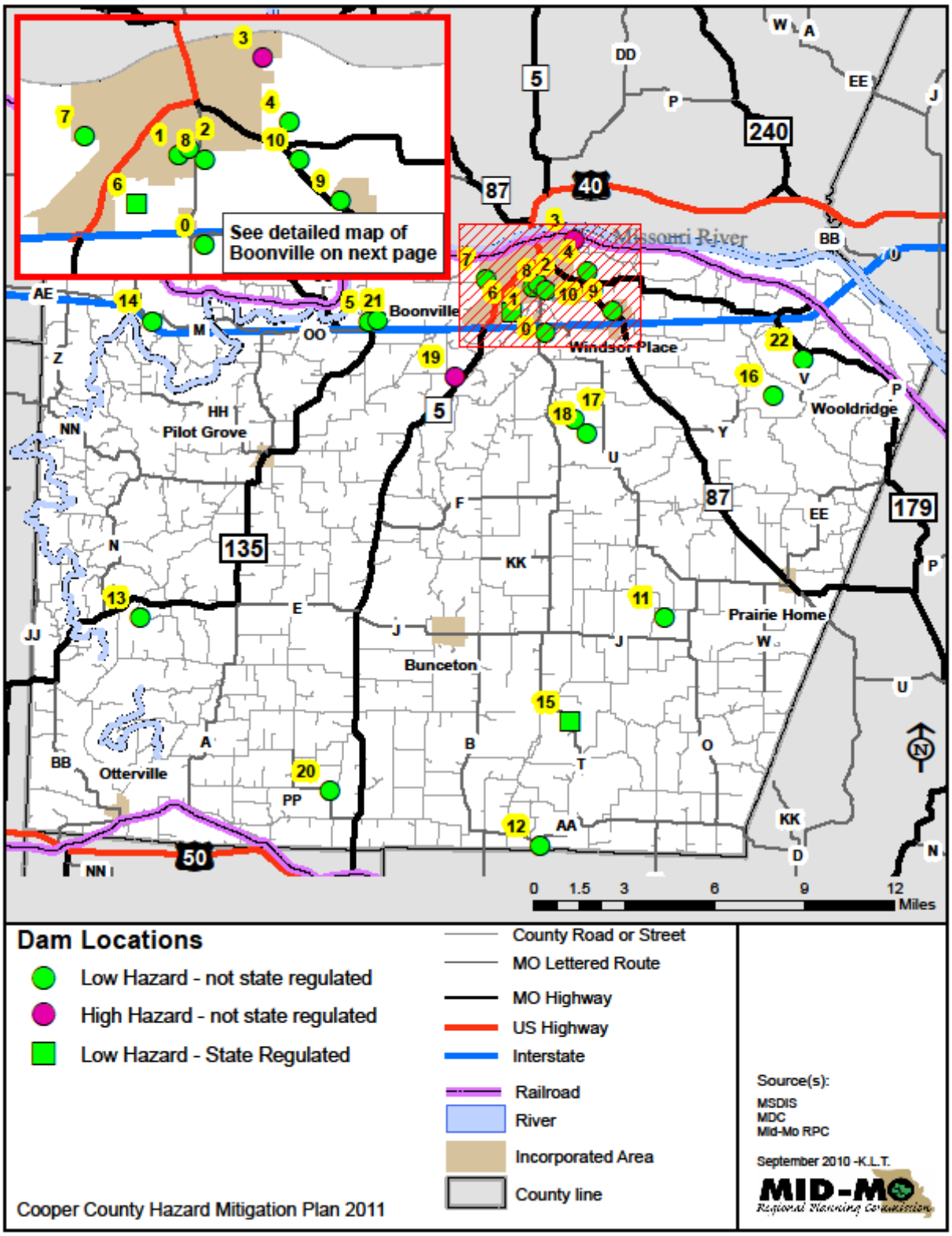
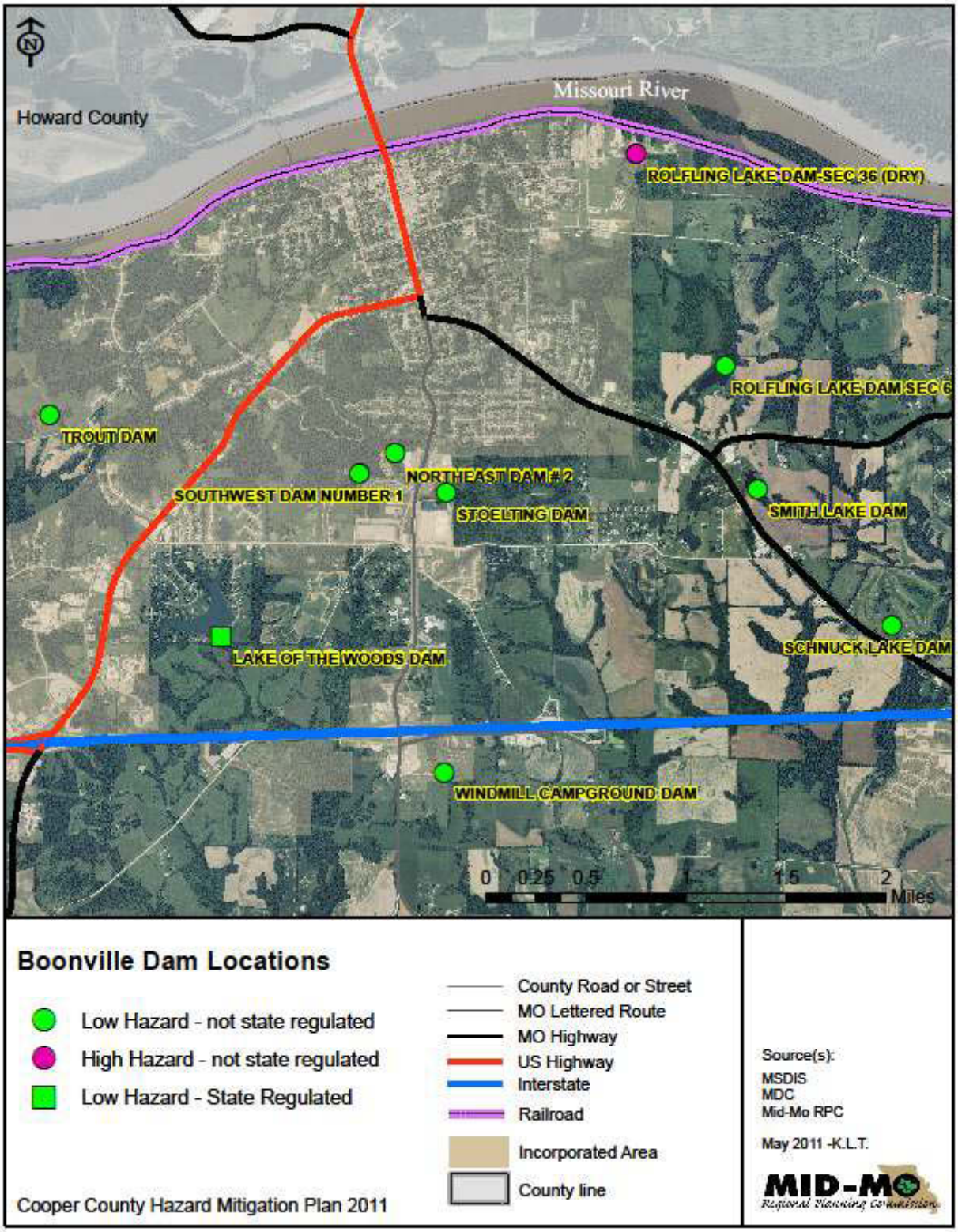


Figure 4.49 (reviewed by Beau Derque, September 2016)



Extent

The speed of onset of a dam failure can vary considerably. In most cases, regular inspections, either formal or informal, will promote a longer period of onset and allow for possible mitigation. Unfortunately, the current lack of required dam inspections increases the likelihood of dam conditions being ignored by owners, a situation that promotes a quicker speed of onset and an increased threat from the hazard.

The extent of hazard that a dam failure poses is also influenced by the reservoir size.

Previous Occurrences

While there have been no dam failures in Cooper County in recent history, the issue was highlighted in the mid-Missouri region by a dam failure in nearby Boone County in 2008 and a near failure in Cole County in 2009.

The Moon Valley Lake Dam in Columbia (Boone County) failed in March 2008. This 18-foot high unregulated dam had been built in 1964; it drained 2,100 acres and had a 13-acre reservoir, according to the DNR database. Moon Valley Lake Dam was classified as high hazard, but there was no loss of life with the dam failure. This may be partially attributable to the fact that Moon Valley Lake was silted in and the main release from the dam failure was silt, which went down the Hominy Branch into the Hinkson Creek. The added silt has caused greater flooding problems on the Hinkson Creek since the time of the dam failure. The City of Columbia estimated the cost of removing the sediment and stabilizing about 2,000 feet of the stream bank to be about $400,000.

Failure of the Renn's Lake Dam in Jefferson City (Cole County) was averted in late October and early November 2009 through the work of emergency crews and volunteers who relieved pressure on the earthen dam by pumping thousands of gallons of water from 7-acre Renn's Lake. The 30-foot high unregulated dam, built in 1950, had been weakened by the growth of trees; heavy rainfall caused a 15-foot section to erode. Renn's Lake is located immediately to the west of U.S. Highway 54, and the failure of the dam would have threatened the highway. The deed to Renn Lake was subsequently transferred to Cole County with plans to breach the dam and drain the lake.

Boone County and Cole County are not the only counties in Missouri to experience dam failures. According to the Missouri State Hazard Mitigation Plan (2007), Missouri has the largest number of manmade dams in any state. The Stanford University's National Performance of Dams Program documented 16 dam failures in Missouri between 1975 and 2001.

More recently, there was a huge dam failure that destroyed Johnson Shut-Ins State Park in Reynolds County. On December 14, 2005, AmerenUE's Taum Sauk Reservoir Dam at their hydroelectric complex failed; 1.5 billion gallons of water were released into the park in 10 minutes. There was no loss of life, even though the superintendent's family was swept out of their home. However, if this failure had occurred during the summer—a time when the popular park has many visitors—it could have resulted in a catastrophic loss of life.

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All of these dam failures indicated that this is a serious problem that needs attention. Many of Missouri's smaller dams are becoming a greater hazard as they continue to age and deteriorate. While hundreds of them need to be rehabilitated, a lack of available funding and questions of ownership loom as obstacles difficult to overcome.

Probability of Future Events

Probability: Low
Severity: Low

ANALYSIS OF RISK

A dam failure in Cooper County could range from very minimal environmental damage to a significant loss of life and infrastructure. All impacts are dependent upon several variables: water, debris, people, and structures.

There is one dam in Cooper County that is considered to pose high hazard should there be a dam break: Friedrich Lake Dam. This dam is privately owned and not regulated by the state and thus not subject to inspection requirements. Friedrich Lake Dam is located south of Boonville on State Highway 5.

State-regulated dams are classified by what lies downstream of the dam and what will be impacted by the failure of that dam. Non-regulated dams received their classifications nearly 30 years ago or more, and development that occurs downstream is not monitored by any agency; this potentially puts the public at risk. Also, development upstream that might increase the contents held by the dam can cause failure. Because there is no entity in charge of non-regulated dams, the original classifications for these dams may not be correct. Some dams may not exist anymore while others may pose a greater downstream threat than their classifications indicate.

Note that ratings for dam failure are based on estimates of homes that lie within a half mile downstream of a high hazard dam. Due to the current lack of inundation studies, dam failure estimates are not exact and may change when proper inundation data is collected. Again, inundation information is not available to accurately quantify vulnerability.

Potential Impact – Life

There is the very real danger of injury or loss of life with a dam failure event. This threat is recognized and built into the dam classification system.

Potential Impact - Existing Structures

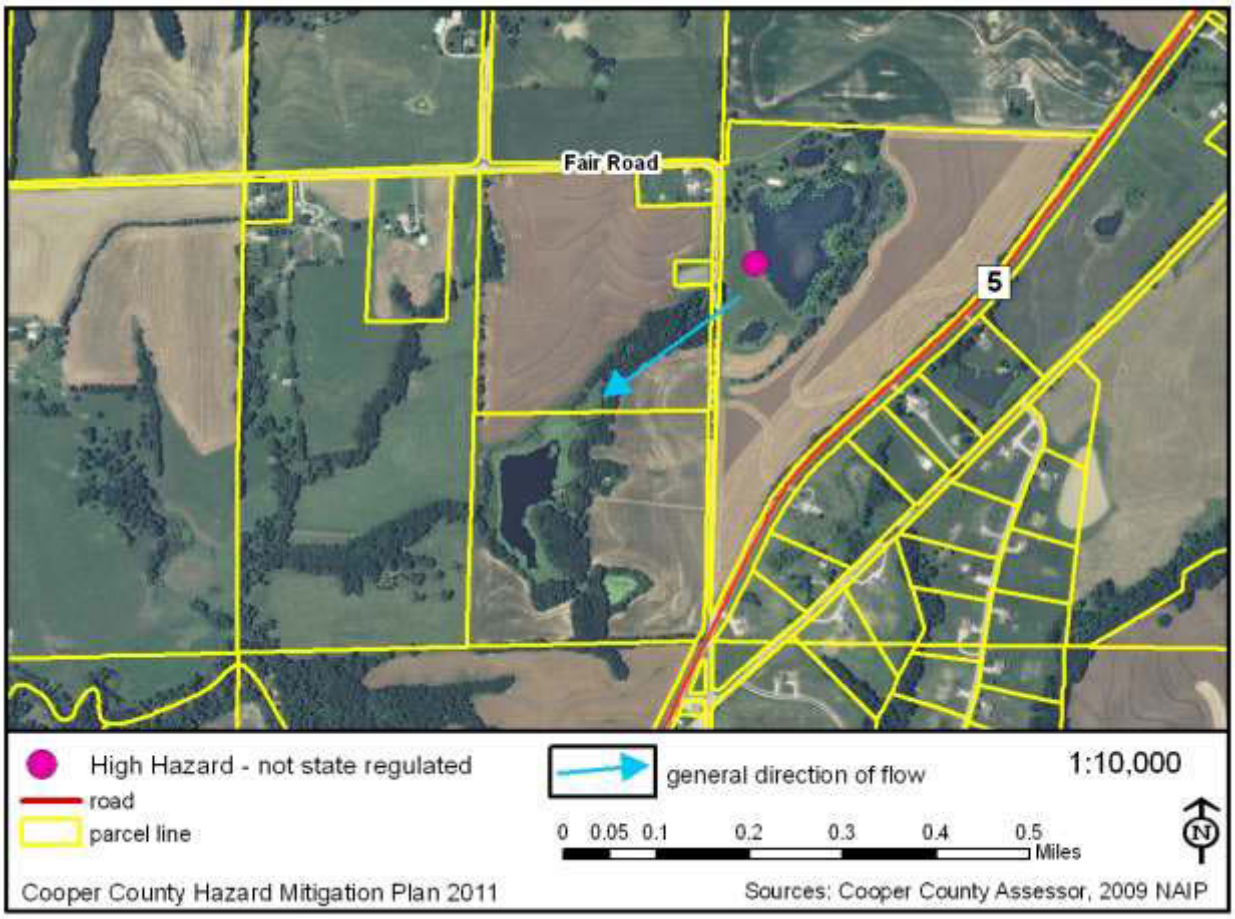
Boonville is the only jurisdiction, aside from unincorporated areas of Cooper County, to have dams inside or within a mile upstream of its corporate boundary. Structures downstream of these dam locations could potentially be at risk if a failure were to occur, depending on the size of the

reservoir behind the dam. Throughout the county, several other dams lie upstream of structures that have the potential of being impacted. The Missouri State Hazard Mitigation Plan 2010 states vulnerability statistics for *State Regulated* dam failure in Cooper County. According to the state plan there are no structures or populations vulnerable to the failure of a *State Regulated* dam.

The potential impact on structures and human life downstream from a dam failure directly correlates to the amount of water and debris that is behind the dam. As stated in the hazard profile, it is important to take into account the age of the data that has been compiled on state-regulated and unregulated dams in the county and in the state. Because data on unregulated dams was collected in the late 1970s and early 1980s, it is not necessarily reliable to use when looking at possible areas of impact.

Figure 4.50 depicts the downstream areas and parcels that are within a half mile of the dam. Because inundation information is not available at this time, it is not possible to know exactly the severity or distance of a dam failure.

Figure 4.50 (reviewed by Beau Derque, September 2016)



Impact - Future Development

Dam failure has the potential to impact future development in the county and its jurisdictions. Because many dams in Cooper County are privately owned and not regulated by the state, the potential for development below aging or unsafe dams is an issue that needs to be addressed. If development occurs without the knowledge of a problem dam that lies upstream, that development is put in jeopardy.

Future impacts may be addressed by inundation studies being done by the Natural Resources Conservation Service's Water Resources Center. The following is an excerpt from their website:

"The Water Resources Center has developed a methodology to complete dam breach inundation studies and produce inundation maps downstream of regulated dams. The Federal Emergency Management Agency (FEMA) has indicated that future funding of state dam safety programs will be linked to the completion of Emergency Action Plans (EAPs) for regulated dams. The WRC's Dam and Reservoir Safety program has prioritized Missouri counties for completion of mapping."

Existing Mitigation Strategies

State-regulated dams are inspected, according to classification, through the Dam Safety Program of the DNR. According to the Missouri DNR, dam owners with dams over 35 feet in height are required to complete an Emergency Action Plan (EAP). The Dam and Reservoir Safety Program coordinates with dam owners, county Emergency Management Directors, and other state and federal agencies to develop plans for all regulated dams. An EAP must include the following criteria:

•Guidance for evaluating emergency situations occurring at a dam.

•Notification charts and emergency contact information.

•A list of residents, businesses, and entities within the downstream inundation zone.

•A list of resources available for responding to a dam emergency.

•An inundation zone map (estimated boundary of the maximum water elevation resulting from a dam breach).

•Basic physical and geographical data for the regulated dam.

The Cooper County emergency management director can provide critical emergency contact information and assistance in identifying structures located within the downstream inundation area.

As of August 2011, Emergency Management Agencies in each county will keep a copy of an owner's EAP for high hazard dams. A template for creating an EAP is available through the Missouri DNR Dam Safety website.

SUMMARY OF VULNERABILITY

There are no dams lying upstream from any school district structures.

Most of the dams in the planning area are located in unincorporated Cooper County. The results of a dam failure could range from very minimal environmental damage to a significant loss of life and infrastructure. All impacts are dependent upon several variables: water, debris, people, and structures. A dam failure would include the breach of a dam wall or embankment allowing the water and debris to flow downstream from the dam.

The dam inventory for the state of Missouri was compiled in the late 1970s and early 1980s. The state has classified two of Cooper County's dams as "High Hazard". One of those High Hazard dams no longer holds water and does not pose a threat. Both High Hazard dams are unregulated. According to data provided by the Missouri Department of Natural Resources, none of the 20 unregulated dams have ever been documented as having been inspected. Because these are unregulated dams, the state has no jurisdiction over maintenance and leads into the overall problem of dam location and development downstream.

State-regulated dams are classified by what lies downstream of the dam and what will be impacted by the failure of that dam. Unregulated dams received their classifications nearly 30 years ago or more and development that occurs downstream is not monitored by any agency; this potentially puts the public at risk. Also, development upstream that might increase the contents held by the dam can cause failure. Because there is no entity in charge of unregulated dams, the original classifications for these dams may not be correct. Some dams may not exist anymore while others may pose a greater downstream threat than their classifications indicate.

4.7 EXTREME HEAT

DESCRIPTION OF HAZARD

Extreme heat is the number one weather-related killer in the United States, according to the National Weather Service (Figure 4.54). In contrast to the visible, destructive, and violent nature of floods, hurricanes, and tornadoes, extreme heat is a silent killer.

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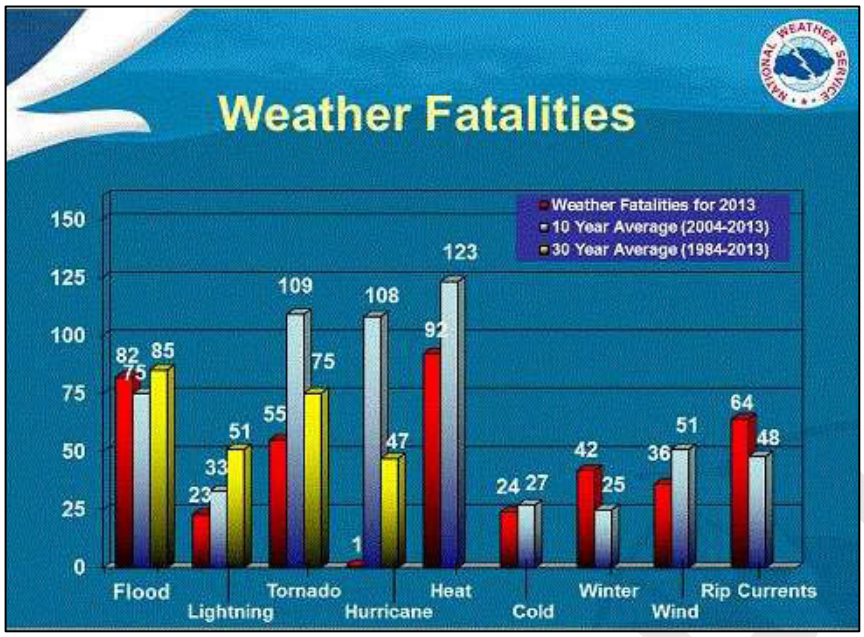
Figure 4.54



As can be seen in the NWS graph, there are no 30-year averages for heat fatalities or a number of other weather-related fatalities. Fatality data on these hazards began to be recorded more recently than fatalities from the more dramatic causes of death such as flood, lightning, tornado, and hurricane.

As the data shows, extreme heat resulted in an average of 92 deaths per year when looked at over a 10-year period; this is 10 more deaths per year than the number caused by flood, the next most frequent cause of death.

Location

The entire planning area is at risk from extreme heat events.

Extent

The planning area routinely experiences prolonged periods with heat indices over 100 (Figure 4.55). The duration of these periods of extreme heat can last two weeks. During the period from 1994 through June 2016, the average length of an extreme heat event was 5.8 days.

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Previous Occurrences

Figure 4.55

Periods of Extreme Heat in Cooper County, 1994-June 2016

Date	Heat Index	Deaths	Injuries	Property Damage	Crop Damage	Duration (days)
06/12/94	100+	4	55	0	50K	12
07/18/99	100-115	22	0	0	0	14
08/28/00	105-110	0	0	0	0	4
09/01/00	100+	3	0	0	0	3
07/06/01	115	2	0	0	0	3
07/17/01	NA	2	0	0	0	8
08/01/01	105-113	4	0	0	0	5
08/09/01	105-110	1	0	0	0	1
07/04/03	105	1	0	0	0	2
07/21/05	105-110	0	0	0	0	5
07/16/06	105-115	4	0	0	0	5
07/29/06	105-115	0	0	0	0	3
08/01/06	105-115	2	0	0	0	2
08/06/07	105-115	0	0	0	0	12
07/18/12	100-110	0	0	0	0	8
TOTALS		45	55	0	50K	

Source: https://www.ncdc.noaa.gov/stormevents/

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ANALYSIS OF RISK

Measure of Probability and Severity - Moderate for all participating jurisdictions

Potential Impact – Life

Heat kills by overloading a body's capacity to cool itself. The human body cools itself by perspiring; the evaporation of perspiration carries excess heat from the body. High humidity often accompanies heat in Missouri and increases the danger to warm-blooded humans and animals. High humidity makes it difficult for perspiration to evaporate and thus interferes with this natural cooling mechanism.

The Heat Index devised by the NWS (Figure 4.56) is a measure of how hot it really feels. The Heat Index takes into account both air temperature and relative humidity. It also gives an indication of the added risk presented by high humidity to bodies attempting to cool.

Figure 4.56

HEAT INDEX

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

Source: http://www.nws.noaa.gov/om/heat/index.shtml

Since 2007, there have been 46 deaths and over 2,877 injuries in Missouri from extreme heat events. The recorded deaths and injuries occurred in St. Louis and St. Louis County; none of the deaths recorded in the data occurred in the planning area.

While these most recent deaths and injuries took place in a major metropolitan area, research shows that residents of both urban and rural areas are vulnerable to excessive heat. Data from the Missouri Department of Health and Senior Services (DHSS) indicates that 39 percent of the 214 deaths in the state from extreme heat in the years 2000 through 2009 occurred outside of the counties of the two major metropolitan areas (Kansas City and St. Louis). This percentage

correlates fairly closely with the percentage of the population residing outside those metropolitan areas, according to the 2010 U.S. Census. It cannot be said that extreme heat is a concern only for major cities.

Many factors, such as age, general level of health, outdoor activity level, alcohol and drug consumption, and availability of air conditioning, affect the actual risk level. The elderly in general are vulnerable to the effects of extreme and/or prolonged heat; the 2010 Census recorded 2,702 citizens in Cooper County (15.3 percent of the population) as 65 years and older. However, any residents without access to air conditioning, or shade and water if outside, are very vulnerable to this hazard. One known death occurred in Boone County, the county just east of the planning area, in August 2002 when a 59-year-old man died from heat exhaustion after collapsing while doing yard work.

Extreme heat events can also result in livestock deaths and fish kills. Drought in conjunction with extreme heat exacerbates the situation.

Potential Impact - Existing Structures

While illness and loss of life are of the most concern with extreme heat, structural impacts may also occur. Structural impacts depend on the length of the period of extreme heat and exacerbating factors such as concurrent drought. Road damage and electrical infrastructure damage may occur with intense and prolonged heat.

Potential Impact - Future Development

Thoughtful future development has the potential to include mitigation for extreme heat in its design. This is true on all levels ranging from actions by individual homeowners to larger redevelopment projects planned by cities. Properly placed shade trees can contribute greatly to lowering inside temperatures and the load placed on cooling systems. Planning for adequate green space as cities infill allows for air movement and shaded locations.

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Existing Mitigation Activities

The following departments, agencies, and organizations are involved in educating the public about the dangers of extremely hot weather and/or issuing alerts when the threat of extreme heat is imminent.

Cooper County Emergency Management and the Cooper County Health Department issue alerts to notify the public of extreme heat conditions. The alerts urge the public to check on their neighbors and to seek cooling in local shopping centers or library, if needed.

Local Media such as television and radio stations issue heat advisories during extreme heat events.

The Missouri Department of Health and Senior Services announces statewide hot weather health alerts according to the following criteria:

- **Hot Weather Health Alert** – Heat indices of 105°F in a large portion of the state are first reached (or predicted).

- **Hot Weather Health Warning** – Heat indices have been 105°F or more for two days in a large portion of the state, or weather forecasts call for continued heat stress conditions for at least 24 to 48 hours over a large portion of the state.

- **Hot Weather Health Emergency** – When extensive areas of the state meet all of the following criteria:
  - High sustained level of heat stress (Heat Index of 105°F for 3 days)
  - Increased numbers of heat-related illnesses and deaths statewide
  - The NWS predicts hot, humid temperatures for the next several days for a large portion of the state.

The National Weather Service (NWS) has devised a method to warn of advancing heat waves up to seven days in advance. The new Mean Heat Index is a measure of how hot the temperatures actually feel to a person over the course of a full 24 hours. It differs from the traditional Heat Index in that it is an average of the Heat Index from the hottest and coldest times of each day.

The National Weather Service initiates alert procedures when the Heat Index is expected to exceed 105°- 110°F for at least two consecutive days. (The exact Heat Index temperature used depends on specifics of the local climate.) The following are released to the media and over NOAA All-Hazard Weather Radio:

- Heat Index values are included in zone and city forecasts.
- Special Weather Statements and/or Public Information Statements are issued; they present a detailed discussion of the Heat Index Values, who is most at risk, and safety rules for reducing risk.
- In severe heat waves, State and local health officials are assisted in preparing Civil Emergency Messages, which include Special Weather Statements and more detailed medical information, advice, and names and telephone numbers of health officials.

The Missouri Department of Health and Human Services also maintains a searchable online map/database of cooling centers throughout the state (https://ogi.oa.mo.gov/DHSS/coolingCenter/index.html).

As of October 2016, the following cooling centers are listed for Cooper County:

- Boonslick Senior Center, 512 Jackson Road, Boonville
- Boonville Library, 618 Main Street, Boonville

The Missouri State High School Activities Association (MSHSAA) provides coaches with educational pamphlets on the dangers of excessive heat.

Weather Forecast Offices of the National Weather Service (NWS) can issue the following warnings about excessive heat:

- **Excessive Heat Outlook**: Potential exists for an excessive heat event in the next 3 to 7 days. An outlook is used to indicate that a heat event may develop. It is intended to provide information to those who need considerable lead time to prepare for the event, such as public utilities, emergency management, and public health officials.

- **Excessive Heat Watch**: Conditions are favorable for an excessive heat event in the next 12 to 48 hours. A watch is used when the risk of a heat wave has increased, but its occurrence and timing is still uncertain. It is intended to provide enough lead time so those who need to set their plans in motion can do so, such as established individual city excessive heat event mitigation plans.

- **Excessive Heat Warning/Advisory**: An excessive heat event is expected in the next 36 hours. The warning is used for conditions posing a threat to life or property. An advisory is for less serious conditions that cause significant discomfort or inconvenience and, if caution is not taken, could lead to a threat to life and/or property.

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SUMMARY OF VULNERABILITY

All jurisdictions are vulnerable to the effects of extreme heat. Extreme heat is already responsible for more weather-related deaths than any other hazard in the country; it is also one of the hazards shown to be increasing with changes in the climate.

Heat stroke and loss of life are the most significant consequences of extreme heat. While heat-related illness and death can occur due to exposure to intense heat in just one afternoon, heat stress on the body has a cumulative effect. The persistence of a heat wave increases the danger.

The elderly in general are vulnerable to the effects of extreme and/or prolonged heat; the 2010 Census recorded 2,702 citizens in Cooper County (15.3 percent of the population) as 65 years and older. However, any residents without access to air conditioning, or shade and water if outside, are very vulnerable to this hazard.

Boonville, the major population center in the planning area, is equipped with cooling centers to help protect those most vulnerable. Warnings regarding the dangers of extreme heat are widely broadcast during times of threat.

In addition to the human toll, prolonged extreme heat can result in livestock deaths, fish kills, and infrastructure damage; drought in conjunction with extreme heat exacerbates the situation.

4.8 DROUGHT

DESCRIPTION OF HAZARD

The National Weather Service defines a drought as "a period of abnormally dry weather that persists long enough to produce a serious hydrologic imbalance (for example, crop damage, water supply shortage, etc.). The severity of the drought depends upon the degree of moisture deficiency and the duration and the size of the affected area."

Droughts occur either through a lack of precipitation (supply droughts) or through overuse of water, which outpaces what the surrounding environment can naturally support (water use droughts). Water use droughts can theoretically happen anywhere but are generally seen in arid climates, not humid places such as Missouri. At the present time, Missouri is most vulnerable to supply droughts brought on by a lack of precipitation.

The period of lack of precipitation needed to produce a supply drought will vary between regions, and the particular manifestations of a drought are influenced by many factors. As an aid to analysis and discussion, the research literature has defined different categories of drought (Figure 4.57). The most common type of drought in Mid-Missouri is the agricultural drought.

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Figure 4.57 **Drought Categories**	
Agricultural	Defined by soil moisture deficiencies
Hydrological	Defined by declining surface and groundwater supplies
Meteorological	Defined by precipitation deficiencies
Hydrological and land use	Defined as meteorological drought in one area that has hydrological impacts in another area
Socioeconomic	Defined as drought impacting supply and demand of some economic commodity
Source: *Missouri Drought Plan, 2002* (Mo DNR)	

Location

The entire planning area is potentially at risk for drought. However, since agricultural drought is most common in Missouri, the unincorporated agricultural areas of Cooper County are most at risk. This is the area where farmers are at risk for crop failure from drought and would suffer the most immediate and severe economic loss.

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Extent

Numerous indices have been developed to measure drought severity; each tool has its strengths and weaknesses.

Palmer Drought Severity Index: One of the oldest and most widely used indices is the Palmer Drought Severity Index (PDSI, Figure 4.58), which is published jointly by NOAA and the U.S. Department of Agriculture (USDA).

Figure 4.58

Palmer Drought Severity Index (PDSI)

Score	Description	Score	Description
Greater than 4	Extreme moist spell	0 to -0.4	Near normal conditions
3.0 to 3.9	Very moist spell	-0.5 to -0.9	Incipient drought
2.0 to 2.9	Unusual moist spell	-1.0 to -1.9	Mild drought
1.0 to 1.9	Moist spell	-2.0 to -2.9	Moderate drought
0.5 to 0.9	Incipient moist spell	-3.0 to -3.9	Severe drought
0.4 to 0	Near normal conditions	**Below -4.0**	Extreme drought

According to the National Integrated Drought Information System (NIDIS), the PDSI "uses temperature and precipitation data to calculate water supply and demand, incorporates soil moisture, and is considered most effective for unirrigated cropland. It primarily reflects long-term drought and has been used extensively to initiate drought relief."

Missouri is divided into six regions of similar climactic conditions for PDSI reporting; Cooper County is located in the West Central Region.

Standardized Precipitation Index: A newer index currently being used by The National Drought Mitigation Center (NDMC) is the Standardized Precipitation Index (SPI). This index is based on the probability of precipitation; the time scale used in the probability estimates can be varied and makes the tool very flexible. The SPI is able to identify emerging droughts months sooner than is possible with the PDSI.

The NDMC uses the PDSI, SPI, and three other indicators to classify the severity of droughts throughout the country on a 5-point scale ranging from DO Abnormally Dry to D4 Exceptional Drought for reports on the U.S. Drought Monitor (Figure 4.59).

Figure 4.59

U.S. Drought Monitor - Drought Severity Classification

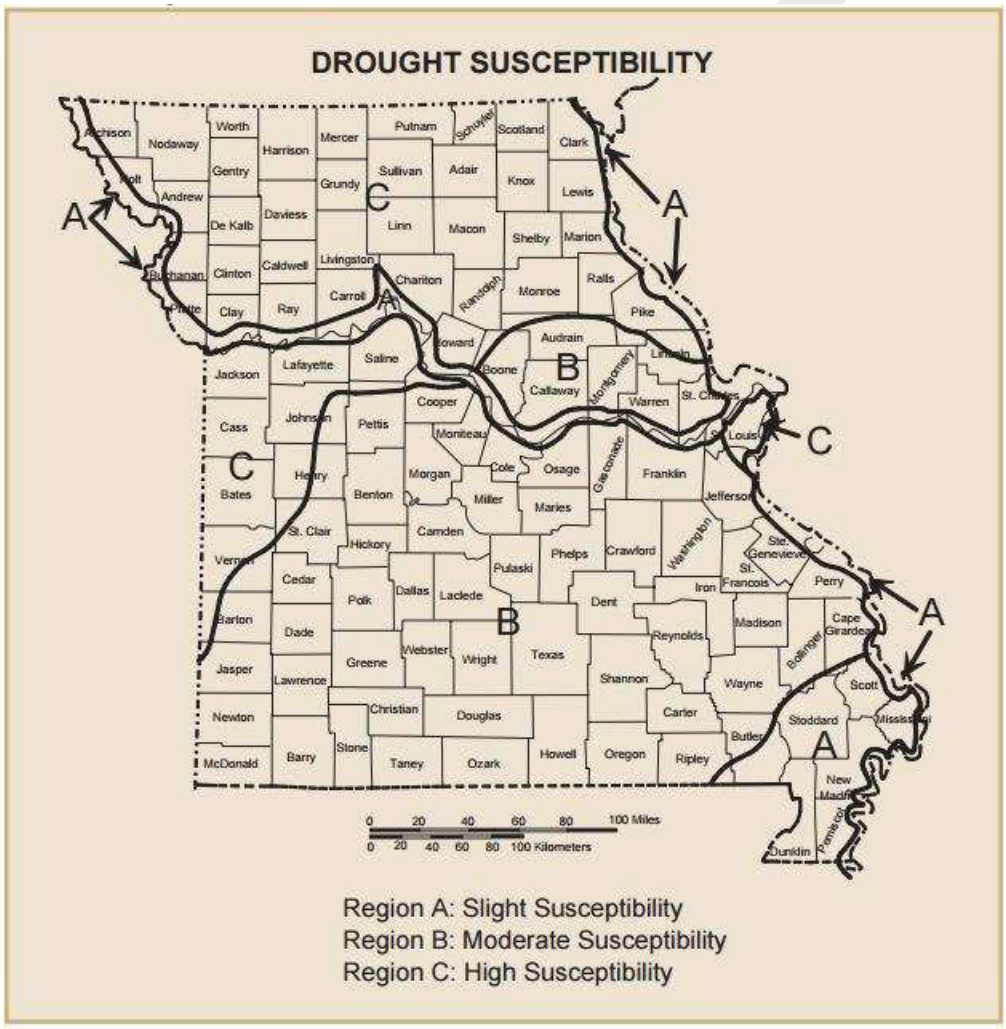
Category	Description	Ranges					
		Possible Impacts	Palmer Drought Index	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Short and Long-term Drought Indicator Blends (Percentiles)
D0	**Abnormally Dry**	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered	-1.0 to -1.9	21-30	21-30	-0.5 to -0.7	21-30
D1	**Moderate Drought**	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested	-2.0 to -2.9	11-20	11-20	-0.8 to -1.2	11-20
D2	**Severe Drought**	Crop or pasture losses likely; water shortages common; water restrictions imposed	-3.0 to -3.9	6-10	6-10	-1.3 to -1.5	6-10
D3	**Extreme Drought**	Major crop/pasture losses; widespread water shortages or restrictions	**-4.0 to -4.9**	**3-5**	**3-5**	**-1.6 to -1.9**	**3-5**
D4	**Exceptional Drought**	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies	**-5.0 or less**	**0-2**	**0-2**	**-2.0 or less**	**0-2**

Source: http://droughtmonitor.unl.edu

Based on the Drought Severity Classification from the NDMC, Cooper County is subject to droughts ranging from D1 (Moderate Drought) to D4 (Exceptional Drought). The most common droughts are in the D1-D2 range. The 2000-2015 data indicates that, in recent years, the average drought in the planning area has lasted 3.4 months.

The Missouri Department of Natural Resources has defined different regions of drought susceptibility in the *Missouri Drought Plan, 2002* (Figure 4.60).

Figure 4.60



Cooper County is primarily in Region B (moderate drought susceptibility) with a northwestern part of the county in Region C (severe drought vulnerability) and a northern strip bordering the Missouri River in Region A (slight drought susceptibility).

More specific information for all three regions is shown in Figure 4.61.

Figure 4.61 **Missouri Drought Susceptibility Regions**		
Region	**Description**	**Location in planning area**
A	"…minor surface and groundwater supply drought susceptibility. It is a region underlain by saturated sands and gravels (alluvial deposits). Surface and groundwater resources are generally adequate for domestic, municipal, and agricultural needs."	Northern area bordering the Missouri River
B	"…moderate drought susceptibility. Groundwater resources are adequate to meet domestic and municipal water needs, but due to required well depths, irrigation wells are very expensive. The topography generally is unsuitable for row-crop irrigation."	Majority of the planning area
C	"…severe drought vulnerability. Surface water resources usually become inadequate during extended drought. Groundwater resources are normally poor, and typically supply enough water only for domestic needs. Irrigation is generally not feasible. When irrigation is practical, groundwater withdrawal may affect other uses. Surface water sources are used to supplement irrigation supplied by groundwater sources."	Northwest part
Source: *Missouri Drought Plan, 2002*		

Previous Occurrences

The Dust Bowl years of the 1930s and early 1940s were dry in Missouri but not as dry as the period from 1953 through 1957. A major nationwide drought in the late 1980s resulted in low water and decreased barge traffic on the Mississippi River and the Missouri River. The fall of 1999 was another serious drought period in the state; in October of that year, all counties in Missouri were declared agricultural disaster areas by the USDA.

The drought that affected the entire state in the summer of 2012 was the worst drought in 30 years, according to the *MO State Hazard Mitigation Plan (2013)*. The planning area and the surrounding region suffered agricultural losses.

Even though Cooper County averages between 38 to 42 inches of precipitation per year, it has been subject to droughts in the past. Between 1999 and 2008, Cooper County had $12,028,047 in Total Crop Insurance Payments for drought damage.

Historical information concerning droughts prior to the 20th century is difficult to find. However, tree-ring research at the University of Missouri, chronicling the years 1912 to 2004, indicates a regular 18.6-year cycle of drought in the Midwest.

More information is available for droughts in the 20th and current centuries. Missouri suffered drought in the 1930s and the early 1940s, along with most of the central United States. These were the Dust Bowl years in the southern plains.

The years from 1953 through 1957 were actually drier years in Missouri than the Dust Bowl years. Missouri was specifically hit in 1954 and 1956 by an extreme decrease in precipitation. Crop yields were down by as much as 50 percent, leading to negative impacts on the agricultural and regional economies of the region.

The last major nationwide drought was in the late 1980s. The 1980s drought hit the Northern Great Plains and Northern Midwest particularly hard. Missouri suffered economic losses due to decreased barge traffic and low water in the Missouri River and the Mississippi River. Furthermore, some municipalities suffered from very low water resources and in some instances exhausted all of their normal water sources, according to the Missouri Hazard Analysis (SEMA, August 1997).

Most of Missouri was in a drought condition during the last half of 1999, according to the Missouri State Hazard Mitigation Plan (2010). In September, the governor declared an agricultural emergency for the entire state. In October, all counties were declared agricultural disaster areas by the U.S. Secretary of Agriculture. By May of 2000, the entire state was under a Phase 2 Drought Alert. The drought continued through the summer of 2000 in various parts of the state.

Another drought hit western and northwestern Missouri in the years 2002 to 2004; Cooper County was on the eastern edge of the serious drought but was put in a Phase 1 Drought Advisory in the summer of 2003.

The county did not fare as well in the drought years of 2005 and 2006, however. The droughts of 2005 and 2006 caused great hardship for many crop and livestock producers in the state. Cooper County was one of 30 Missouri counties in Phase 3 Conservation in July 2005. In August, all 114 Missouri counties and the City of St. Louis were designated as natural disasters for physical and/or production loss loan assistance from the Farm Service Agency (FSA); conditions began to improve in late August/September 2005. By September of 2006, however, the county was again in Phase 3 Conservation, which persisted through most of November. In October, Cooper County was one of 85 Missouri counties designated by the USDA as primary natural disaster areas due to losses from the drought conditions of 2006. Conditions began to improve with a large snowstorm in late November/early December.

Cooper County was in a Phase 1 Drought Advisory in both February and October of 2007.

Drought Vulnerability in Cooper County

Overview

All jurisdictions in the planning area are vulnerable to the effects of drought; the unincorporated agricultural areas of Cooper County are most vulnerable to the effects of drought because of crop loss. In addition to damage to crops, produce, livestock, and soil, and the resulting economic consequences, the arid conditions created by drought pose an increased risk of fire.

Potential Impact on Existing Structures

Excessive drought can cause damage to roads, streets, water mains, and building foundations. The arid conditions created by drought also pose an increased risk of fire and wildfire and thus to structures.

Drought can also have far reaching economic consequences beyond the agricultural sector; businesses dependent upon that sector can suffer serious losses. A severe drought can affect the economics of an entire region.

Structural impact in regard to this hazard is minimal to non-existent. Drought does, however, have far reaching economic consequences in regard to crop failure and high economic loss. The economic loss incurred would heavily impact the agricultural industry and those businesses dependent upon that industry for products. The following damage information is from the Missouri State Hazard Mitigation Plan 2013:

Figure 3.2.4 **Drought Damage in Cooper County, Missouri**	
Total Crop Insurance Paid For Drought Damage 1998-2012	$39,925,217
Crop Claims Ratio Rating	4
Annualized Crop Insurance Claims/Drought Damage	$2,661,681
Crop Exposure (2007 Census of Agriculture)	$42,447,000
Annual Crop Claims Ratio	6.27%
Crop Loss Ratio Rating	4
Missouri State Hazard Mitigation Plan (2013)	

Potential Impact on Future Development

Future development in the county can be at risk from the effects of drought. Good land management techniques are crucial in mitigating future impacts.

Drought is primarily an issue of water supply for the rural and agricultural parts of the planning area. The majority of the land in Cooper County is agricultural, and agriculture plays an important role in the life and economy of the area. This makes drought mitigation an especially important concern as population increases. Good land management techniques are crucial in mitigating future impacts. Good land management techniques and the interconnection of water supplies will become increasingly important in mitigating the impacts of drought as growth occurs.

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ANALYSIS OF RISK

Probability and Severity: Low

The primary effect of drought in the planning area is on the economic livelihood of those in the agricultural sector. According to the *2012 US Census of Agriculture*, 85 percent of Cooper County land use is tied to farming activities. In 2012 the market value of Cooper County farm products was estimated at almost $78.3 million.

Potential Impact – Life

Both crops and livestock are at risk from drought. During the exceptional drought conditions in 2012, there were large sell-offs of livestock in the mid-Missouri region.

The psychological and economic stresses involved for those working directly in the agricultural sector can be great in times of drought. Uncertainty, high stress, and fear are not compatible with optimal health.

Existing Mitigation Activities

The Missouri Department of Natural Resources publishes a weekly map from The Drought Monitor on their website at http://www.dnr.mo.gov/env/wrc/drought/nationalcondition.htm. The Drought Monitor is a comprehensive drought monitoring effort involving numerous federal agencies, state climatologists, and the National Drought Mitigation Center. It is located at the National Drought Mitigation Center in Lincoln, Nebraska. The new Drought Monitor Map, based on analysis of data collected, is released weekly on Thursday at 8:30 a.m. Eastern Time. The map focuses on broad-scale conditions and is linked to the data sets analyzed.

The University of Missouri Extension has a number of publications for both farmers and homeowners to help mitigate the effects of drought. The publications are available at http://extension.missouri.edu/main/DisplayCategory.aspx?C=257

The National Drought Mitigation Center (NDMC) is located at the University of Nebraska-Lincoln. The following is a description of their activities from their website (http://drought.unl.edu/):

"The National Drought Mitigation Center (NDMC) helps people and institutions develop and implement measures to reduce societal vulnerability to drought, stressing preparedness and risk management rather than crisis management. Most of the NDMC's services are directed to state, federal, regional, and tribal governments that are involved in drought and water supply planning. The NDMC, established in 1995, is based in the School of Natural Resources at the University of Nebraska-Lincoln. The NDMC's activities include maintaining an information clearinghouse and drought portal; drought monitoring, including participation in the preparation of the U.S. Drought Monitor and maintenance of the web site (drought.unl.edu/dm); drought planning and mitigation; drought policy; advising policy makers; collaborative research; K-12 outreach; workshops for federal, state, and foreign governments and international organizations; organizing and conducting seminars, workshops, and conferences; and providing data to and answering questions for the media and the general public. The NDMC is also participating in

numerous international projects, including the establishment of regional drought preparedness networks in collaboration with the United Nations' Secretariat for the International Strategy for Disaster Reduction."

SUMMARY OF VULNERABILITY

Drought of some degree is a common occurrence in the planning area. The unincorporated agricultural areas of Cooper County are the most vulnerable, but all jurisdictions are potentially vulnerable to cascading economic effects during extended and serious drought conditions. In addition to damage to crops, produce, livestock, soil and the resulting economic consequences, the arid conditions created by drought pose an increased risk of fire. There is also the risk of damage to infrastructure from drought.

Drought conditions are carefully monitored at the state and national levels; state law requires the Missouri Department of Natural Resources to implement a drought response system to ensure the quantity and quality of available water resources.

The Missouri Rural Water Association can assist with backup generators when needed and available.

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4.9 WILDFIRE

DESCRIPTION OF HAZARD

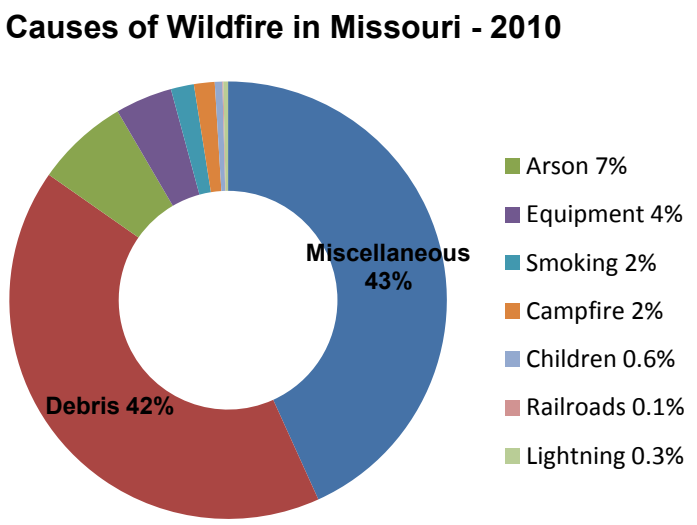
Large and widespread wildfires, such as occur in the western United States, have not been a problem in Cooper County in recent history. However, smaller wildfires/natural cover fires occur every year. In Cooper County, the majority of the fires and the greatest acreage loss occur during the spring fire season (February 15 through May 10).

These fires may take place at any time of the year, but the majority occur during the spring fire season (February 15 through May 10). Spring is the time of the year when rural residents burn garden spots and brush piles. Many landowners also believe it is necessary to burn the woods in the spring to grow more grass, kill ticks, and get rid of brush. These factors, combined with low humidity and high winds, result in higher fire danger at this time of year. The spring fire season abates with the growth of the new season's grasses and other green vegetation.

Numerous fires also occur in October and November due to the dryness associated with fall in Missouri. Many rural residents use this time of year to burn leaves and debris, thus raising the possibility of a fire that might burn out of control.

The major causes of wildfires in Missouri are various human activities, according to statistics from the Missouri Department of Conservation (Figure 4.65).

Figure 4.65



Source:http://mdc.mo.gov/landwater-care/fire-management/wildfires/missouri-fire-statistics

Location

The rural areas of Cooper County and the rural/urban interfaces are most at risk from wildfires. Debris burning is consistently the number one cause of wildfires in Missouri. Fires caused by lightning are rare despite 50 to 70 thunderstorm days per year.

Representatives of the Cooper County Fire Department reported that the annual burning of agricultural fields is also a major contributor to wildfires.

The Wildland Urban Interface (WUI) is defined as "the area where structures and other human development meet or intermingle with undeveloped wildland" in a 2001 Federal Register report. There is a higher risk scenario for wildfire in these areas where high fuel loads and structures meet or overlap.

A Wildland Urban Interface (WUI) map (Figure 4.66) does not depict any high risk areas due to the lack of heavy forested areas and intense farming practices. A map of agricultural land throughout the county will be used to highlight those areas that have been classified as being the highest risk areas (see Figure 4.67).

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Figure 4.66

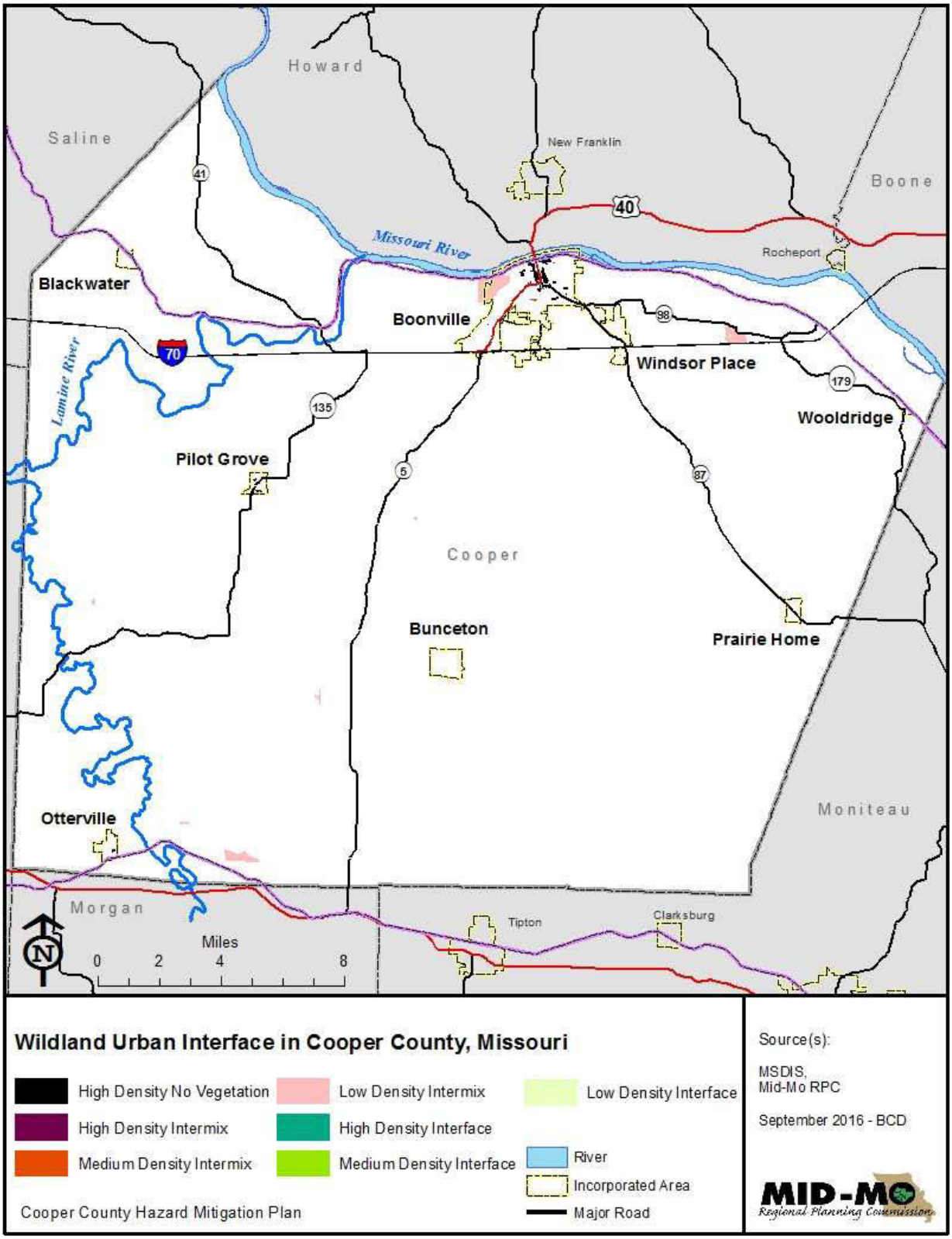
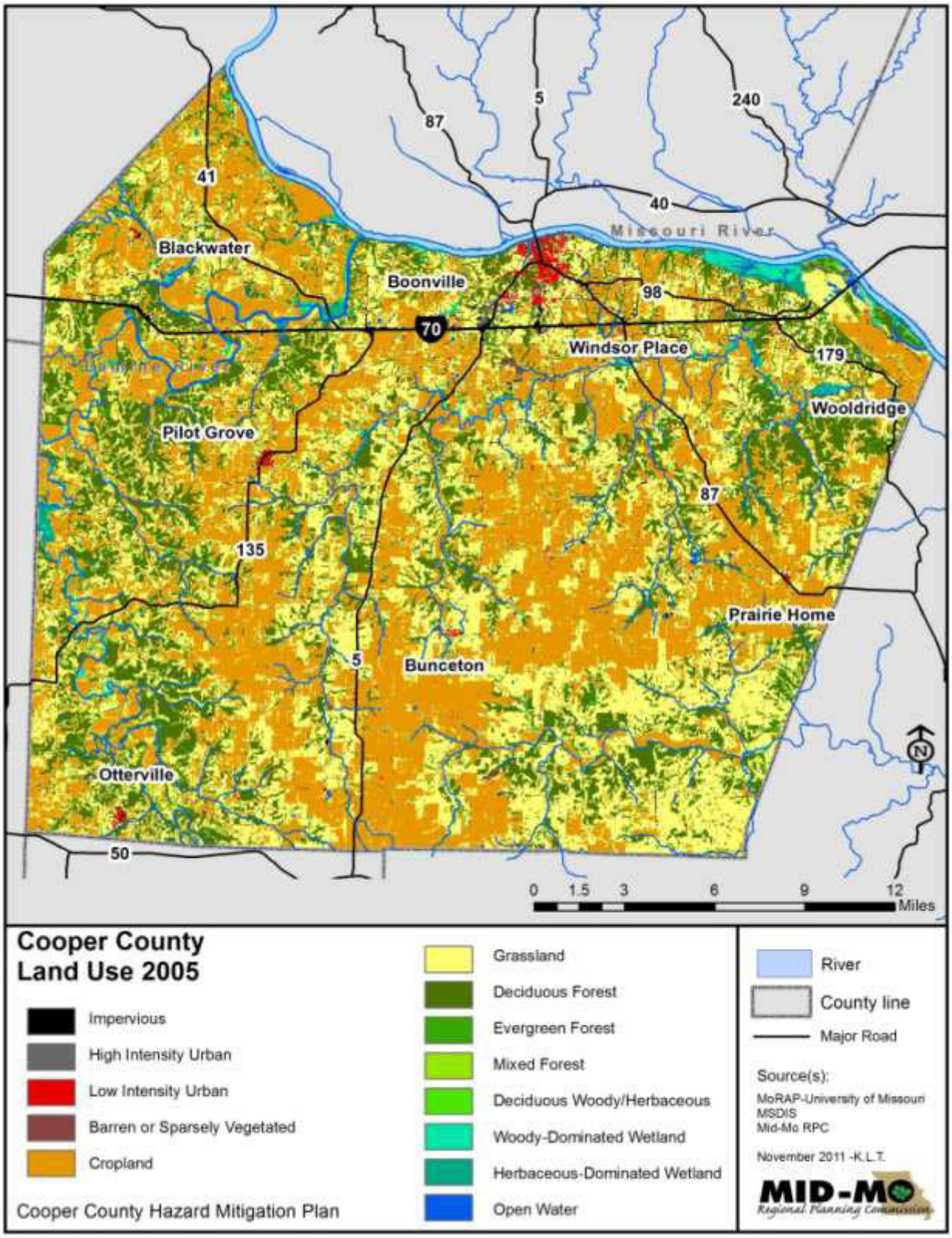

Howard
Saline
New Franklin
Boone
Missouri River
Rocheport
Blackwater
Boonville
Windsor Place
Lamine River
Wooldridge
Pilot Grove
Cooper
Bunceton
Prairie Home
Otterville
Moniteau
Morgan
Tipton
Clarksburg
Miles
0 2 4 8
Wildland Urban Interface in Cooper County, Missouri
High Density No Vegetation
Low Density Intermix
Low Density Interface
High Density Intermix
High Density Interface
Medium Density Intermix
Medium Density Interface
River
Incorporated Area
Major Road
Cooper County Hazard Mitigation Plan
Source(s):
MSDIS,
Mid-Mo RPC
September 2016 - BCD
MID-MO
Regional Planning Commission

Figure 4.67 (reviewed by Beau Derque, September 2016)



Extent

Most fires in the planning area are brush fires, which are usually dealt with in less than a few hours.

Previous Occurrences

Large and widespread wildfires, such as occur in the western United States, have not been a problem in Cooper County in recent history. Most fires have stemmed from open debris burning and agricultural burning. Several small fires occur in the early spring and fall in mostly agricultural areas in the county.

Probability and Severity of Future Events

Probability: low
Severity: low

The probability of wildfires increases during conditions of excessive heat, dryness, and drought. The probability is also higher in spring and late fall. The Missouri State Hazard Mitigation Plan points out that the probability of wildfires may increase to high during conditions of excessive heat, dryness, and drought. The probability is also higher in spring and late fall.

ANALYSIS OF RISK

Potential Impact - Existing Structures

While wildfires in the central Missouri area have the potential to destroy buildings, data from the entire Mid-Missouri RPC region indicates that this is more the exception than the rule. Wildfires are usually quickly suppressed, and the damage to the built environment is minimal.

The Missouri State Hazard Mitigation Plan 2010 estimates that Cooper County has a low potential for wildfire occurrence (4-year average of 23.4 occurrences a year) and a medium potential for the amount of acres that could burn (4-year average of 213 acres burned a year).

Potential Impact - Future Development

Potential impacts of this hazard on future development are not quantifiable with the resources available.

Existing Mitigation Activities

State of Missouri Statutes: Missouri Revised Statute 49.266, adopted in August 2013, confers the right of county commissions to adopt an order or ordinance issuing a burn ban upon a determination made by the state fire marshal:

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> Upon a determination by the state fire marshal that a burn ban order is appropriate for a county because:
>
> (1) An actual or impending occurrence of a natural disaster of major proportions within the county jeopardizes the safety and welfare of the inhabitants of such county; and
> (2) The U.S. Drought Monitor has designated the county as an area of severe, extreme, or exceptional drought, the county commission may adopt an order or ordinance issuing a burn ban, which may carry a penalty of up to a class A misdemeanor. State agencies responsible for fire management or suppression activities and persons conducting agricultural burning using best management practices shall not be subject to the provisions of this subsection. The ability of an individual, organization, or corporation to sell fireworks shall not be affected by the issuance of a burn ban. The county burn ban may prohibit the explosion or ignition of any missile or skyrocket as the terms "missile" and "skyrocket" are defined by the 2012 edition of the American Fireworks Standards Laboratory, but shall not ban the explosion or ignition of any other consumer fireworks as the term "consumer fireworks" is defined under section 320.106.

The use of Red Flag Days by fire and public works departments notifies the public of heightened fire risk. Emergency response systems**,** well-trained fire departments, and numerous county roads improve response times to fire events, thus decreasing the chances of fire spread.

The Missouri Department of Conservation and the State Fire Marshal have published an informational booklet entitled “Living with Wildfire”, which educates homeowners on assessing a property’s vulnerability to wildfire and making changes to decrease the risk.

SUMMARY OF VULNERABILITY

Wildfires in Cooper County tend to be limited in their spatial extent, thus minimizing their impact. According to the Missouri Department of Conservation, 49 percent of all wildfires in Missouri result from debris burning that gets out of hand and starts a wildfire. People and structures in the path of a wildfire are all at risk of minimum to extensive damage. Wildfire is defined as an uncontrolled fire that destroys forests and many other types of vegetation, as well as animal species.

While wildfires occur on a regular basis, they are usually easily suppressed by a quick response from the fire districts and thus limited in their spread and destruction.

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4.10 EARTHQUAKE

DESCRIPTION OF HAZARD

The United States Geological Society (USGS) describes an earthquake as "a sudden movement of the earth's crust caused by the release of stress accumulated along geologic faults or by volcanic activity." Earthquakes can be one of the most destructive forces of nature causing death, destruction of property, and billions of dollars of damage.

The New Madrid Seismic Zone (NMSZ), which runs through southeastern Missouri, is the most active seismic zone east of the Rocky Mountains. Any hazard mitigation planning in Missouri must, of necessity, take possible earthquakes into account.

Missouri and much of the Midwest can feel earthquakes from very far away because the geology of the area is more amenable to ground shaking than the California geology. New Madrid earthquakes can cover up to twenty times the area of typical California earthquakes because of this differing geology.

Location

The entire planning area is at risk for the effects of an earthquake along the New Madrid Seismic Zone. Areas close to the Missouri River may be particularly vulnerable. The soil, or alluvium, along river channels is especially vulnerable to liquefaction from earthquake waves; river alluvium also tends to amplify the waves.

Extent

The magnitude of an earthquake is a measurement of the actual energy released by the quake at its epicenter. In the U.S., it is commonly measured by the Richter Scale denoted with an Arabic numeral (e.g. 4.0).

Earthquakes along the New Madrid Seismic Zone with magnitudes around 6.0 or greater would be of concern for the planning area.

Previous Occurrences

Historical quakes along the New Madrid Seismic Zone in southeastern Missouri have been some of the largest in U.S. history since European settlement. The Great New Madrid Earthquake of 1811-1812 was a series of over 2000 quakes, which caused destruction over a very large area. According to information from Missouri SEMA's Earthquake Program, some of the quakes measured at least 7.6 in magnitude, and five of them measured 8.0 or more.

The 1811-1812 quakes changed the course of the Mississippi River. Some of the shocks were felt as far away as Washington D.C. and Boston.

The first federal disaster relief act was a result of the Great New Madrid Earthquake of 1811-1812. President James Madison signed an act into law that issued "New Madrid Certificates" for government lands in other territories to residents of New Madrid County who wanted to leave the area.

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Probability of Future Events - Moderate

It is difficult to predict the probability of an earthquake occurring along the New Madrid Seismic Zone that would be significant enough to affect the planning area. The following information from Missouri DNR helps to illustrate why this is difficult:

> The active faults in the NMSZ are poorly understood because they are not expressed at the ground surface where they can be easily studied. The faults are hidden beneath 100- to 200-foot thick layers of soft river deposited soils called alluvium.
>
> Microseismic earthquakes (magnitude less than 1.0 to about 2.0), measured by seismographs but not felt by humans, occur on average every other day in the NMSZ (more than 200 per year).
>
> Active faults that have generated dangerous earthquakes in historic times or the recent geologic past (the last 10,000 years) are not always microseismically active. In fact, in some settings, these quiet faults are considered the most dangerous ones because high built-up stress has locked the two sides of the fault together, thereby preventing the microseismic earthquakes. This is thought to happen as a prelude to a major rupture of the fault. It is not known if faults of this type exist in the NMSZ. If they do exist, there is no easy way to locate them.

If one looks strictly at the historical record for earthquakes of 6.5 magnitude or greater, there have been 2 years (1811 and 1812) out of the last 204 years in which such earthquakes have occurred. This equals less than 1% probability in any given year (Probability= 2/204*100= 0.98%). However, there were many serious quakes in just the two years of 1811 and 1812, according to Missouri DNR.

In 2002, U.S. Geological Survey (USGS) and the Center for Earthquake Research and Information (CERI) at the University of Memphis released the following expectations for earthquakes in the NMSZ in following 50 years:

- 25-40% percent chance of a magnitude 6.0 and greater earthquake.
- 7 -10% chance of a magnitude 7.5 - 8.0 quake (magnitudes similar to those in 1811-1812)

According to information provided by MO SEMA, the above expectations can be translated into the following likelihoods for a given year in the 50-year period:

- 1.0-1.6% likelihood of a magnitude 6.0 and greater earthquake
- 0.28-0.40% likelihood of a magnitude 7.5-8.0 earthquake

Since a magnitude 6.0 earthquake would affect the planning area, the probability has been determined to be moderate.

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ANALYSIS OF RISK

Severity: High

Potential Impact - Existing Structures

The intensity of an earthquake refers to the potentially damaging effects of a quake at any particular site. An earthquake of a specific magnitude will have different intensities depending on a location's distance from the epicenter of the quake, intervening soil type, and other factors.

Intensity is measured by the Modified Mercalli Intensity Scale (MMI) and expressed by a Roman numeral (Figure 4.73).

Figure 4.73

Modified Mercalli Intensity Scale

I. Instrumental	Not felt by many people unless in favorable conditions.
II. Feeble	Felt only by a few people at best, especially on the upper floors of buildings. Delicately suspended objects may swing.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV. Moderate	Felt indoors by many people, outdoors by few people during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rock noticeably. Dishes and windows rattle alarmingly.
V. Rather Strong	Felt outside by most, may not be felt by some outside in non-favorable conditions. Dishes and windows may break and large bells will ring. Vibrations like large train passing close to house.
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books fall off shelves; some heavy furniture moved or overturned; a few instances of fallen plaster. Damage slight.
VII. Very Strong	Difficult to stand; furniture broken; damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture moved.
IX. Ruinous	General panic; damage considerable in specially designed structures, well designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Disastrous	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Rails bent.
XI. Very Disastrous	Few, if any, masonry structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Catastrophic	Total damage - Almost everything is destroyed. Lines of sight and level distorted. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move position.

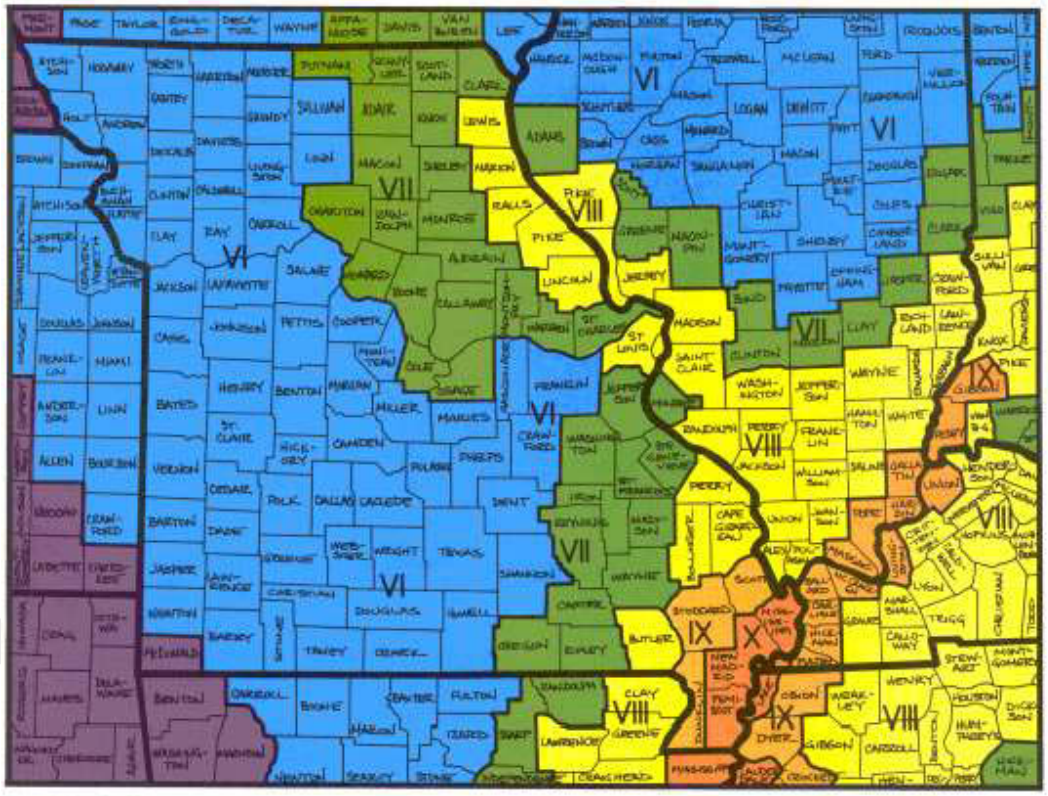
Source: http://en.wikipedia.org/wiki/Mercalli_intensity_scale

According to the USGS, Cooper County is one of the many counties in Missouri in which a 7.6-magnitude earthquake with an epicenter on or near the New Madrid Seismic Zone would have a strong impact.

The State Emergency Management Agency (SEMA) has made projections of the highest earthquake intensities which would be experienced throughout the state of Missouri should various magnitude quakes occur along the New Madrid Seismic Zone (Figure 4.74).

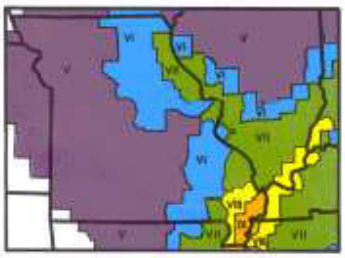
Figure

PROJECTED EARTHQUAKE INTENSITIES



is map shows the highest projected Modified Mercalli intensities by county from a potential magnitude - 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

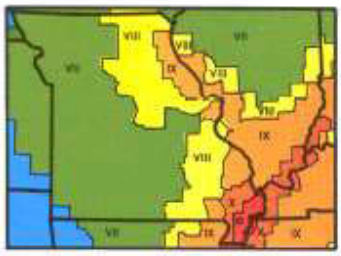
6.7



7.6

This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude - 6.7 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

8.6



This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude - 8.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

The pertinent information for Cooper County is summarized in Figure 4.75.

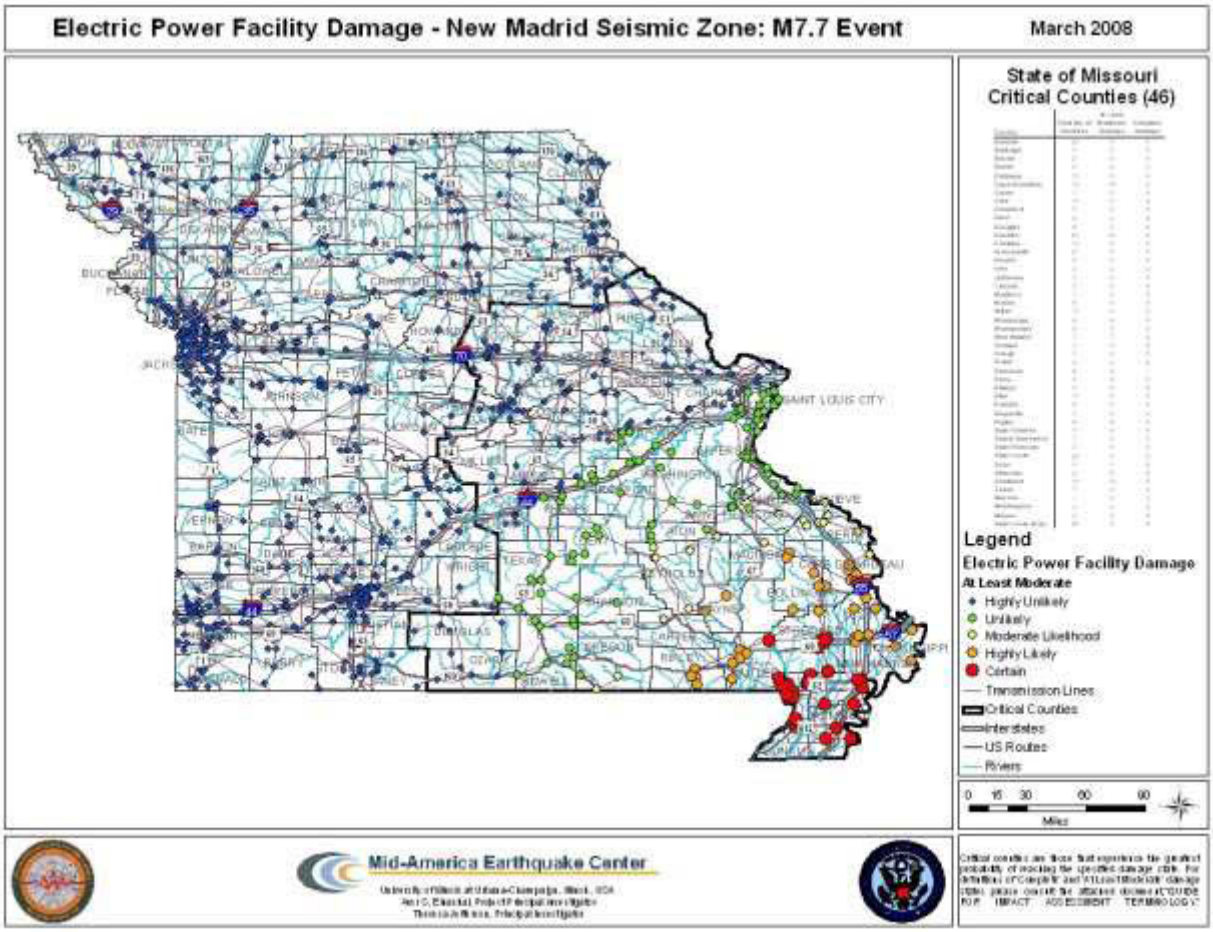
Figure 4.75

Projected Earthquake Hazard for Cooper County

Magnitude at NMSZ	Probability of Occurrence (2002 -2052)	Intensity (MMI)	Expected Damage
6.7	25-40%	V	Minimal to none
7.6	7-10%	VI	Slight

In 2008, the Mid-America Earthquake Center mapped the expected probability of at least moderate damage to electric power facilities from a 7.7-magnitude earthquake in the NMSZ; such damage was considered "highly unlikely" in the planning area (Figure 4.76). This correlates well with the projected damage to *poorly* built structures from a 7.6-magnitude quake.

Figure 4.76



Missouri State Hazard Mitigation Plan (2013) Analysis: Specific modeling of damage and loss from earthquake scenarios has been conducted for the state using HAZUS 2.1 software; the findings are included in the *Missouri State Hazard Mitigation Plan (2013)*. (HAZUS software is used by FEMA to compare relative risk from earthquakes and other natural hazards.)

The following analyses were done:

1. Annualized Loss Scenario based on eight earthquake return periods (100, 200, 500, 750, 1000, 1500, 2000, and 2500 years)

2. 2% Probability of Exceedance in 50 Years Scenario – a "worst case scenario"

The analyses used demographic data based on the 2010 Census; site-specific essential facility data was based on the 2011 HSIP inventory data.

The analyses for Cooper County are discussed in the following pages.

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Annualized Loss Scenario

The *MO State Hazard Mitigation Plan (2013)* explains the annualized loss scenario as follows:

HAZUS defines annualized loss as the expected value of loss in any one year. The software develops annualized loss estimates by aggregating the losses and their exceedance probabilities from the eight return periods. Annualized loss is the maximum potential annual dollar loss resulting from various return periods averaged on a "per year" basis. It is the summation of all HAZUS-supplied return periods multiplied by the return period probability (as a weighted calculation).

The results of the modeling for Cooper County are shown in Figure 4.77.

Figure 4.77

HAZUS-MH Earthquake Loss Estimation
Annualized Loss Scenario for Cooper County

Building Loss Total	Loss Ratio %*	Income Loss Total	Economic Loss to Buildings Total **	Loss Ratio Rank***
$43,000	0	$13,000	$56,000	93

*Loss ratio equals the sum of structural and nonstructural damage divided by the entire building inventory value within the county.

**Total economic loss includes inventory loss, relocation loss, capital-related loss, wages loss, and rental income loss

***Out of 115 (114 counties and the City of St. Louis)

Source: Missouri State Hazard Mitigation Plan (2013)

Cooper County has among the lowest loss ratios in the state, and the county's estimated building damage in actual dollars ranks 70th. For comparison, the modeling estimates the annualized total economic loss to buildings in St. Louis County (ranked number 1) at $29,748,000 and in the City of St. Louis (ranked number 2) at $9,613,000.

In Cooper County, there is the potential for building damage even at a considerable distance from the New Madrid Fault. However, the percentage of buildings sustaining damage and/or the level of damage sustained would be much lower than in a county adjacent to the fault. The loss ratio reflects this and gives an indication of both the potential economic impact of an earthquake and the difficulty of recovery in the county.

2% Probability of Exceedance in 50 Years Scenario

This analysis models a worst-case scenario using a level of ground shaking recognized in earthquake design. The *MO State Hazard Mitigation Plan (2013)* gives the following explanation of the modeling:

The methodology is based on probabilistic seismic hazard shaking grids developed by the U.S. Geological Survey (USGS) for the National Seismic Hazard Maps that are included with HAZUS-MH. The USGS maps provide estimates of peak ground acceleration and spectral

acceleration at periods of 0.3 second and 1.0 second, respectively that have a 2% probability of exceedance in the next 50 years. The International Building Code uses this level of ground shaking for building design in seismic areas. This scenario used a 7.7 driving magnitude in HAZUS-MH, which is the magnitude used for typical New Madrid fault planning scenarios in Missouri. While the 2% probability of exceedance in the next 50 years ground motion maps incorporate the shaking potential from all faults with earthquake potential in and around Missouri, the most severe shaking is predominately generated by the New Madrid Fault.

The results of the modeling for Cooper County are shown in Figure 4.78.

Figure 4.78

HAZUS-MH Earthquake Loss Estimation

2% Probability of Exceedance in 50 Years Scenario for Cooper County

Structural Damage	Non-Structural Damage	Contents Damage and Inventory Loss	Loss Ratio %*	Income Loss	Total Economic Loss to Buildings**	Loss Ratio Rank***
$6,754,000	$19,413,000	$6,782,000	1.54	$8,889,000	$41,838,000	65

*Loss ratio equals the sum of structural and nonstructural damage divided by the entire building inventory value within the county.

**Total economic loss includes inventory loss, relocation loss, capital-related loss, wages loss, and rental income loss.

***Out of 115 (114 counties and the City of St. Louis)

Source: Missouri State Hazard Mitigation Plan (2013)

The modeling suggests that damages from a worst case scenario earthquake in the NMSZ (7.7 magnitude) would be greater in Cooper County than the Modified Mercalli map of Missouri suggests. Caution indicates that mitigation and preparedness be focused on the most conservative estimates (in this case, those that predict greater injury and damage) unless these have been shown to be incorrect.

Even a significant earthquake event in the NMSZ that does not cause great damage in Cooper County could still possibly cause cascading economic losses in the county. There is the potential for disruption of road and rail traffic to the eastern part of the state, including the metropolitan area of St. Louis. Regions of the state outside of the severely damaged areas would probably be called upon for emergency and recovery assistance.

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Potential Impact - Life

Social impacts have also been modeled through HAZUS-MH for this 2% Probability of Exceedance in 50 Years (Worst Case) Scenario. The modeling was done for displacement of households, sheltering needs, and the following four levels of casualty severity:

Level 1 – Injuries will require medical attention but hospitalization is not needed
Level 2 – Injuries will require hospitalization but are not considered life-threatening
Level 3 – Injuries will require hospitalization and can become life threatening if not promptly treated.
Level 4 – Victims are killed by the earthquake.

The data in Figure 4.79 shows the estimated social impact in Cooper County of an earthquake occurring at 2 a.m., a time when most people would be in their homes.

Figure 4.79

Social Impact Estimates (HAZUS-MH Modeling)
2% Probability of Exceedance in 50 Years Scenario for Cooper County
2 a.m. Time of Occurrence

Level 1	Level 2	Level 3	Level 4	Displaced Households	Short-Term Shelter Needs
9	1	0	0	13	9

Source: Missouri State Hazard Mitigation Plan (2013)

The potential for "emotional aftershocks" also exists with any earthquake event. Major earthquake events require mental health services for people dealing with loss, stress, anxiety, fear, and other difficult emotions. Even a smaller quake, however, has the potential for emotional repercussions; the sudden movement of something experienced as stable for one's entire life (the earth itself) can be very traumatic.

Potential Impact - Future Development

The standards followed in new construction will impact vulnerability to earthquake damage; the building codes in place in Cooper County and the incorporated communities contain a basic level of seismic safety. Building new structures according to even more stringent earthquake-resistant codes would lessen the potential damage should an earthquake occur; however, this type of mitigation activity may not be cost effective for many communities.

Existing Mitigation Activities

Personnel of the Cooper County Emergency Management Agency are well-trained and well-equipped to respond to disasters of all types.

School Districts The Revised Statutes of Missouri, Section 160.451, require that, "The governing body of each school district which can be expected to experience an intensity of ground shaking equivalent to a Modified Mercalli of VII or above from an earthquake occurring along the New Madrid Fault with a potential magnitude of 7.6 on the Richter Scale shall

establish an earthquake emergency procedure system in every school building under its jurisdiction."

The educational institutions in Cooper County are not subject to these statutory requirements because the county is categorized as a VI in the Modified Mercalli Intensity Scale.

County Bridges All county bridges are inspected by MoDOT on a two-year cycle; if an earthquake impacted the planning area, MoDOT would be in charge of county bridge inspection post-earthquake.

SAVE Coalition This is a program of the Missouri State Emergency Management Agency. According to the SEMA website:

> The Missouri Structural Assessment and Visual Evaluation (SAVE) Coalition is a group of volunteer engineers, architects, building inspectors, and other trained professionals that assists the Missouri State Emergency Management Agency with building damage inspections. After a disaster, SAVE volunteers are trained to move quickly to determine which buildings are safe to use and which should be evacuated.

SUMMARY OF VULNERABILITY

The entire planning area is vulnerable to the risk of damage from an earthquake in the New Madrid Seismic Zone (NMSZ) located in southeastern Missouri. But Cooper County is not one of the 46 "critical counties" where school districts are required by state law to establish earthquake emergency procedure systems in every school.

Studies and predictions indicate that there would be damage to poorly built structures in the planning area from a 7.6-magnitude (Richter) quake in the NMSZ. In addition to structural damage and possible injury and loss of life, the planning area could be affected by an influx of people needing sheltering, the disruption of the flow of goods, calls for assistance from other areas, and the psychological traumatization of the population.

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4.11 LAND SUBSIDENCE/SINKHOLE

DESCRIPTION OF HAZARD

"Land subsidence is sinking of the earth's surface due to the movement of earth materials below the surface. This sinking can be sudden or gradual […]. In Missouri, subsidence is primarily associated with sinkholes but […] can also occur from void space left by mining and natural caves." (*MO State Hazard Mitigation Plan, 2013*)

Gradual or sudden land subsidence is a key sign of sinkhole formation. The Stormwater Design Manual from Boone County, Cooper County's neighbor to the east, distinguishes between two types of sinkholes associated with karst topography:

- Depression sinkholes which have a defined drainage area and are generally shown as closed contours on a topographic map; best management practices are required to protect groundwater when runoff from development drains into these areas

- Collapse sinkholes are areas of "karst-related subsidence with no defined drainage area when occurring outside of a depression sinkhole. Collapse sinkholes can occur in the bottom of a depression sinkhole and are commonly referred to as the 'eye' of the sinkhole"

Construction excavation and well drilling can also cause sinkholes, according to the Missouri Department of Natural Resources (DNR).

In addition to being at risk for land subsidence and sinkhole collapse associated with karst topography, the planning area is at risk from land subsidence/collapse associated with underground mining and exploratory drilling for petroleum.

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Location

The only known sinkhole areas in the planning area are in unincorporated Cooper County (see Figure 4.80). It is important to note that future sinkhole development has the potential to occur near these areas and also in other areas that have no developed sinkholes. Gradual or sudden land subsidence is a key sign of sinkhole formation.

The map also shows potential collapse areas around the known sinkholes and underground mines; these collapse areas were mapped by the Missouri DNR. But these may not be the only potential collapse areas; further development may bring to light previously unknown sinkhole areas in the karst regions and also more abandoned underground mines.

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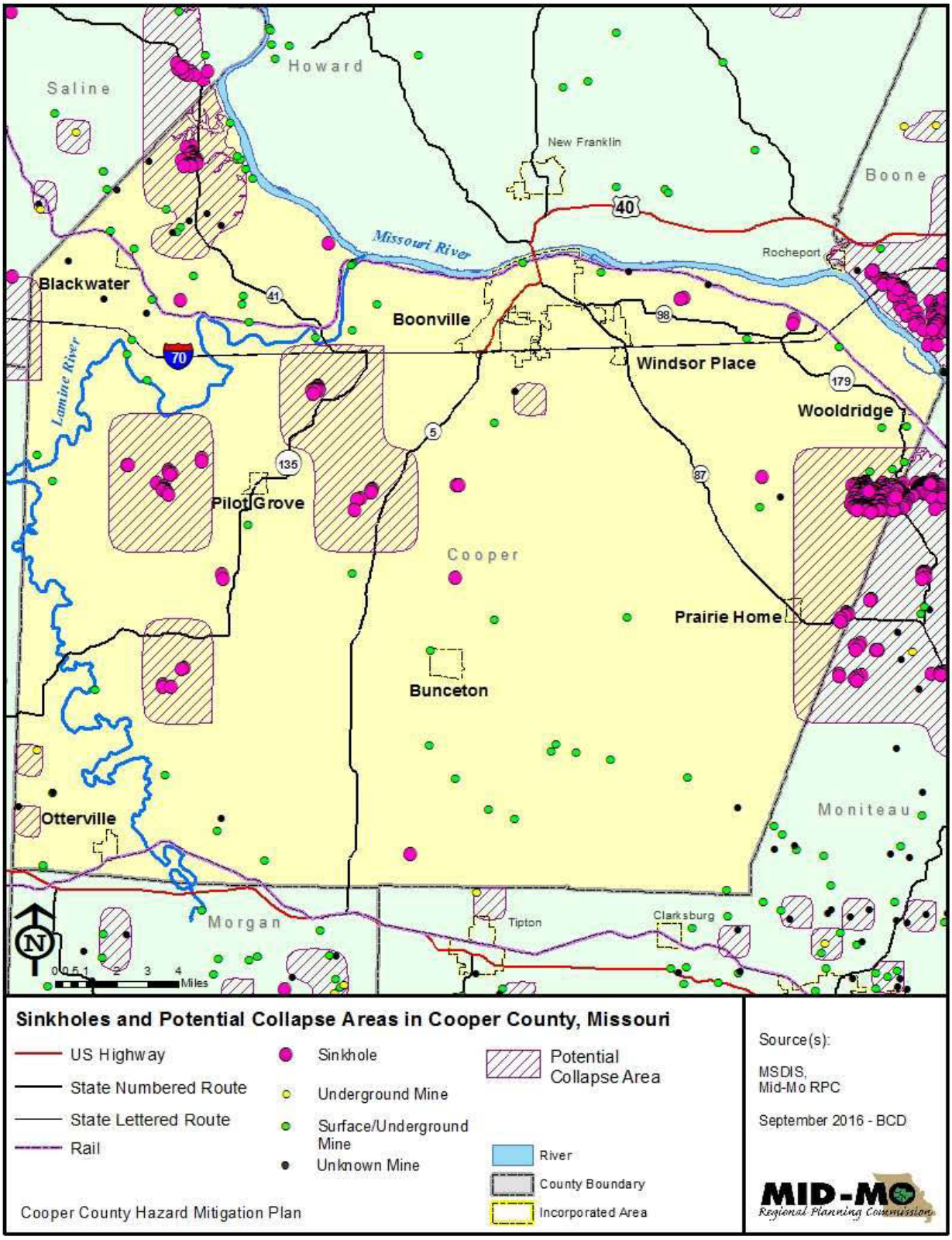
Figure 4.80


Saline
Howard
New Franklin
Boone
Missouri River
Rocheport
Blackwater
Boonville
Windsor Place
Wooldridge
Lamine River
Pilot Grove
Cooper
Prairie Home
Bunceton
Otterville
Moniteau
Morgan
Tipton
Clarksburg
Miles
Sinkholes and Potential Collapse Areas in Cooper County, Missouri
US Highway
State Numbered Route
State Lettered Route
Rail
Sinkhole
Underground Mine
Surface/Underground Mine
Unknown Mine
Potential Collapse Area
River
County Boundary
Incorporated Area
Source(s):
MSDIS,
Mid-Mo RPC
September 2016 - BCD
Cooper County Hazard Mitigation Plan
MID-MO
Regional Planning Commission

Extent

Sinkholes can vary "from a few feet to hundreds of acres and from less than one to more than 100 feet deep," according to the USGS.

There have been 15,891 sinkholes identified in Missouri. One hundred and sixty sinkhole collapses examined by the Missouri Department of Natural Resources between 1970 and 2007 were less than 10 feet in diameter and less than 10 feet deep. However, there were also some very large collapses within the state: one collapse drained a lake near St. Louis; one drained a sewage lagoon in West Plains; and one swallowed a garage with a car in it in Nixa.

Previous Occurrences

There have been no *recorded* recent occurrences of sinkhole collapse in Cooper County. Just because no occurrences have been recorded does not mean that they have not happened. Previous occurrences of sinkhole development in other parts of Missouri with similar geologic features are a source of concern.

According to the Missouri DNR, sewage lagoons in West Plains and Republic in southern Missouri were drained of their contents due to the development of sinkholes. Sinkholes drain directly into underground water sources and can impact or pollute area water sources.

In West Plains, sinkholes had drained the lagoon twice before the final collapse; local officials had tried to patch the collapses with cement and other materials. The final collapse in 1978 resulted in sewage draining directly into underground water sources. Mammoth Spring in Arkansas was contaminated, and more than 800 local residents reported illness, according to the Missouri DNR. While this occurred in southern Missouri, the potential exists for a similar situation to occur in the planning area.

Probability and Severity of Future Events

Probability - low
Severity - low

ANALYSIS OF RISK

It is very difficult to predict the severity of a sinkhole collapse due to their great variance in size, varying speeds of collapse onset, and proximity to the built environment. The severity of a sinkhole collapse will also be greater if contamination occurs.

Potential Impact – Life

Sinkhole collapse poses a potential threat to human life; there have been numerous news stories in recent years of collapsing sinkholes swallowing up people. In 2013, a man hunting in southern Missouri lost his life when he stepped in a sinkhole that had possibly opened up due to recent heavy rain.

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Sinkhole collapse potentially poses a threat to public health via contamination of the water supply. According to information from the Missouri DNR, a 1978 sinkhole collapse in southern Missouri drained the West Plains lagoon, resulting in sewage draining directly into underground water sources. More than 800 local residents reported illness, and Mammoth Spring in Arkansas was contaminated.

According to the *Boone County Stormwater Design Manual*, groundwater in karst systems can move as much as a mile per day; this is contrasted to non-karst areas where groundwater may only move a few feet per year. Obviously, the potential for quick and widespread contamination of groundwater is a major concern in karst areas; "a contaminant may reach some springs or wells within a few hours after entering the groundwater system." It is important to note that due to the nature of karst topography, some of the karst sinkhole areas may drain into watersheds other than the ones in which they are located. This makes the impact of pollutants in these areas harder to quantify.

Potential Impact - Existing Structure

Sinkholes vary in size and can potentially cause damage to roads, water/sewer lines, buildings, and lagoons. It is difficult to determine the potential impact of land subsidence and sinkholes on existing structures for a number of reasons:

> There is a lack of data on historic damages caused by land subsidence and sinkhole collapse in Missouri.
>
> Even with the mapping of known and possible sinkhole locations, it is difficult to predict where a sinkhole will collapse and if the collapse will be significant enough to damage any structures in the vicinity.

Because sinkhole collapse is not predictable, there is no direct way to assess a cost impact for this hazard. Vulnerable structures, roads, or property could potentially be impacted by a sudden and usually localized drop in elevation. The resulting damage incurred from the sinkhole could result in broken roads, building collapse, compromises to water sources, environmental impacts, and/or loss of life. While loss of life could occur, it would most likely be minimal.

Potential Impact - Future Development

It is difficult to assess the effects of sinkholes on future development because sinkhole development is unpredictable and few sinkhole areas have been identified in the planning area. However, it should be noted that future development can affect the impact of this hazard. Construction of septic tanks, lagoons, and structures can cause shifts in soil and may plug or disturb karst areas, allowing for the formation of a sinkhole. Also, soil disturbance can cause the drainage pattern to change, which may lead to blockage of a sinkhole and potentially cause flooding.

SUMMARY OF VULNERABILITY

Land subsidence and sinkhole collapse are not of great concern in the planning area.

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There are no known sinkholes in any areas that would impact a school district structure.

The only known sinkhole areas in the planning area are in unincorporated Cooper County. It is important to note the potential for future sinkhole development near these areas and in other areas that presently do not have developed sinkholes. Gradual or sudden land subsidence is a key sign of sinkhole formation.

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