Part III: Risk Assessment

Natural Hazard Identification/Elimination Process

Many sources were researched for data relating to natural hazards that have or may affect Christian County. Primary sources included FEMA, SEMA, National Climate Data Center (NCDC) and National Oceanic and Atmospheric Administration (NOAA). The US Geological Survey (USGS) and the Center for Earthquake Research and Information (CERI) were major sources for earthquake information. The Missouri Department of Natural Resources (MDNR) Dam Safety Division provided information concerning the dams in Missouri. The Missouri Department of Conservation (MDC) provided the majority of the wildfire information relevant to Christian County. Other sources included county and municipal officials; existing municipal, county, regional and state plans; and information from local residents.

Hazards relevant to Christian County were identified by researching the above noted data sources for incidences of natural hazards occurring in the county. In addition, hazards that are regional in scope and that have or may affect Christian County are also included in this risk assessment.

Community-Wide Hazard Profile and List of Hazards Identified

Research indicates that tornadoes and severe thunderstorms have adversely impacted Christian County, causing injury, death, and millions of dollars in property damage. On May 4, 2003, devastating tornadoes ripped through southwest Missouri. One of these tornadoes cut a path of destruction through Lawrence County before entering the Christian County panhandle. This tornado damaged 150 structures, destroyed another 27 buildings, killed one person and caused three injuries in the panhandle area before moving into Greene County. Historical records further show there are several other hazards besides tornadoes and severe thunderstorms that can or will eventually affect the county. Such hazards include flooding, severe winter weather, drought, extreme heat, earthquakes, dam failure, land subsidence (sinkholes) and wildfires.

Natural disasters have been known to cause technological hazards such as power failure, interruption of public transportation and water supplies, and loss of economic activities. These emergencies can trigger civil disturbance, a loss of records through computer failure, and result in health hazards from water contamination and unsanitary conditions. Economic loss can affect the area in several ways depending on the duration of interruption. The following diagram provides an example of cascading natural hazards while Table 3-1 notes cascading hazards that may result from individual natural hazard events.

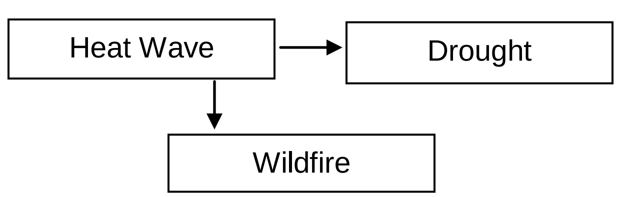


Table 3-1: Cascading Hazards Resulting from Natural Disasters

Natural Disaster	Power and Communications Interruption	Water Supply Interruption	Business Interruption	Civil Unrest	Computer Failure and/or Loss of Records	Transportation Interruption	Health and/or Environmental Hazards
Tornado/Storm	X	X	X	X	X	X	X
Flood	X	X	X		X	X	X
Severe Winter Weather	X	X	X		X	X	X
Drought	X	X					X
Heat Wave	X	X		X			X
Earthquake	X	X	X	X	X	X	X
Dam Failure	X	X	X	X		X	X
Wildfire	X					X	X
Sinkholes	X	X				X	

Hazards Not Included and Reasons for Elimination

Landslides occur in all 50 states; however, most areas affected have characteristics of steep slopes, periodic heavy rains, clay rich soils or areas where vegetation has been lost after wildfires. It is highly unlikely that this hazard would have much of a notable impact on Christian County. Coastal storms, hurricanes and tsunamis are also very unlikely due to the county's location in the central region of the United States. Also, the risk of avalanche and volcanic activity is not pertinent due to the lack of geologic structure, steep slopes, and location. Levee failure was omitted due to the fact that there are no levees in Christian County. Therefore, these hazards are eliminated from consideration.

Hazard Event Severity Ratings

The following sections profile the identified hazards which have adversely affected or which may affect Christian County. The profiles include a description of the hazard, historical occurrences and damages experienced in the county, an analysis of future probable severity and risk, and general recommendations for mitigation. The criteria, shown in Table 3-2, for evaluating future probable severity is based on the Severity Ratings Table derived from SEMA's Regional Planning Commission *Hazard Mitigation Planning Guide 2002:*

Table 3-2: SEMA Severity Ratings Table	
Severity Level	**Characteristics**
Catastrophic	Multiple deaths. Complete shutdown of facilities for 30 days or more. More than 50 percent of property is severely damaged.
Critical	Injuries and/or illnesses result in permanent disability. Complete shutdown of critical facilities for at least 2 weeks. More than 25 percent of property is severely damaged.
Limited	Injuries and/or illnesses do not result in permanent disability. Complete shutdown of critical facilities for more than 1 week. More than 10 percent of property is severely damaged.
Negligible	Injuries and/or illnesses are treatable with first aid. Minimal quality-of-life impact. Shutdown of critical facilities and services for 24 hours or less. Less than 10 percent of property is severely damaged.
Source: SEMA. Regional Planning Commission *Hazard Mitigation Planning Guide 2002.*	

Hazard Event Statement of Probability Rankings

The statements of probability in the hazard profile section of this plan are based on language from the previous plan. For hazards where the probability percent can be calculated from the number of NOAA recorded events over a known time frame, the ranks were strictly applied by their definition in Table 3-3. These hazards include tornadoes, severe thunderstorm events (high wind, hail and lightning), riverine and flash floods and events associated with severe winter weather (heavy snow, ice storm and extreme cold). The remaining hazards of dam failure, heat wave, drought, and sinkholes lack sufficient information to calculate a probability percent. In these cases, the same ranks are stated but represent a more intuitive indication based on known locations of existing hazard areas and likely scenarios based on past events.

Table 3-3: Definitions of Statement of Probability Rankings for Identified Hazards		
Probability Rank	**Definition**	**Probability %**
Highly Likely	Event probable in the next year	100 +
Likely	Event probable in the next 10 years	10 - 99.9
Possible	Event probable beyond 10-50 years	2 - 9.99
Unlikely	Event probable beyond 50 + years	0 - 1.9

Hazard Profile Format

The Hazard Profiles contained in this Risk Assessment are designed to better inform the reader of the natural hazards that affect the planning area, where those hazards occur, what damages those hazards might cause, past occurrences of the hazard, and the probability of the hazard occurring again. The Hazard Identification section contains a description of the hazard and a basic overview of how the event occurs in nature. The Location section describes where the hazard in likely to occur, including a possible discussion of floodplains or Wildland-Urban Interface. The Extent section describes what damages officials can expect from each hazard as well as a discussion of the impact of the hazard on the planning area. The Past Occurrences section provides a discussion of recorded occurrences of the hazard as well as information on the severity of the events and the damages cause to property and life. The Probability section includes estimated probabilities for each hazard based on the frequency of past occurrences.

Tornado

Hazard Identification

Tornadoes are the most concentrated and violent storms produced by the earth's atmosphere. Weather conditions which are conducive to tornadoes often produce a wide range of other dangerous storm activities, including severe thunderstorms, downbursts, straight line winds, lightning, hail, and heavy rains. Historical tornado data archived by the Storm Prediction Center ranks Missouri 9th in the nation for the number of reported tornadoes from 1950-1996 (Storm Prediction Center, *Tornado Reports by State*).

Tornadoes, spawned from the largest of thunderstorms, are a vortex storm with two components of winds. The first is the rotational winds that can measure up to 500 miles an hour and the second is an uplifting current of great strength. Although tornadoes have been documented in all 50 states, most occur in the central United States. The unique geography of the central United States allows for the development of thunderstorms that spawn tornadoes. The jet stream, which is a high velocity stream of air, determines which area of the central United States will be prone to tornado development. The jet stream normally separates the cold air of the north from the warm air of the south. During the winter, the jet stream flows west to east over Texas to the Carolina coast. As the sun "moves" north, so does the jet stream, which at summer solstice flows from Canada across Lake Superior to Maine. During its move north in the spring and its recession south during the fall, the jet stream crosses Missouri causing the large thunderstorms that breed tornadoes (SEMA, *Missouri Hazard Analysis*, A-1).

Most tornadoes are just a few dozen yards wide and only briefly touch down on the ground. However, more violent tornadoes may stay on the ground for upward of 300 miles and carve out a path nearly a mile wide. The average forward speed of a tornado is 30 miles per hour but may vary from nearly stationary to 70 miles per hour. The average tornado moves from southwest to northeast, but tornadoes have been known to move in any direction. Tornadoes are most likely to occur between 3:00 p.m. and 9:00 p.m., but may occur at any time of the day. In Missouri, tornadoes occur most frequently between April and June, but can occur at any time during the year (National Disaster Education Coalition, *Talking About Disaster*, p. TO-1).

Location

There are no likely locations for future occurrences as the threat from this hazard is county-wide.

***Extent** (Magnitude/Severity)*

The extent of damage caused by a tornado depends of the strength of the storm. Possible damage can vary from branches broken off of trees and sign boards being damaged to well-built structures being blown off of their foundations and completely leveled and automobiles being thrown through the air for over 100 meters. The scale used to measure the strength and destructive power of tornadoes is the Enhanced Fujita Scale (EF-Scale), which is a revised version of the original Fujita Scale developed by Dr. Theodore Fujita in 1971. The EF-Scale was developed by a group of engineers and meteorologists in 2007 to better depict the actual winds speeds and their degree of damage. The EF-Scale found that wind speeds necessary to cause a certain level of damage were slower than the original F-Scale. The F-Scale and the EF-scale rank tornadoes according to wind speed and the severity of damage caused (*A Recommendation for an Enhanced Fujita Scale (EF-Scale)*). These estimates vary with the height of the structure and exposure. Table 3-4 notes the F-Scale, Enhanced F-Scale, and examples of typical damage.

Table 3-4: Fujita and Enhanced Fujita Tornado Damage Scale

Fujita Scale			Operational EF Scale		Typical Damage
F Number	**Fastest 1/4 Mile (mph)**	**3 Second Gust (mph)**	**EF Number**	**3 Second Gust (mph)**	
0	40-72	45-78	**0**	**65-85**	**Light damage -** Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
1	73-112	79-117	**1**	**86-110**	**Moderate damage -** Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
2	113-157	118-161	**2**	**111-135**	**Considerable damage -** Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
3	158-207	162-209	**3**	**136-165**	**Severe damage -** Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
4	208-260	210-261	**4**	**166-200**	**Devastating damage -** Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
5	261-318	262-317	**5**	**Over 200**	**Incredible damage -** Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yds.); trees debarked; incredible phenomena will occur.

The EF-scale takes an additional step by determining the tornado's three-second gusts by estimating the point of damage based on a judgment of the amount of damage, or the degrees of damage (DOD), to 28 different types of structures, or damage indicators (DI), listed in Table 3-5.

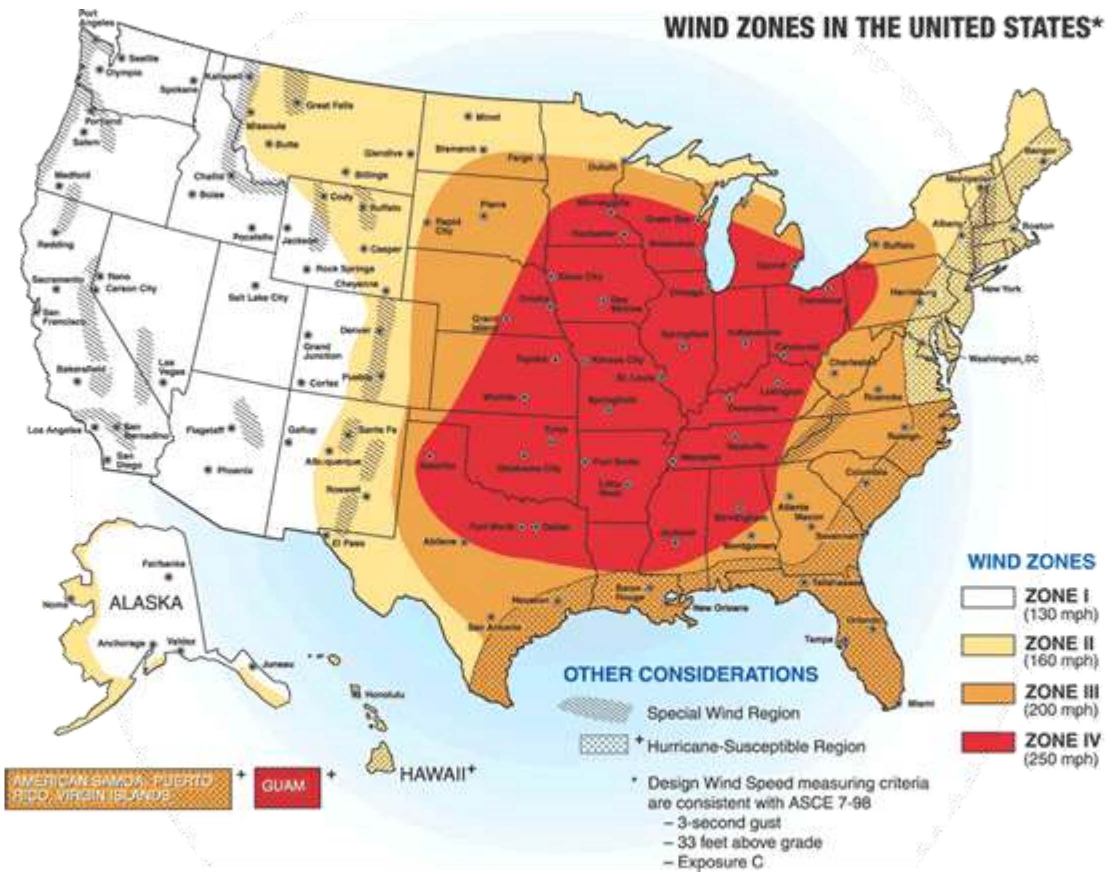
Table 3-5: Enhanced Fujita Damage Indicators and Degrees of Damage

DI No.	Damage Indicator (DI)	Degrees of Damage (DOD)	DI No.	Damage Indicator (DI)	Degrees of Damage (DOD)
1	Small Barns or Farm Outbuildings (SBO)	8	15	Elementary School [Single Story; Interior or Exterior Hallways] (ES)	10
2	One- or Two-Family Residences (FR12)	10	16	Junior or Senior High School (JHSH)	11
3	Manufactured Home – Single Wide (MHSW)	9	17	Low-Rise Building [1–4 Stories] (LRB)	7
4	Manufactured Home – Double Wide (MHDW)	12	18	Mid-Rise Building [5–20 Stories] (MRB)	10
5	Apartments, Condos, Townhouses [3 stories or less] (ACT)	6	19	High-Rise Building [More than 20 Stories] (HRB)	10
6	Motel (M)	10	20	Institutional Building [Hospital, Government or University Building] (IB)	11
7	Masonry Apartment or Motel Building (MAM)	7	21	Metal Building System (MBS)	8
8	Small Retail Building [Fast Food Restaurants] (SRB)	8	22	Service Station Canopy (SSC)	6
9	Small Professional Building [Doctor's Office, Branch Banks] (SPB)	9	23	Warehouse Building [Tilt-up Walls or Heavy-Timber Construction] (WHB)	7
10	Strip Mall (SM)	9	24	Electrical Transmission Lines (ETL)	6
11	Large Shopping Mall (LSM)	9	25	Free-Standing Towers (FST)	3
12	Large, Isolated Retail Building [K-Mart, Wal-Mart] (LIRB)	7	26	Free-Standing Light Poles, Luminary Poles, Flag Poles (FSP)	3
13	Automobile Showroom (ASR)	8	27	Trees: Hardwood (TH)	5
14	Automobile Service Building (ASB)	8	28	Trees: Softwood (TS)	5

Source: Enhanced Fujita Tornado Damage Scale

Figure 3-1 shows Wind Zones in the United States. All of Missouri is in Zone IV, and is therefore at risk for 250 mph winds. This windspeed is an important factor in the construction of tornado safe rooms.

Figure 3-1: Wind Zones in the United States



The severity of impact for a given tornado is fairly predictable based on the EF-Scale ranking and whether or not the tornado occurs near a population center, agricultural area or over grazing lands. As referenced the Missouri State Hazard Mitigation Plan, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that they analyzed was tornadoes. The report analyzed the different aspects of normal life might be affected by a tornado. Table 3-6 contains information from that analysis of tornadoes.

Table 3-6: EMAP Impact Analysis: Tornadoes	
Subject	**Detrimental Impact**
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for inundation area and moderate to light for other adversely affected areas.
Health and Safety of Personnel Responding to the Incident	Localized impact expected to limit damage to personnel in the areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Delivery of Services	Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
The Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the flood or HazMat spills.
Economic and Financial Condition	Local economy and finances adversely affected, possibly for an extended period of time.
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.
Source: Missouri State Hazard Mitigation Plan, 2010	

Based on the magnitude of previous tornadoes in Christian County, the probable future severity based on each EF-Scale ranking is shown in Table 3-7.

Table 3-7: Probable Future Severity: Tornadoes	
F0	Negligible
F1	Limited
F2	Limited
F3	Critical
F4	Catastrophic
F5	Catastrophic

The enormous power and destructive capability of tornadoes are beyond our capabilities to control. The severity of the effects of a tornado will continue to be high. Deaths, injuries, and property damages will continue to be a result of these phenomena. However, technological advances will facilitate earlier warning than previously available. Advanced warning systems, combined with improved construction techniques and public education, offer the potential for reductions in the number of deaths and injuries as well as property damage.

Past Occurrences

Since 1954, 29 tornadoes ranging from F0 to F4 magnitude have been recorded in Christian County, according to the National Climatic Data Center. Of those 29 events, 21 resulted in damages totaling over $90 million, one death and 11 injuries. Four events each caused estimated property damages of $2.5 million or more. However, detailed information on the areas affected and the losses incurred are not available. Those 21 events which resulted in damage are shown in Table 3-8. As described in Table 3-6, an F4 tornado on November 29, 1991 caused an estimated $25 million in property damages in southern Greene and northern Christian counties (north of Ozark). Although the National Climatic Data Center storm events database does not specify the actual damages or loss in either Greene County or Christian County from this event, Christian County emergency management personnel recall that the greatest damages occurred in Greene County and that this tornado ripped the roofs off commercial structures and destroyed or damaged several homes in the area north of Ozark and Nixa and south of the Highway 65 and Highway 60 interchange in southern Springfield (Greene County). In April of 1994, an F1 tornado caused $500,000 in property damage and $1,000 in crop damage in Christian County. The tornado first touched down just south of the City of Ozark and ran a seven mile course ending just southeast of Sparta. The roofs were blown off of three homes at Lone Hickory Road and County Road W and a barn was blown on to a house towards the end of the tornado track near Sparta.

Table 3-8: Tornado History – Christian County, 1954 - 2010

Location	Date	Magnitude	Death	Injury	Property Damage	Crop Damage
Christian	03/24/1954	F1	0	0	$25,000	0
Christian	04/05/1965	F1	0	0	$25,000	0
Christian	12/14/1971	F2	0	0	$2,500,000	0
Christian	04/24/1975	F1	0	1	$25,000	0
Christian	04/24/1975	F1	0	0	$25,000	0
Christian	08/16/1977	F0	0	0	$3,000	0
Christian	12/24/1982	F2	0	0	$2,500,000	0
Christian	10/16/1984	F1	0	2	$2,500,000	0
Christian	10/18/1984	F0	0	0	$3,000	0
Christian	03/14/1990	F1	0	0	$25,000	0
Christian	11/29/1991	F4	0	0	$25,000,000 (Greene & Christian Cos.)	0
Ozark	04/28/1994	F1	0	0	$500,000	$1,000
Billings	05/04/2003	F3	1	3	$5,100,000 (Lawrence & Greene Cos.)	0
Clever	03/12/2006	F3	0	3	50,000,000 (Lawrence & Greene Cos.)	0
Sparta	3/12/2006	F3	0	0	$50,000	0
Ozark	6/18/2007	F0	0	1	0	0
Clever	09/06/2007	F0	0	0	$2,000	0

Table 3-8: Tornado History – Christian County, 1954 - 2010						
Location	**Date**	**Magnitude**	**Death**	**Injury**	**Property Damage**	**Crop Damage**
Riverdale	01/07/2008	F1	0	1	$200,000	0
Montague	01/08/2008	F1	0	0	$250,000	0
Nixa	04/09/2009	F0	0	0	$100,000	0
Garrison	05/08/2009	F1	0	0	$2,000,000 (Taney & Douglas Cos.)	0
Totals			1	11	$90,832,000	$1,000
Source: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms						

The only death recorded in Christian County from a tornado event occurred on May 4, 2003 when devastating tornadoes ripped through southwest Missouri. One of these tornadoes began in Newton County as an F2. The tornado progressed through Lawrence County becoming an F3, and into the Christian County panhandle, and ending in Greene County. In Christian County alone 150 structures were damaged and 27 completely destroyed. There was a total of $5.1 million in property losses, one fatality, and three injuries. The entire tornado resulted in seven fatalities, 48 injuries, and over $33.1 million in property damages (total numbers include Christian County). This storm event was one of the most devastating in the area in over 50 years.

More recently, on March 12, 2006 another F3 tornado touched down in Lawrence County and scoured a similar path as the 2003 event, traversing the rural area between Billings and Clever. This tornado was on the ground for 17 miles before weakening in southern Greene County and causing damage to 138 homes and destroying 127 others in a subdivision of well-built homes northeast of Nixa. The entire event injured 3 persons and resulted in an estimated $50 million in property damage.

Probability

The risk of tornado in Christian County is likely. Table 3-9 shows the likelihood of future tornadoes based on F-Scale rankings, based on NOAA-NCDC data from 1950-2010. According to the *Missouri State Hazard Analysis*, Christian County was among the 40 counties that experienced 15 tornadoes or more between 1950 and 2000, placing it in the top 35% of tornado-affected counties in Missouri. Although most tornadoes affecting Christian County have rated lower on the Fujita Scale, several of these events resulted in substantial property loss.

Table 3-9: Likelihood of Future Tornado Occurrence			
F#	**# Of Events**	**% Risk**	**Probable Risk of Occurrence**
F0	10	16.6	Likely
F1	13	21.7	Likely
F2	2	3.3	Possible
F3	2	3.3	Possible
F4	2	3.3	Possible
F5	0	0.0	Unlikely

Severe Thunderstorm (High Winds/Hail/Lightning)

Hazard Identification

Thunderstorm

The National Weather Service (NWS) considers a thunderstorm severe if it produces hail at least three-quarters of an inch in diameter, has winds of 58 miles per hour or higher, or produces a tornado. Thunderstorms may occur singly, in clusters or in lines. Some of the most severe weather occurs when a single thunderstorm affects one location for an extended time. Lightning is a major threat during a thunderstorm. Lightning is very unpredictable, which increases the risk to individuals and property. In the United States, 75 to 100 people are killed each year by lightning, although most lightning victims do survive (National Disaster Education Coalition, Talking About Disaster, p. TS-2).

High Winds

A severe thunderstorm can produce winds that can cause as much damage as a weak tornado and these winds can be life threatening. The damaging winds of thunderstorms include downbursts, microbursts, and straight-line winds. Downbursts are localized currents of air blasting down from a thunderstorm, which induce an outward burst of damaging wind on or near the ground. Microbursts are minimized downbursts covering an area of less than 2.5 miles across. They include a strong wind shear (a rapid change in the direction of wind over a short distance) near the surface. Microbursts may or may not include precipitation and can produce winds at speeds of more than 150 miles per hour. Damaging straight-line winds are high winds across a wide area that can reach speeds of 140 miles per hour (*State of Missouri Hazard Mitigation Plan*, 2010).The National Weather Service in Springfield, Mo uses the following scales, as represented in Table 3-10 and Table 3-11, to warn residents and emergency managers of thunderstorm and non-thunderstorm wind risk.

Table 3-10: National Weather Service Thunderstorm Wind Gust Legend

Risk Level	**Definition**
None	**No thunderstorm wind risk**
Limited	**Risk for sub-severe wind gusts (less than 58 mph)** Or Probability of severe wind gusts (58 mph or greater) within 25 miles of a point: **Less than 15%**
Elevated	Probability of severe wind gusts (58 mph or greater) within 25 miles of a point: **Equal to or greater than 15%**
Significant	Probability of severe wind gusts (58 mph or greater) within 25 miles of a point: **Equal to or greater than 45%**
Extreme	Probability of severe wind gusts (58 mph or greater) within 25 miles of a point: **Equal to or greater than 60%**

Source: National Weather Service

Table 3-11: National Weather Service Non-Thunderstorm Wind Gust Legend	
Risk Level	**Definition**
None	**Sustain winds < 20 mph** and **Wind gusts < 30 mph**
Limited	**Sustain winds 20-29 mph** and **Wind gusts 30-44 mph**
Elevated	**Sustain winds < 30-39 mph** and **Wind gusts < 45-57 mph**
Significant	**Sustain winds 40-49 mph** and **Wind gusts 58-64**
Extreme	**Sustain winds ≥ 50 mph** and **Wind gusts ≥ 65 mph**
Source: National Weather Service	

Hail

Hail is precipitation in the form of lumps of ice that form in some storms. They are usually round and typically vary from .25 inch to 3 inches in diameter. Hail generally forms in thunderstorms between strong currents of rising air called updrafts and the current of air descending toward the ground or downdraft. Hail develops when updrafts carry water droplets to a height where freezing occurs. Ice particles grow in size, finally becoming too heavy to be supported by the updraft and fall to the ground. Large hailstones indicate strong updrafts in storms. Large hailstones fall at speeds faster than 100 mph and account for significant damage (*Denver Regional Natural Hazard Mitigation Plan*, 2010 Draft).

Lightning

Lightning is caused when turbulent air inside a thundercloud creates positively and negatively charged areas, with the negative charges clustering at the bottom of the cloud. Because opposite charges attract each other, positive charges on the ground collect beneath the cloud and follow it. When the positive and negative charges finally meet, they complete an electrical circuit, and create lightning. Not all lightning forms in the negatively charged area low in the thunderstorm cloud. Some lightning originates in the cirrus anvil at the top of the thunderstorm. This area carries a large positive charge. Lightning from this area is called positive lightning. This type is particularly dangerous for several reasons. It frequently strikes away from the rain core, either ahead or behind the thunderstorm. It can strike as far as five or 10 miles from the storm, in areas that most people do not consider to be a lightning risk area.

The other problem with positive lightning is it typically has a longer duration, so fires are more easily ignited. Positive lightning usually carries a high peak electrical current, which increases the lightning risk to an individual. (*Denver Regional Natural Hazard Mitigation Plan*, 2010 Draft) Nationwide, lightning kills 75 to 100 people each year.

During the period of 1992 through 1996, seven people died in Missouri as a result of lightning strikes, compared to two deaths from tornadoes during the same period (*State of Missouri Hazard Mitigation Plan*, 2010).

Location

The entire county is at risk for thunderstorm related hazards.

Extent (*Magnitude/Severity****)***

The damages that result from severe thunderstorm primarily result from high winds, hail and lightning. Thunderstorms frequently occur in the planning area and residents need to be prepared for the types of damages that each aspect of the hazard can cause. Scientists have developed various scales that outline damages caused by different intensities of each hazard associated with severe thunderstorms.

The Beaufort Wind Scale was developed in 1805 by Sir Francis Beaufort of England to better understand the effects of high winds not only over land but over water. Table 3-12 shows the Beaufort Wind Scale.

Table 3-12: Beaufort Wind Scale

Force	Wind MPH	WMO Classification	Appearance of Wind Effects	
			On the Water	On Land
0	Less than 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-7	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	8-12	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	13-18	Moderate Breeze	Small waves 1-4 ft. becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	19-24	Fresh Breeze	Moderate waves 4-8 ft taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	25-31	Strong Breeze	Larger waves 8-13 ft, whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	32-38	Near Gale	Sea heaps up, waves 13-20 ft, white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	39-46	Gale	Moderately high (13-20 ft) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Whole trees in motion, resistance felt walking against wind

Table 3-12: Beaufort Wind Scale				
Force	**Wind MPH**	**WMO Classification**	**Appearance of Wind Effects**	
			On the Water	**On Land**
9	47-54	Strong Gale	High waves (20 ft), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	55-63	Storm	Very high waves (20-30 ft) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	64-72	Violent Storm	Exceptionally high (30-45 ft) waves, foam patches cover sea, visibility more reduced	Extensive widespread damage
12	73+	Hurricane	Air filled with foam, waves over 45 ft, sea completely white with driving spray, visibility greatly reduced	Extreme destruction, devastation
Source: http://www.spc.noaa.gov/faq/tornado/beaufort.html, http://www.orcadian.co.uk/weather/beaufort.htm				

The Tornado and Storm Research Organisation (TORRO) has developed a scale to better understand the effects of various size hail stones. Table 3-13 shows the TORRO Hail Scale.

Table 3-13:TORRO Hailstorm Intensity Scale			
	Intensity Category	**Typical Hail Diameter (mm)***	**Typical Damage Impacts**
H0	Hard Hail	5	No damage
H1	Potentially Damaging	5-**15**	Slight general damage to plants, crops
H2	Significant	10-**20**	Significant damage to fruit, crops, vegetation
H3	Severe	20-**30**	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored
H4	Severe	25-**40**	Widespread glass damage, vehicle bodywork damage
H5	Destructive	30-**50**	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
H6	Destructive	40-**60**	Bodywork of grounded aircraft dented, brick walls pitted
H7	Destructive	50-**75**	Severe roof damage, risk of serious injuries
H8	Destructive	60-**90**	(Severest recorded in the British Isles) Severe damage to aircraft bodywork
H9	Super Hailstorms	75-**100**	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
H10	Super Hailstorms	>100	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open
*Approximate range (typical maximum size in bold), since other factors (e.g. number and density of hailstones, hail fall speed and surface wind speeds) affect severity.			

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that was addressed was severe thunderstorms. The report analyzed the different aspects of normal life might be affected by a severe thunderstorm. Table 3-14 contains information from that analysis of severe thunderstorms.

Table 3-14: EMAP Impact Analysis: Severe Thunderstorms

Subject	Detrimental Impact
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for incident areas and moderate to light for other adversely affected areas.
Health and Safety of Personnel Responding to the Incident	Localized impact expected to limit damage to personnel in the areas at the time of the incident
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible
Delivery of Services	Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services
The Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the storm or HazMat spills
Economic and Financial Condition	Losses to private structures covered, for the most part, by private insurance
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Source: Missouri State Hazard Mitigation Plan, 2010

The future estimated severity of high wind, hail and lightning is shown in Table 3-15.

Table 3-15: High Wind, Hail and Lightning-Estimated Future Severity

Event	Severity Level
High Winds	Limited
Hail	Negligible
Lightning	Negligible

Severe thunderstorms losses are usually attributed to associated hazards of hail, downburst winds, lightning and heavy rains. Losses to hail and high wind are typically insured losses that are localized and do not result in disaster declarations. However, in some cases, impacts are severe and widespread and assistance outside the participating jurisdiction’s capabilities is necessary. Hail and wind also can have devastating impacts on crops. Severe thunderstorms-related heavy rains that lead to flooding are accounted for in the flooding profile.

Past Occurrences

Thunderstorm Winds

Since 1950, Christian County has experienced 163 thunderstorm and high wind events. The high winds of these thunderstorms caused over $10 million in property damage since 1950. Those events which have resulted in damages are shown in Table 3-16. In April of 1996, a thunderstorm complex containing straight-line winds of 80 mph affected the western part of the county. The main damage was in a path from Billings to Clever where over a total of 150 homes and businesses sustained damage. The hardest hit was the City of Clever where 100 homes and businesses were severely damaged. Two people were injured in Clever when winds hit a mobile home park, overturning several trailers. This event resulted in $2.5 million of property damage. Another thunderstorm event in April of 2000 damaged three area junior high and high schools. The powerful winds of this storm downed numerous trees and utility poles all throughout the county, causing over $300,000 worth of property damage.

Table 3-16: Thunderstorm Winds History – Christian County, 1994 - 2010

Location	Date	Death	Injury	Property Damage
Nixa	4/21/1994	0	0	$5,000
Ozark	6/07/1994	0	0	$5,000
Oldfield	1/17/1996	0	0	$2,000
Billings	4/28/1996	0	2	$2,500,000
Linden	6/18/1996	0	0	$15,000
Billings	6/18/1996	0	0	$15,000
Billings	7/22/1996	0	0	$5,000
Linden	8/17/1997	0	0	$2,000
Spokane	3/27/1998	0	0	$1,000
Highlandville	5/23/1998	0	0	$5,000
Ozark	5/25/1998	0	0	$3,000
Ozark	6/15/1998	0	0	$3,000
Sparta	11/10/1998	0	0	$30,000
Chestnut Ridge	4/03/1999	0	0	$10,000
Ozark	4/08/1999	0	0	$8,000
Ozark	7/01/1999	0	0	$1,000
Garrison	8/11/1999	0	0	$10,000
Nixa	4/20/2000	0	0	$240,000
Ozark	4/20/2000	0	0	$90,000
Ozark	9/11/2000	0	0	$5,000
Clever	2/09/2001	0	0	$1,000
Riverdale	5/20/2001	0	0	$5,000
Ozark	7/05/2001	0	0	$10,000
Billings	5/08/2002	0	0	$5,000
Nixa	7/24/2004	0	0	$5,000
Nixa	04/05/2005	0	0	$5,000
Ozark	05/03/2006	0	0	$5,000
Ozark	07/10/2006	0	0	$5,000
Ozark	07/10/2006	0	0	$5,000

Table 3-16: Thunderstorm Winds History – Christian County, 1994 - 2010				
Location	**Date**	**Death**	**Injury**	**Property Damage**
Chadwick	08/06/2006	0	0	$5,000
Riverdale	05/26/2007	0	0	$10,000
Sparta	06/30/2007	0	0	$3,000
Nixa	08/18/2007	0	0	$2,000
Terrell	01/08/2008	0	0	$5,000
Spokane	01/08/2008	0	0	$150,000
Clever	04/22/2008	0	0	$50,000
Mc Cracken	07/26/2008	0	0	$2,000
Clever	02/26/2009	0	0	$10,000
Nixa	04/09/2009	0	0	$5,000
Billings	05/08/2009	0	0	$7,000,000
McCracken	07/11/2009	0	0	$50,000
Highlandville	4/24/2010	0	0	$1,000
Ozark Airpark Arpt	4/24/2010	0	0	$5,000
Billings	6/16/2010	0	0	$15,000
Christian Center	7/29/2010	0	0	$15,000
Totals		0	2	$10,382,000
Source: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms				

Hail

Hail is also a result of thunderstorms. Christian County has had 168 hail events dating from January 1, 1950 to June 2, 2010 with 11 events resulting in $71,000 in property damages. On March 3, 1993 a hail event resulted in $50,000 in property damage. Typically the damage is to cars and any satellite receivers that may be located on top of houses. Broken windows are not uncommon, depending on the angle of the hail. Table 3-17 shows the hail history of Christian County.

Table 3-17: Hail History: Christian County, 1955-2010				
Event Type	**No. of Occurrences**	**Death**	**Injury**	**Property Damage**
Hail*	168	0	0	$71,000
*Of all hail events, 11resulted in property damage.				
Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms				

Lightning

A third hazard accompanying storms is lightning. There are three instances in Christian County that resulted in thousands of dollars in property damage. The first event occurred on June 20, 1994, when lightning struck the roof of a vinegar plant in Nixa, setting several tanks on fire. Four of those tanks, containing 65,000 gallons of vinegar, were destroyed. The city incurred $50,000 in property damages as a consequence of this event. The second lightning incident happened on July 28, 2001, when lightning caused both electrical and water damage, estimated to be about $20,000, to the county courthouse in Ozark. The third event occurred on April 5, 2009, when lightning struck a brick mailbox causing it to explode – bricks were thrown through a window of a house and a few vehicles were damaged. It is most likely that other lightning events have occurred in Christian County; however, additional information on historical events is not available. The entire county is at risk from lightning strikes. Table 3-18 provides data lightning history in Christian County.

Table 3-18: Lightning History: Christian County, 1955-2010				
Event Type	**No. of Occurrences**	**Death**	**Injury**	**Property Damage**
Lightning	3	0	0	$80,000
Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms				

Probability

Table 3-19 notes the probability of the severe thunderstorm events of high winds, hail and lightening based on past occurrences between 1955 and 2010.

Table 3-19: Likelihood of Future Thunderstorm Events Occurrence			
Event	**# of Events**	**% Risk**	**Probable Risk of Occurrence**
High Winds	163	296.4	Highly Likely
Hail	164	298.2	Highly Likely
Lightning	3	5.6	Possible

Flood (Riverine and Flash)

Hazard Identification

A flood is a partial or complete inundation of normally dry land areas. There are two basic types of flooding--riverine flooding and flash flooding. Riverine flooding is defined as the overflow of rivers, streams, drains, and lakes due to excessive rainfall, rapid melting of snow and/or ice. Riverine flooding is often associated with frontal systems that produce prolonged periods of rain over a large area. This type of flooding often takes days or weeks to develop and it is the cumulative effect of water from remote and local sources that contributes to water overflowing the banks of rivers within a larger geographic area (NOAA Flood Forecasting). Flash flooding is characterized by a rapid rise of water along waterways or low lying areas that cannot be dispersed by soil absorption, surface runoff, or drainage infrastructures. Flash flooding typically occurs when slow moving or intense thunderstorms travel over an area depositing large amounts of water in a short time. This type of flooding can also result from the sudden release of water held by an ice or debris jam or dam failure. Flash floods are the most life-threatening type of flood because they can develop in just a matter of hours and reach peak levels within minutes. Most flood-related deaths result from this type of flood event (NOAA Flood Forecasting).

Poor drainage and new development in urban areas can cause flash flooding in areas other than those in the floodplains and low lying areas. Sheet flooding is defined as a condition where stormwater runoff forms a sheet of water to a depth of six inches or more and occurs most often in areas where there are no clearly defined drainage channels. This type of flooding is becoming increasingly prevalent as development outstrips the ability of the drainage infrastructure to properly carry and disburse the water flow.

Several factors contribute to flooding. Two key factors are rainfall intensity and duration. Intensity is the rate of rainfall, and duration is how long the rain lasts. Topography, soil conditions, and ground cover also play important roles. Urbanization further aggravates the flooding potential by increasing runoff two to six times over what would occur on natural terrain. As land is converted from fields or woodlands to urban uses and, it loses its ability to absorb rainfall. During periods of urban flooding, streets can become swift moving rivers and viaducts can become death traps as they fill with water. Flooding also occurs due to combined storm and sanitary sewers that cannot handle the tremendous flow of water that often accompanies storm events. Typically, the result is water backing up into basements, which damages mechanical systems and can create serious public health and safety concerns.

Locations

Riverine flooding is most likely to impact developed areas along the Finley and James Rivers, specifically, the city of Ozark and west of Nixa. Flash flooding events pose the most pervasive hazard of the two flood types in the county due to permeability of soils, slopes, increasing urban development and extensive network of streams and rivers. Sustained rainfall or downpours at the rate of one inch per hour have caused street flooding in incorporated areas and made a significant number of low water crossings impassible. In the instances of low water crossings, flash flooding occurs in the floodplain while low-lying areas in all jurisdictions are susceptible to flash floods outside the 100-year floodplain.

According to data available on the NOAA website, there are a number of locations in Christian County that have experienced flooding. The cities of Ozark and Clever have experienced street flooding. In the Ozark area, there has been flooding along the Finley River, on Old Prospect Road between Hwy W and Elk Valley Road, and along Bull's Creek at Center Road five miles south of Ozark. In the Nixa area, there flooding has occurred on Tracker Road west of Hwy 160 and at Eagle Crest, on Hwy 14, on Nicholas Road south of Hwy AA, on Essex Road, and on Riverdale road four miles south of Nixa. There has also been flooding along Hwy F between Nixa and Ozark. Swan Creek has flooded John Ford Road, Marshfield Road, Braden Road and Aztec Road near Sparta. Hwy ZZ has flooded north of Sparta. In the Clever area, there has been flooding along Hwy K. Tory Creek has flooded Hwy O and Hwy F south of Highlandville. Wilson Road has flooded south of Wilson's Creek National Battlefield. South of Republic, Terrell Road, Beal Road and Hwy P have flooded. Hwy CC has flooded near Fremont Hills. Pedelo Creek has flooded near County Road U.

Figures 3-2 and 3-3 display the mapped 100-year floodplain and low water crossings in Christian County.

Figure 3-2: Christian County 100-Year Floodplain

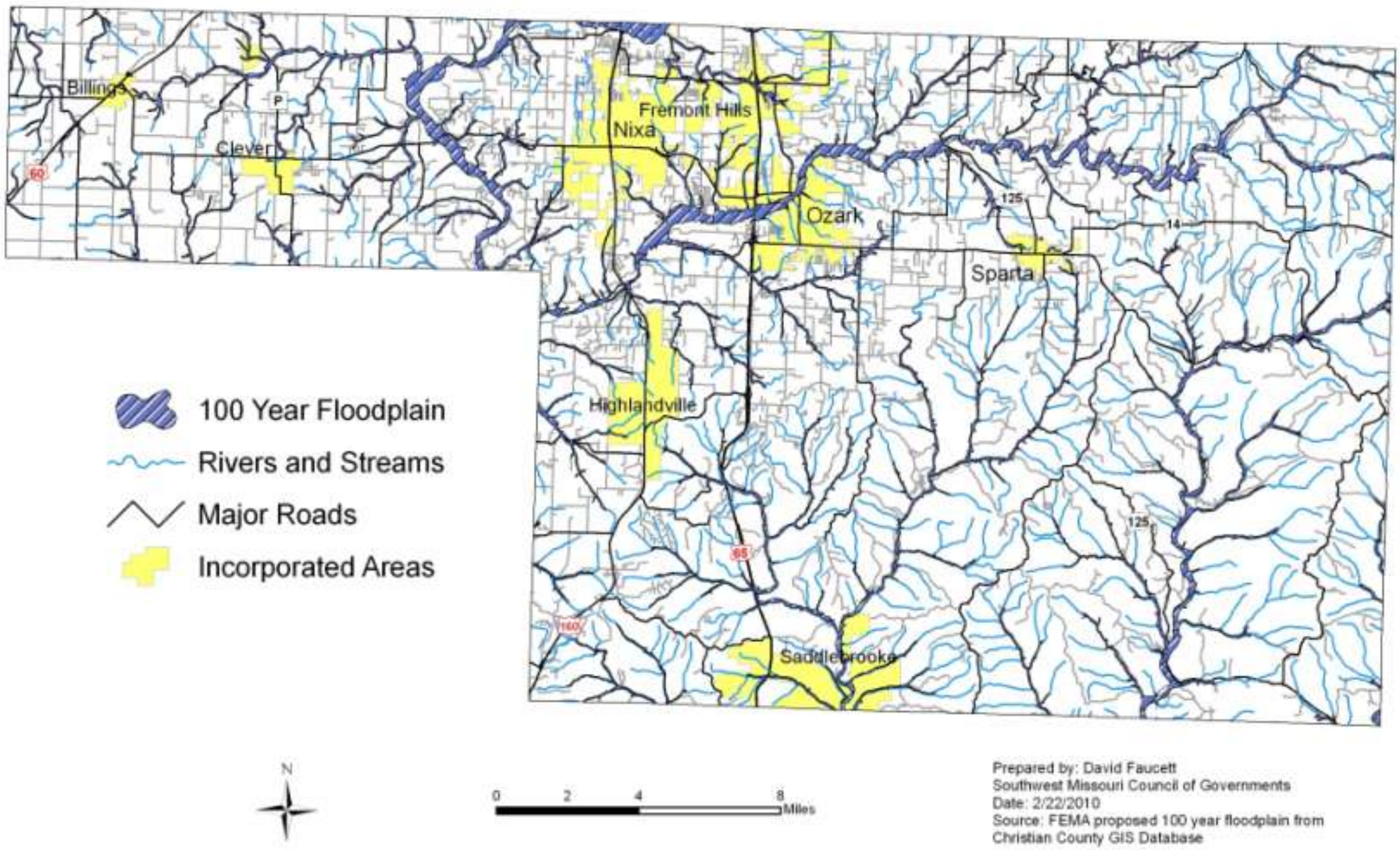
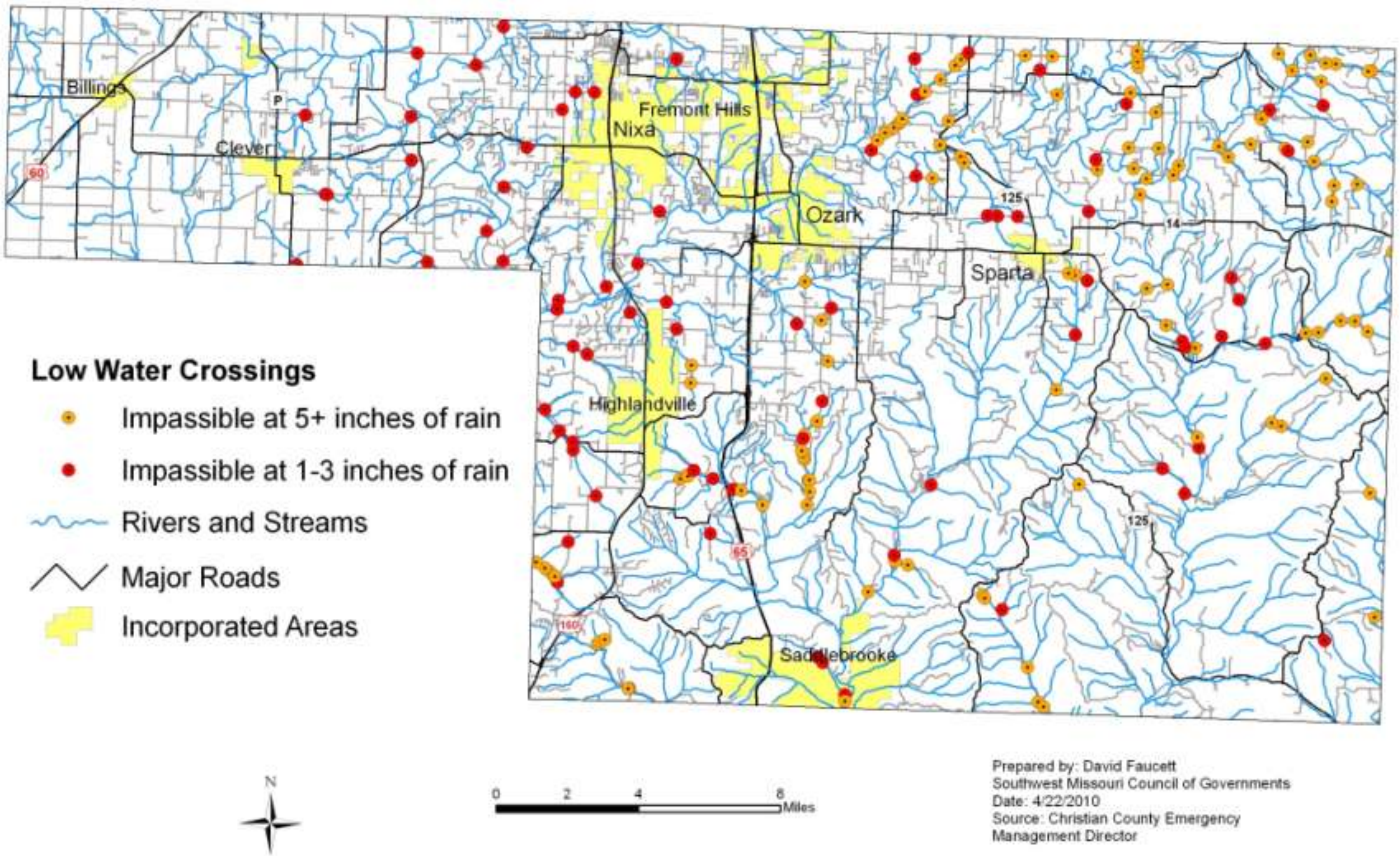


Figure 3-3: Christian County Low Water Crossings



Extent **(**Magnitude/Severity**)**

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that they addressed was Flooding. The report analyzed the different aspects of normal life might be affected by a flood. Table 3-20 contains information from that analysis of Flooding.

Table 3-20: EMAP Impact Analysis: Flooding

Subject	**Detrimental Impact**
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for inundation area and moderate to light for other adversely affected areas.
Health and Safety of Personnel Responding to the Incident	Localized impact expected to limit damage to personnel in the flood areas at the time of the incident.
Continuity of Operations	Damage to facilities/personnel in the area of the incident may require temporary relocation of some operations.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Delivery of Services	Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
The Environment	Localized impact expected to be severe for incident areas and moderate to light for other areas affected by the flood or HazMat spills.
Economic and Financial Condition	Local economy and finances adversely affected, possibly for an extended period of time.
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.

Source: Missouri State Hazard Mitigation Plan, 2010

According to SEMA's Severity Ratings Table, the 2002 flood would qualify as critical. There was some significant damage in 1993 as well, however, most other flood events had minimal impact on quality of life, no critical facilities or services were shut down for more than 24 hours, and property damage was less than 10%. Therefore, the probable severity of future floods could range from critical to negligible in the floodplain areas. See Table 3-21 for event ratings for floods from 1993 to 2009.

Table 3-21: Flood Event Ratings, 1993-2010			
Event	**Critical**	**Limited**	**Negligible**
September 1993	X		
November 1993		X	X
June 1995			X
September 1996			X
June 1997			X
July 1997			X
February 1998			X
March 1998			X
May 1999			X
May 2000			X
June 2000			X
July 2000			X
February 2001			X
December 2001			X
June 2001			X
July 2001			X
May 2002	X		
November 2004			X
January 2008			X
March 2008		X	

Past Occurrences

A total of 55 flood events between 1993 and 2010 are recorded by the NCDC for Christian County. However, the majority of these floods represent flash flooding causing road closures and minimal property and crop damages in Christian County. In the fall of 1993 extensive damage was caused by flooding in Christian County. Two 18-year old women drowned attempting to cross a low water bridge across Pedelo Creek. Swan Creek also flash flooded over numerous farm roads. The Finley and James Rivers both rose out of their banks. Also in late September of 1993, flash flooding along the Finley River damaged numerous businesses as the river reached record levels. More significant damage occurred as the result of flooding in May of 2002. In Christian County, the sudden flooding of the Finley River caused a local car dealership to move over 50 cars from the flood waters. Flood waters also shut down a local restaurant on the north side of town. The owners of the restaurant stated that the river was more damaging than the 1993 flood, which was actually higher. However, this time the river was swifter, more furious, and took longer for the water to recede. The waters damaged several items in the kitchen, including a salad refrigerator, and a grand piano. A local poultry farm had to transport 100 birds to drier land. The flood waters destroyed three pens and covered about two acres of their farmland. See Table 3-22 for the history of flood events from 1993 to 2010 that have resulted in monetary damages.

In April and May of 2002, a series of severe thunderstorms caused disastrous flooding all throughout southern Missouri, including Christian County. The severity of these storms amounted to several million dollars in property damage, as well as deaths and injuries. The flooding began in early May and was prolonged by continuous storms with torrential rainfall. The flash flooding caused by these storms were described by the NWS Hydrologic Information Center as severe and life-threatening, with nearly every road flooded, several water rescues and a number of people left stranded. Loss of agricultural lands, homes, businesses, and infrastructure, as well as the temporary closing of some local businesses contributed to economic losses. The total statewide losses were estimated to be $14.3 million in property damage and $200,000 in crop damage.

Table 3-22: Flood History – Christian County, 1993-2010

Location	Date	Type	Death	Injury	Property Damage	Crop Damage
Ozark	09/25/1993	Flash Flood	0	0	$5,000,000	0
Oldfield	11/14/1993	Flash Flood	2	0	$50,000	0
Central & Southern MO	04/11/1994	River Flood	0	0	$5,000,000 Statewide	$5,000,000 Statewide
SW MO	05/07/2002	Flood	2	0	$14,300,000 Statewide	$200,000 Statewide
SW MO	05/12/2002	Flood	0	0	$700,000	0
Christian	11/24/2004	Flood	0	0	$10,000	0
Billings	01/07/2008	Flash Flood	0	0	$500,000	0
Linden	03/17/2008	Flash Flood	0	0	$5,000,000	0
Totals			4	0	$26,020,000	$5,200,000

Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

Data found in the Nation Climatic Data Center was analyzed to identify the number of events reported by jurisdiction in Table 3-23.

Table 3-23: Summary of Flood Events by Jurisdiction, 1993-2010

Jurisdiction	Events
Billings	3
Clever	2
Highlandville	1
Ozark	11
Nixa	4
Sparta	1

Seasonal patterns of flooding are shown in Table 3-24. The threat of flooding is a more natural occurrence in the spring, when late winter or spring rains, coupled with melting snow, fill river basins with too much water, too quickly. Spring also represents the onset of severe weather in the form of thunderstorms, tornadoes, and heavy rains which generate flash flooding along these storm fronts. However, as demonstrated by the events in Christian County, flooding can occur at anytime of the year.

Table 3-24: Flood Events by Month, 1993-2010	
Month	**# of Events**
January	5
February	4
March	5
April	2
May	8
June	14
July	6
August	1
September	4
October	1
November	3
December	2

Another occurrence of severe or prolonged thunderstorm activity could result in a repeat of the excessive damages caused by the floods of 1993 and 2002.

Probability

Christian County faces several risks for flooding. The surface waters in Christian County drain in a southerly direction with the exception of the extreme panhandle portion of the county. Most waters eventually drain into the White River from the James and Finley Rivers and from Swan and Bull Creeks. The small area draining north includes the Pickeral and Turnback Creeks, which drain into the Sac River. The Finley River flows directly through the City of Ozark, and has caused major urban flooding in the past. The smaller streams and creeks in Christian County mainly affect low water crossings and bridges on county maintained roads and low-lying agricultural land.

The NOAA database of recorded flood events in Christian County, beginning in 1993, was used to distinguish between the probability of riverine and flash floods in Table 3-25.

Table 3-25: Likelihood of Future Riverine and Flash Flood Events in Christian County			
Flood Type	**Events**	**% Risk**	**Probable Risk of Occurrence**
Riverine	13	76.47	Likely
Flash	42	247.06	Highly Likely

Based on the seasonal patterns outlined in the Past Occurrences section, probabilities have been calculated for each month and can be seen in Table 3-26.

Table 3-26: Flood Events by Month, 1993-2010			
Month	**# of Events**	**% Risk**	**Probable Risk of Occurrence**
January	5	29.4	Likely
February	4	23.5	Likely
March	5	29.4	Likely
April	2	11.8	Likely
May	8	47.1	Likely
June	14	82.4	Likely
July	6	35.3	Likely
August	1	5.9	Possible
September	4	23.5	Likely
October	1	5.9	Possible
November	3	17.6	Likely
December	2	11.8	Likely

Probabilities have also been calculated for flooding events in each jurisdiction in the planning area, as shown in Table 3-27.

Table 3-27: Summary of Flood Events by Jurisdiction, 1993-2010			
Jurisdiction	**# of Events**	**% Risk**	**Probable Risk of Occurrence**
Billings	3	17.6	Likely
Clever	2	11.8	Likely
Highlandville	1	5.9	Possible
Ozark	11	64.7	Likely
Nixa	4	23.5	Likely
Sparta	1	5.9	Possible

NFIP Participation and Repetitive Losses

Christian County and the communities of Clever, Fremont Hills, Highlandville, Nixa and Ozark participate in the National Flood Insurance Program (see Part II, page 2-47). Repetitive losses to the NFIP in Christian County are included in Appendix B.

Severe Winter Weather (Snow, Ice, Extreme Cold)

Hazard Identification

Severe winter weather, including winter storm, heavy snow, ice storms and extreme cold, can affect any area of Missouri. Severe weather, such as snow, ice storms and extreme cold can cause injuries, deaths and property/crop damage in various ways. Winter storms are considered deceptive killers because most deaths are indirectly related to the storm. Causes of death range from traffic accidents due to adverse driving conditions such as icy roads, to heart attacks caused by overexertion while shoveling snow and other related activities. Hypothermia or frostbite may be considered the most direct cause of death and injuries which can be attributed to winter storms and/or severe cold.

Winter weather can range from a moderate snow over a few hours to blizzard conditions with blinding wind-driven snow that lasts several days or periods of large ice accumulation. Some winter weather events may be large enough to affect several states, while others may affect only a single community. Many winter weather events are accompanied by low temperatures and heavy and/or blowing snow, which can severely reduce visibility.

Winter Storm

A Winter Storm is a winter weather event containing a mixture of snow, cold, wind, sleet and freezing rain. They can cause driving to be dangerous and can cause power outages.

Heavy Snow

A heavy snow event contains large amount of just snowing falling over a period of time. Large amounts of snow can cause travel to become dangerous and the sheer weight of the snow can cause roofs and structures to collapse.

Ice/Sleet/Freezing Rain

Sleet is raindrops that freeze into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects; however, it can accumulate like snow and cause a hazard to motorists. An ice storm occurs when freezing rain falls onto a surface with a temperature below freezing; this causes it to freeze to surfaces, such as trees, cars, and roads, forming a glaze of ice. Even small accumulations of ice can cause a significant hazard. Heavy accumulations of ice can bring down trees, electric power lines and poles, telephone lines and communications towers. Such power outages create an increased risk of fire, as home occupants seek the use of alternative fuel sources (wood, kerosene, etc. for heat, and fuel burning lanterns or candles for emergency lighting).

Wind Chill and Extreme Cold

In addition to severe winter weather such as snow and ice, Wind Chill factor can also be dangerous for any community. Wind Chill is defined by National Weather Service as the temperature it “feels like” outside and is based on the rate of heat loss from exposed skin caused by the effects of wind and cold. As the wind increases, the body is cooled at a faster rate causing the skin temperature to drop. Wind Chill does not impact inanimate objects like car radiators and exposed water pipes, because these objects cannot cool below the actual air temperature. Table 3-28 shows the risk levels for extreme cold according to the National Weather Service in Springfield, MO.

Table 3-28: National Weather Service Extreme Cold Risk Legend

Risk Level	Definition
None	Minimum apparent temperature greater than or equal to 10 degrees F
Limited	Minimum apparent temperature -9 to 9 deg. F
Elevated	Minimum apparent temperature -10 to -24 deg. F
Significant	Minimum apparent temperature -25 to -34 deg. F
Extreme	Minimum apparent temperature less than or equal to -35 degrees F
Source: National Weather Service	

Location

While severe winter weather is more prevalent north of the Missouri River, it frequently strikes all of Christian County during its seasonal pattern. No parts of the county are exempt from this natural hazard. Winter storm events in which borderline conditions exist between freezing rain and icing conditions instead of rain or snow are highly unpredictable. The duration of the more serious events combined with other factors, such as high winds, are also highly unpredictable. The degree of severity may be localized to a small area due to a combination of climatic conditions.

Rural areas often see the effects of severe winter weather more than cities. Lower traffic levels allow snow or ice to accumulate on rural roads while road crews work to clear many miles of roads throughout the county. In southwest Missouri, it is not uncommon for schools in the small towns and rural areas to close after only a relatively low snowfall due to the difficulty of driving.

Extent (*Magnitude/Severity****)***

The costs of severe winter weather are difficult to measure. In addition to damages that can result from ice storms, crops and livestock can be killed or injured due to deep snow or severe cold. Local governments, home owners, businesses and power companies may be faced with spending hundreds of thousands of dollars for repair, restoration of services, plowing, debris removal and landfill hauling.

All types of winter weather will affect Christian County. Although the county has experienced several severe winter weather events that caused damages and economic loss, the overall severity of events is limited. There has been no past loss of life in the county. Primary roads are generally not closed for more than 24 hours. Schools may close for several days, but are not critical to day to day operations of the county or municipalities. Most major business and government offices/services essential to day to day life continue to function. Severe winter weather typically has not caused major disturbances in day to day life, and based on historical occurrences, the probable severity of future events would be negligible for essential government services to limited for farmers and small business.

The types of watches and warnings issued by the National Weather Service during severe winter weather events are listed below:

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. Often the greatest hazard is 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.

Blizzard Warning: Snow and strong winds will combine to produce a blinding snow (near zero visibility), deep drifts and life threatening wind chill.

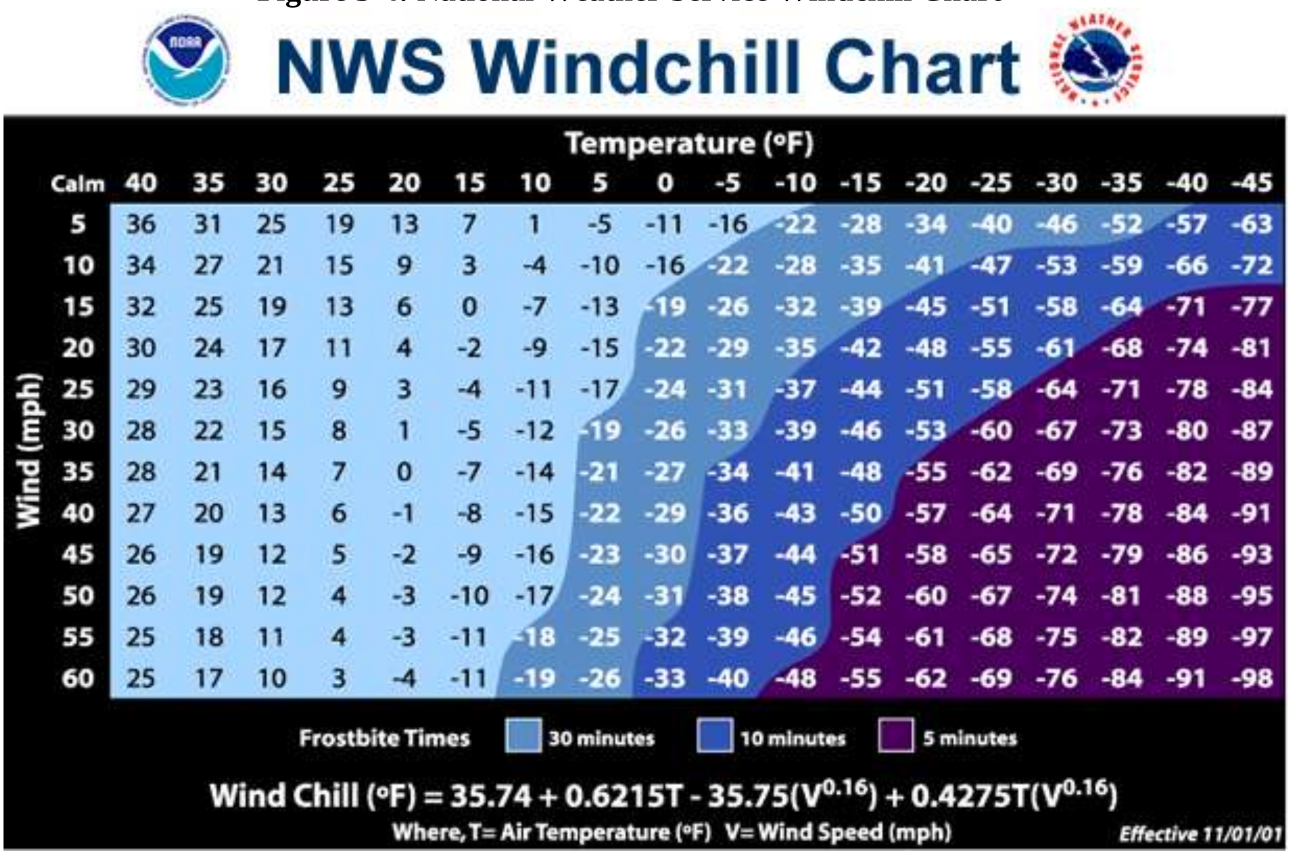
Source: NWS http://www.erh.noaa.gov/er/iln/winter/PSA4.htm

Prolonged exposure to wind chill conditions can cause frostbite or hypothermia for an individual. Frostbite, according to the Centers for Disease Control and Prevention is an injury to the body caused by freezing body tissue. The most susceptible parts of the body are the extremities such as fingers, toes, ear lobes, or the tip of the nose symptoms include a loss of feeling in the extremity and a white or pale appearance. Medical attention is needed immediately for frostbite. The area should be SLOWLY re-warmed. Figure 3-8 below shows possible wind and temperature conditions and the real temperature's effect on the skin due to the heat loss from exposed skin. The chart below includes three shaded areas of frostbite danger. Each shaded area shows how long (30, 10 and 5 minutes) a person can be exposed before frostbite develops.

Another possible condition of severe winter weather is hypothermia. Hypothermia is defined as an abnormally low body temperature (below 95 degrees Fahrenheit) by the Centers for Disease Control and Prevention. Warning signs include uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness, and apparent exhaustion. Medical attention is needed immediately. If it is not available, begin warming the body SLOWLY. Due to the danger of Wind Chill conditions, The National Weather Service will inform residents when Wind Chill conditions reach critical thresholds. A Wind Chill Warning is issued when wind chill temperatures are life threatening. A Wind Chill Advisory is issued when wind chill temperatures are potentially hazardous. Table 3-29 and Figure 3-4 provide more information about wind chill definitions and the threat of frostbite for prolonged exposure. The Excessive Cold Threat Level in Table 3-30 defines various levels of warnings of possible wind chill or extreme temperatures effect on a given area (NWS).

Table 3-29: Wind Chill Definitions	
Wind Chill Advisory:	Wind chills are expected to be between 20 and -34 degrees
Wind Chill Warning:	Wind chills are expected to be -35 degrees or colder.
Source: NWS http://www.erh.noaa.gov/er/iln/winter/PSA4.htm	

Figure 3-4: National Weather Service Windchill Chart



NWS Windchill Chart

Temperature (°F)

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

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

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

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

Effective 11/01/01

Table 3-30: Excessive Cold Threat Level	
Excessive Cold Threat Level	**Threat Level Descriptions**
Extreme	**"An Extreme Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -35° F or below for 3 hours or more. Or, lowest air temperature less than or equal to -20° F.
High	**"A High Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -28° F to -35 ° F for 3 hours or more. Or, lowest air temperature -15° to -20° F.
Moderate	**"A Moderate Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -20° F to -28 ° F or below for 3 hours or more. Or, lowest air temperature -10° to -15° F.
Low	**"A Low Threat to Life and Property from Excessive Cold."** It is likely that wind chill values will drop to -15° F to -20 ° F or below for 3 hours or more. Or, lowest air temperature -5° to -10° F.
Very Low	**"A Very Low Threat to Life and Property from Excessive Cold."** It is likely that that wind chill values will drop to -10° F to -15 ° F or below for 3 hours or more. Or, lowest air temperature zero to -5° F.
Non-Threatening	**"No Discernable Threat to Life and Property from Excessive Cold."** Cold season weather conditions are non-threatening.
Note: Cold season weather conditions become hazardous when the associated cold is considered to be "excessive" according to local standards. Cold temperatures may support the occurrence of a freeze, low wind chills, freezing/frozen precipitation, and/or frost.	

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that they addressed was severe winter weather. The report analyzed the different aspects of normal life might be affected by a severe winter weather. Table 3-31 contains information from that analysis of severe winter weather.

Table 3-31: EMAP Impact Analysis: Severe Winter Weather	
Subject	**Detrimental Impact**
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for inundation area and moderate to light for other adversely affected areas.
Health and Safety of Personnel Responding to the Incident	Adverse impact expected to be severe for unprotected personnel and moderate to light for trained, equipped, and protected personnel.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the areas of the incident. Power lines and roads most adversely affected.
Delivery of Services	Localized disruption of roads, facilities, and/or utilities caused by incident may postpone delivery of some services.
The Environment	Environmental damage to trees, bushes, etc.

Table 3-31: EMAP Impact Analysis: Severe Winter Weather	
Subject	**Detrimental Impact**
Economic and Financial Condition	Local economy and finances may be adversely affected, depending on damage.
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Fulfillment of some contracts may be difficult. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.
Source: Missouri State Hazard Mitigation Plan, 2010.	

Past Occurrences

Since 1994, Christian County has experienced 30 occurrences of winter storm, heavy snow, ice storm, and/or extreme cold. There are no reported deaths for these events. However, there were substantial property damages and some crop damage. Table 3-32 summarizes these severe winter weather occurrences, while Table 3-33 lists details for those events that resulted in damages in Christian County.

Table 3-32: Severe Winter Weather History - Christian County, 1994-2010					
Event Type	**# of Occurrences**	**Death**	**Injury**	**Property Damage**	**Crop Damage**
Winter Storm	17	0	0	$ 3,185,000 34 Counties	$0
Heavy Snow	5	0	0	$ 6,120,000 39 Counties	$0
Ice Storm	6	0	0	$1,425,000	$0
Extreme Cold	2	0	0	$125,000 34 Counties	$105,000 34 Counties
Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms					

Table 3-33: Severe Winter Weather Events Details - Christian County, 1994-2010					
Event Type	**Date**	**Death**	**Injury**	**Property Damage**	**Crop Damage**
Winter Storm					
Southwest MO	1/07/1995	0	0	$15,000 13 counties	$0
Southwest MO	1/18/1995	0	0	$100,000 22 counties	
Southwest & South-central MO	01/01/1996	0	0	$10,000 13 counties	$0
Southern Missouri	01/01/1999	0	0	$2,800,000 33 counties	$0
Southwest & South-central MO	03/19/1999	0	0	$260,000 23 counties	$0
Heavy Snow					
Southern Missouri	03/08/1994	0	0	$5,000,000 39 counties	$0
Central & Southern MO	01/08/1997	0	0	$670,000 30 counties	$0
Missouri Ozarks	12/12/2000	0	0	$450,000 34 counties	$0
Ice Storm					
Christian County	11/24/1996	0	0	$400,000	$0
Central & Southern MO	02/21/2001	0	0	$25,000 31 counties	$0
Southwest Missouri	01/14/2007	0	0	$1,000,000 9 counties	$0
Extreme Cold					
Southern Missouri	12/12/2000	0	0	$125,000 34 counties	$105,000 34 counties
Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms					

Winter Storm

Seventeen winter storms are recorded which affected many counties throughout the southwest, south-central and central regions of Missouri. Of these seventeen events, five resulted in total property damages of $3,070,000 for all counties. Most damages from these events resulted from downed power lines and trees. The thirteen winter storm events caused several automobile accidents; however, no deaths or injuries were directly related to the storms.

Heavy Snow

Christian County experienced five heavy snow events since 1994, three of which caused over $6,120,000 in damages in the southwest and south-central regions of the state. Heavy snowfall on March 8, 1994 caused an estimated $5 million in property damages throughout a 39 county area of southern Missouri. Much of the damages from this event were due to downed power lines and collapse of older roofs on homes and barns. On January 8, 1997, heavy snow resulted in $670,000 in damages, mostly due to the costs of snow removal. The third event occurred on December 12, 2000 when over a foot of snow blanketed the area, resulting in $450,000 in losses from collapsing roofs and carports and snow removal. Damages are not recorded for the heavy snowfall on December 10, 2003. The entire county is at risk from heavy snow events. See Table 3-34 for occurrences of snowfall extremes by month from 1948 to 2001.

Table 3-34: Monthly Snowfall Extremes, 1948-2001

Month	High (in)	Year	1-Day Max (in)	Date
January	18.5	1977	6.0	01-31-1982
February	18.0	1993	16.0	02-08-1980
March	16.0	1970	8.0	03-12-1968
April	3.0	1971	3.0	04-05-1971
May	0.0	-	-	-
June	0.0	-	-	-
July	0.0	-	-	-
August	0.0	-	-	-
September	0.0	-	-	-
October	0.5	1993	0.5	10-30-1993
November	8.0	1972	8.0	11-19-1972
December	12.0	1990	8.0	12-23-1966
Season (July-June)	24.0	1983-1984	16.0	02-08-1980

Source: http://mrcc.sws.uiuc.edu/climate_midwest/historical/snow/mo/236452_ssum.html

Ice Storm

Ice storms can occur alone or with snow. The NCDC Storm Events database indicates six ice storm events without snow in Christian County since 1996. The most significant event was January 12, 2007, which is noted as one of the greatest disasters to ever impact southwest Missouri. Several counties experienced ice accumulations up to two and a half inches. Power outages and catastrophic tree damage were the main impacts resulting from this historic event. Power outages occurred for over three weeks in many areas. Several indirect fatalities due to the extreme elements were documented. Carbon monoxide poisoning occurred within a few homes as gas generators were being used in garages, which allowed for dangerous levels of carbon monoxide to seep into houses.

The second most significant of these ice storms struck Christian County on November 24, 1996, covering the area with freezing rain that resulted in ice accumulations up to two inches thick. Power lines and trees were downed by the weight of the ice, causing widespread power outages. The community of Highlandville was the hardest hit with power outage for a week. Damages from this event totaled $400,000. The third ice storm to affect Christian County and 30 other counties in southern Missouri occurred on February 21, 2001. A total of $25,000 in damages was recorded for this event, primarily due to downed power lines.

Although the NCDC database does not include records for winter storms in Christian County prior to 1994, people throughout the southwest Missouri region remember the ice storm on December 25, 1987. A light rain began to fall early on December 25th, turning to ice by noon. Precipitation continued to fall through the day and evening; as the ice accumulated, the weight snapped tree limbs and uprooted trees, downed power lines, and collapsed roofs and buildings. Power outages were extensive through many counties, causing disruption to residences, business, agricultural production, and government operation. Local residents remember this to be one of the worst ice storms to hit the southwest Missouri area. The entire county is at risk from ice storms.

Extreme Cold

Two extreme cold temperature events are recorded for Christian County. Of the two events, one resulted in property and crop damage in several counties. This event occurred on December 12, 2000 when a deep trough of low pressure came through the area. The extremely cold temperatures, combined with snow and ice, caused water main breakage, roof leakage and hazardous roadways. In some cases farmers had difficulty feeding their livestock and several calves died from severe stress caused by the cold. In all, this event resulted in an estimated $125,000 property loss and $105,000 crop loss. The entire county is at risk from extreme cold.

Probability

Christian County's risks for future severe winter weather events are noted in Table 3-35. It is likely that the county will experience a severe winter weather event in any given year, based on occurrences between 1994 and 2010.

Table 3-35: Likelihood of Severe Winter Weather Events			
Event Type	**# of Events**	**% Risk**	**Future Occurrence**
Winter Storm	17	106.3	Likely
Heavy Snow	5	31.3	Likely
Ice Storm	6	37.5	Likely
Extreme Cold	2	12.5	Likely

Drought

Hazard Identification

Drought is defined as a period of prolonged dryness. The impacts of drought are not limited to agriculture, but can extend to encompass the whole economy. Impacts can adversely affect a community's water supply, the corner grocery store, commodity markets, and tourism. According to the National Drought Mitigation Center, drought costs the U.S. economy an average of $7-9 billion a year. While there's no cost estimate for the Droughts of 1999-2000 and 2006 that gripped Missouri and much of the nation, losses from the Great Drought of 1988-89 were assessed at $39 billion.

Drought's impact on society results from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand development places on groundwater reservoirs. A drought situation often is exacerbated by development practices that decrease the percolation of surface water into groundwater reservoirs. Recent droughts in both developing and developed countries and the resulting economic and environmental impacts have underscored society's vulnerability to this "natural" hazard.

Current drought literature commonly distinguishes between four categories of drought:

- Meteorological Drought – This is a reduction over time. This definition is regionally based. In the United States, this is indicated by less than 2.5 mm of rainfall in 48 hours, which is the first indication of drought.

- Agricultural Drought – This happens when soil moisture cannot meet the demands of a crop. This happens after a meteorological drought but before a hydrological drought.

- Hydrological Drought – This refers to reduction in surface and subsurface water supplies. This is measured through stream flow and lake, reservoir, and ground water levels.

- Socioeconomic Drought – This occurs when water shortages affect people, either in terms of water supply or economic impacts (i.e. loss of crops so price increases).

Location

There are no likely locations for future occurrences as the threat from this hazard is county-wide.

Extent (*Magnitude/Severity****)***

It is possible for Christian County and the state of Missouri to experience a drought at any time throughout any given year. Table 3-36 shows the probable risk for Christian County experiencing any one phase of drought:

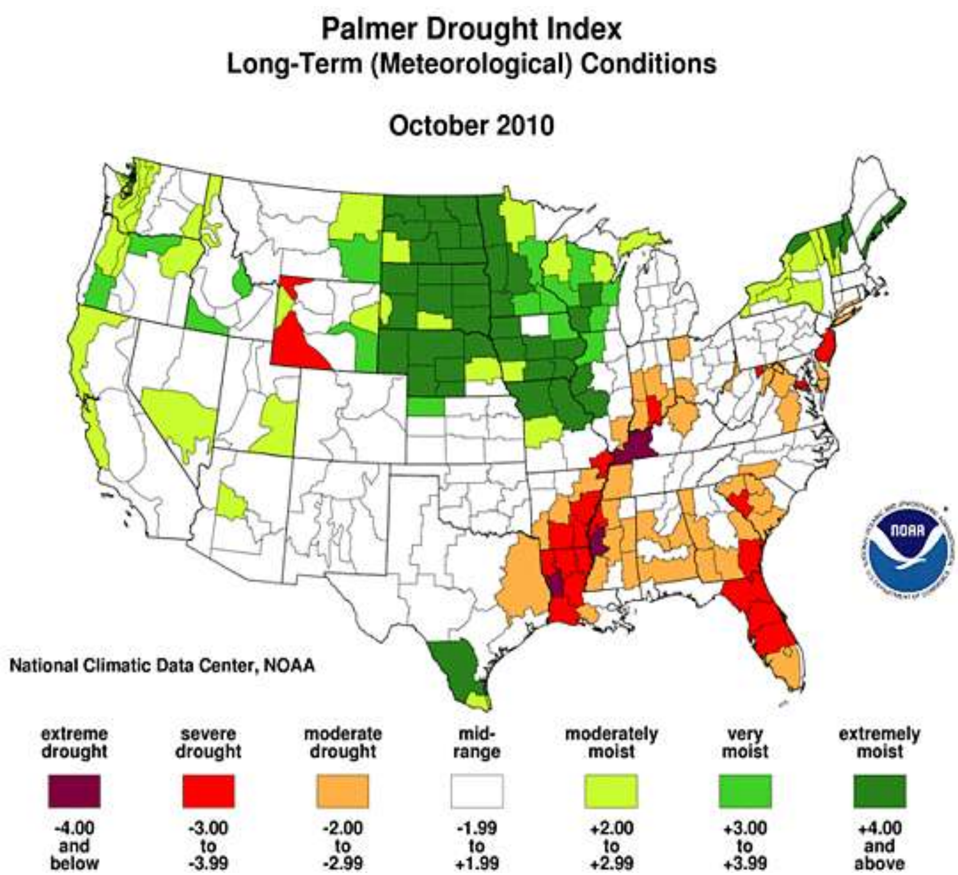
Table 3-36: Severity of Drought – Christian County

Phase	Probable Severity
I	Negligible
II	Limited
III	Critical
IV	Critical

The most commonly used indicator of drought and drought severity is the Palmer Drought Severity Index (PDSI), jointly published by the NOAA and the United States Department of Agriculture. The PDSI measures the departure of water supply (in terms of precipitation and stored soil moisture) from demand (the amount of water required to recharge soil and keep rivers, lakes and reservoirs at normal levels). The result is a scale from +4 to -4, ranging from an extremely moist spell to extreme drought. By relating the PDSI number to a regional index, long-term wet or dry tendencies can be determined.

Regional indicators such as the PDSI are limited in that they respond slowly to deteriorating conditions. However, observing surface conditions and groundwater measurements may provide only a snapshot of a very small area. Therefore, the use of a variety of drought indicators is essential for effective assessment of drought conditions, with the PDSI being the primary drought severity indicator. Figure 3-5 displays the PDSI for the month of October, 2010.

Figure 3-5: Palmer Drought Index



Source: Climate Prediction Center, NOAA.
http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html

The American Water Works Association has outlined the phases of drought (see Table 3-37). This outline shows how severe Christian County's water shortage was during the droughts of 1999-2000. It also shows how a small percentage of a water shortage could have had an even larger effect on the economy.

Table 3-37: Phases of Drought	
Phase I – Watch	5-10 % shortage (voluntary reductions)
Phase II – Warning	10-20 % shortage (voluntary or mandatory reductions)
Phase III – Emergency	20-35% shortage (mandatory reductions)
Phase IV – Critical	35-50% shortage (mandatory reductions)
Source*:* http://www.awwa.org/Advocacy/pressroom/drought.cfm	

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that they addressed was drought. The report analyzed the different aspects of normal life might be affected by a drought. Table 3-38 contains information from that analysis of drought.

Table 3-38: EMAP Impact Analysis: Drought	
Subject	**Detrimental Impacts**
Health and Safety of Persons in the Area at Time of Incident	Most damage expected to be agricultural in nature. However, water supply disruptions may adversely affect people.
Health and Safety of Personnel Responding to the Incident	Nature of hazard expected to minimize any serious damage to properly equipped and trained personnel.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan.
Property, Facilities, and Infrastructure	Nature of hazard expected to minimize any serious damage to facilities.
Delivery of Services	Nature of hazard expected to minimize serious damage to services, except for moderate impact on water utilities.
The Environment	May cause disruptions in wildlife habitat, increasing interface with people, and reducing numbers of animals.
Economic and Financial Condition	Local economy and finances dependent on abundant water supply adversely affected for duration of drought.
Regulatory and Contractual Obligations	Regulatory waivers unlikely, but permits expedited. Fulfillment of some contracts may be difficult. Impact may reduce deliveries.
Reputation of or Confidence in the Entity	Ability to respond and recover may be questioned and challenged if planning, response, and recovery not timely and effective.
Source: Missouri State Hazard Mitigation Plan, 2010.	

Past Occurrences

In Missouri, the 1999-2000 droughts began in July of 1999 and developed rapidly into a widespread drought just three months later. The entire state was placed under a Phase I Drought Advisory level by DNR and the Governor declared an Agricultural Emergency. Agricultural reporting showed a 50 percent crop loss from the 50 of the 114 counties, with severe damage to pastures for livestock, corn crops, and soybean. In October of 1999 the U.S. Agriculture Secretary declared a federal disaster, making low-interest loans available to farmers in Missouri and neighboring states. The drought intensity increased through autumn and peaked at the end of November 1999. That five-month period became known as the second driest period since 1895.

A wetter than normal winter diminished dry conditions in central and southern Missouri, but long-term moisture deficits continued to exist. Overall dry conditions returned through much of the state in March 2000, and costly wildfires and brush fires (26 total Missouri wildfires were reported in 1999-2000, National Climatic Data Center) erupted in many counties. By May the entire state was under a Phase II Drought Alert level. By mid-July 2000 there was some relief for parts of the state but not enough. Several counties were still in a Phase II or were upgraded to Phase III Drought Conditions. Christian County was never upgraded and was downgraded to normal levels by the end of July 2000. The three occurrences of recorded drought caused regional crop losses totaling and estimated $660,000. The 2006 drought occurred over a four month period beginning in January of that year. This drought was classified as severe in Christian County. All time record dry conditions were experienced at both Springfield and Joplin in southwest Missouri. Although this drought was severe it did not result in reported damages as it occurred outside of the growing season.

Probability

It is possible for Christian County and the state of Missouri to experience a drought at any time throughout any given year. Table 3-39 shows the probable risk for Christian County experiencing any one phase of drought:

Table 3-39: Likelihood of Drought - Christian County

Phase	Probable Risk
I	Likely
II	Possible
III	Possible
IV	Unlikely

Heat Wave

Hazard Identification

According to the NOAA, heat is the number two killer among natural hazards. Only the cold temperatures of winter take a greater toll. In contrast to the visible, destructive, and violent nature of floods, hurricanes, and tornadoes, a heat wave is a silent killer. Heat kills by overloading the human body's capacity to cool itself. In the disastrous heat wave of 1980, more than 1,250 people died nationwide. In a normal year, about 175 Americans succumb to the bodily stresses of summer heat.

Air temperature is not the only factor to consider when assessing the likely effects of a heat wave. High humidity, which often accompanies heat in Missouri, can increase the harmful effects of heat. Relative humidity must also be considered, along with exposure, wind, and activity. The Heat Index devised by the NWS combines air temperature and relative humidity. Also known as the *apparent* temperature, the Heat Index is a measure of how hot it really feels. For example, if the air temperature is 102 degrees and the relative humidity is 55% then it feels like 130 degrees; 28 degrees hotter than the actual ambient temperature.

Location

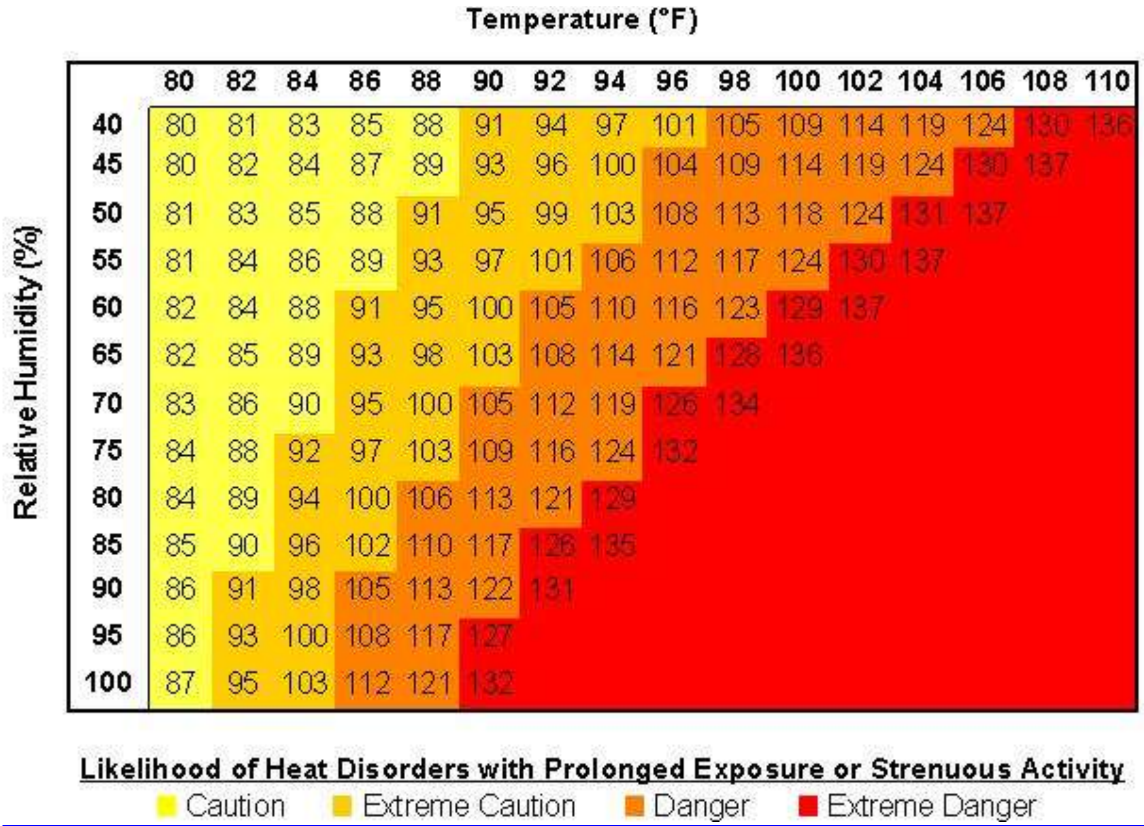
The entire planning area is at risk for Heat Wave.

Extent (*Magnitude/Severity****)***

Figure 3-6 provides a heat index chart. To determine the heat index from this table, find the air temperature along the top of the chart and the relative humidity along the left side. Where the two intersect is the heat index for any given time of day. In addition, the NWS recently 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.

To find the Heat Index from Figure 3-6 shown below, find the air temperature along the top of the chart and the relative humidity along the left side. Where the two intersect is the Heat Index for any given time of day.

Figure 3-6: Heat Index Chart (Temperature & Relative Humidity)



Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity
Caution Extreme Caution Danger Extreme Danger

The definitions of Cautions and Dangers can be found in Table 3-40.

Table 3-40: Risk Level Possible Heat Disorder	
Caution	Fatigue possible with prolonged exposure and physical activity.
Extreme Caution	Sunstroke, heat cramps and heat exhaustion possible.
Danger	Sunstroke, heat cramps, and heat exhaustion likely, and heat stroke possible.
Extreme Danger	Heat stroke highly likely with continued exposure.

Based on 30-year statistics from the National Weather Service indicating the State's mean number of days above 90 degrees during the summer months, Missouri is vulnerable to heat waves ranging from high to moderate risk in the July and August months.

Table 3-41 describes the conditions for The National Weather Service’s three response levels, based upon the Heat Index, in order to alert the public to potential heat hazard. Table 3-42 defines the heat wave severity levels.

Table 3-41: Heat Wave Response Levels	
Heat Index	**Response Level**
Heat Index 115+ F for 3+ hours w/minimum Heat Index mid-70s F for 24 hours or Heat Index 105+ F w/minimum Heat Index mid-70s F for more than 3 days	Warning
Heat Index 105+ F for 3+ hours w/minimum Head Index mid-70s F for 24 hours	Advisory
Potential for Excessive Heat Warning	Watch
Source: NOAA. National Weather Service Forecast Office-Springfield, MO.	

Based on information from the Missouri Department of Health and the National Weather Service, the probability of heat wave in Missouri is moderate and severity is moderate, but could be upgraded to severe.

There are several risk factors associated with heat-related death and illnesses, such as lack of air conditioning, age, or outdoor activities. Heat-related death and illness can occur with exposure to intense heat in just one afternoon, as well as continuous exposure. Heat stress caused by continuous exposure has a cumulative effect.

In addition to the human toll, the MCC, in a paper on the 1999 heat wave, points out the other possible impacts on our environment. These impacts include infrastructure damage and failure, highway damage, crop damage, water shortages, livestock deaths, fish kills, and lost productivity among outdoor-oriented businesses. The future probable severity for Christian County shown in Table 3-42 is based on heat index levels.

Table 3-42: Heat Wave Severity Levels	
Heat Index of 130˚F or higher	**Catastrophic**
Multiple deaths	Highly Likely
Multiple injuries	Highly Likely
Property damage	Likely
Crop damage	Likely
Heat Index of 105˚F to 129˚F	**Critical**
Multiple deaths	Possible
Multiple injuries	Likely
Property damage	Possible
Crop damage	Likely
Heat Index of 90˚F to 104˚F	**Limited**
Multiple deaths	Unlikely
Multiple injuries	Unlikely
Property damage	Possible
Crop damage	Possible
Heat Index of less than 90˚F	**Negligible**
Multiple deaths	Unlikely
Heat Index of less than 90˚F	**Negligible**
Multiple injuries	Possible
Property damage	Unlikely
Crop damage	Possible

Heat waves are often a major contributing factor to power outages (brownouts, etc.) as the high temperatures result in a tremendous demand for electricity for cooling purposes. Power outages for prolonged periods increase the risk to heat stroke and subsequent fatalities due to loss of cooling and proper ventilation. Other interrelated hazards include water shortages, brought on by drought-like conditions and high demand. Local advisories which list priorities for water use and rationing are common during heat waves. Government authorities report that civil disturbances and riots are more likely to occur during heat waves, as well as incidents of domestic violence and abuse. The extreme heat can also have an adverse impact on animals, including livestock and other farm animals. According to the Missouri State Hazard Mitigation Plan, updated in July 2010, the following types of people are at risk for heat related illness and would be severely impacted:

- Those vulnerable to heat stress due to physical condition
    - Older people
    - Children
    - People overweight or underweight
- People with limited independence due to physical or mental disorders
    - People in institutional settings without air conditioning
    - People working in heat under stress (firefighters, police, emergency medical technicians)
    - People in urban environments where heat retention in asphalt, concrete, and masonry is a factor (heat island effect)
    - People with low income who lack resources for air conditioning, transportation, medical care, etc.
- Those with increased risk from work or leisure activities
    - People who work outdoors (utility crews, construction crews, etc.)
    - Military personnel and trainees
    - Athletes
- Those more difficult to reach through normal communications
    - People who live alone
    - People who are homeless
    - People who do not speak English
    - People who cannot read
    - People who are culturally, socially, or geographically isolated

The State Hazard Plan addresses warning signs that the heat is beginning to have an impact on animals. The warning signs are as listed below:

- Restlessness and crowding under shade or at water tanks/areas
- Open-mouthed breathing or panting and increased salivating
- Increased respiration rates
- Gasping and lethargic demeanor

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that was addressed was a heat wave. The report analyzed the different aspects of normal life might be affected by a heat wave. Table 3-43 contains information from that analysis of heat wave.

Table 3-43: EMAP Impact Analysis: Heat Wave	
Subject	**Detrimental Impacts**
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be severe for unprotected personnel and moderate to light for protected personnel.
Health and Safety of Personnel Responding to the Incident	Nature of hazard expected to minimize any serious damage to properly equipped and trained personnel.
Continuity of Operations	Unlikely to necessitate execution of the Continuity of Operations Plan.
Property, Facilities, and Infrastructure	Nature of hazard expected to minimize any serious damage to facilities.
Delivery of Services	Extent of agricultural damage depends on duration. Water supplies and electricity may be disrupted.
The Environment	May cause disruptions in wildlife habitat, increase interface with people, and reduce numbers of animals.
Economic and Financial Condition	Local economy and finances dependent on stable electricity and water supply adversely affected for duration of heat wave.
Regulatory and Contractual Obligations	Regulatory waivers likely unnecessary. Fulfillment of some contracts and deliveries may be difficult if electricity and water disrupted.
Reputation of or Confidence in the Entity	Ability to manage situation may be questioned and challenged if planning and response not timely and effective.
Source: Missouri State Hazard Mitigation Plan, 2010.	

Past Occurrences

Table 3-44 shows the most recent heat waves to affect Christian County and the southern Missouri region. At least 120 people reported heat-related illnesses during these events. Although none of the 16 deaths occurred in Christian County, it is possible that death or illness from a heat wave event could occur in the future. The event of 1994 also caused $50,000 in crop damages within the region. None of these heat waves have happened within the last nine years, but never the less they could still happen at anytime.

Table 3-44: Christian County Regional Heat Waves, 1994-2010		
Date	**Heat Index (°F)**	**Deaths**
June 12, 1994	100+	4
July 23, 1999	105-115	6
August 1, 1999	100+	2
August 27, 2000	100-110	1
September 1, 2000	100	0
July 17, 2001	100+	1
August 1, 2001	100-110	2
Source: NCDC: http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms		

Probability

The National Weather Service defines a heat wave as three consecutive days of 90°F plus temperatures. These high temperatures generally occur from June through September, but are most prevalent in the months of July and August. Missouri experiences about 40 days per year above 90 degrees, based on a 30-year average compiled by the NWS from 1961-1990. July leads this statewide mean with 15 days above 90 degrees, followed by August with an average of 12 days over 90. June and September average 6 days and 4 days respectively for temperatures above 90 during the same 30-year period. In the southwest region of Missouri, including Christian County, days with temperatures of 90 degrees and above generally occur during the month of July. A review of the data for 1999-2002 shows Christian County could experience a brief heat wave every year. Table 3-45 notes the county's risk of experiencing heat waves according to Heat Index severity levels.

Table 3-45: Likelihood of Probable Severity - Heat Wave

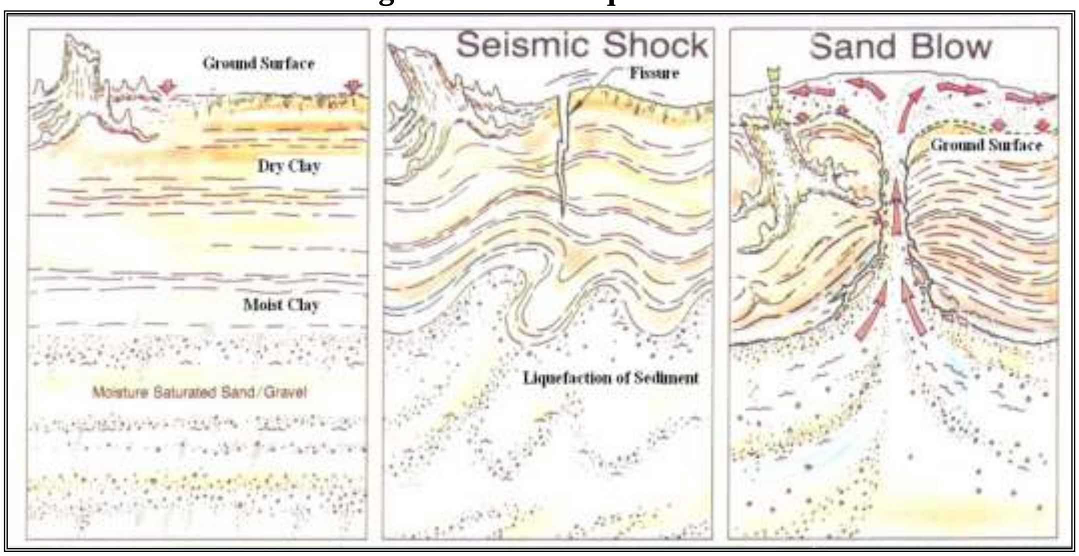
Index	Probable Severity
Extreme Danger	Unlikely
Danger	Possible
Extreme Caution	Possible
Caution	Highly Likely

Earthquake

Hazard Identification

According to SEMA, earthquakes can be defined as shifts in the Earth's crust causing the surface to become unstable. This instability can manifest itself in intensity from slight tremors to large shocks. The duration can be from a few seconds up to five minutes. The period of tremors and shocks can last up to several months. The larger shocks can cause ground failure, landslides, uplifts, and liquefaction and sand blows. Figure 3-7 shows the ground as normal and how the shock of an earthquake can create liquefaction and sand blows.

Figure 3-7: Earthquake Shock



Source: http://www.gsa.state.al.us/gsa/EQ2/newmad.html

The earth's crust is made up of gigantic plates, referred to as tectonic plates. These plates form the lithosphere and vary in thickness from $6^1/_2$ miles (beneath oceans) to 40 miles (beneath mountain ranges) with an average thickness of 20 miles. These plates "float" over a partially melted layer of crust called the athenosphere. The plates are in motion and where a plate joins another, they form boundaries. Plates moving toward each other are called a convergent plate boundary. Plates moving away from each other are called a divergent plate boundary. The San Andreas Fault in California is a horizontal motion boundary, where the Pacific plate is moving north while the North American plate is moving west. These movements release built up energy in the form of earthquakes, tremors, and volcanism (volcanoes). Fault lines such as the San Andreas come all the way to the surface and can be readily seen and identified. There are also fault lines that do not come all the way to the surface (subterranean faults), yet they can store and release energy when they adjust (Missouri State Emergency Management Agency, *Missouri Hazard Analysis*, F-1).

The subterranean faults were formed many millions of years ago on or near the surface of the earth. Subsequent to that time, these ancient faults subsided, while the areas adjacent were pushed up. As this fault zone (also known as a rift) lowered, sediments filled in the lower areas. Under pressure, the sediments hardened into limestones, sandstones, and shales – thus burying the rifts. The pressures on the North American plate and the movements along the San Andreas Fault by the Pacific plate have reactivated the buried rift(s) in the Mississippi embayment. This rift system is called the Reelfoot Rift.

Location

The entire planning area is at risk for earthquakes.

Extent (*Magnitude/Severity****)***

In 2003, the United States Geological Survey (USGS) and the Center for Earthquake Research and Information at the University of Memphis (CERI) updated forecasts of earthquake probability in the New Madrid fault zone. The probability of a magnitude 6.0 or greater earthquake is 25 to 40 percent through the year 2053. The probability of a repeat of the 1811-1812 earthquakes, estimated at a 7.5 to 8.0 magnitude, is seven to 10 percent through the year 2053 (USGS, *Scientists Update New Madrid*). With almost 12.5 million people living in the area, steps are being taken to reduce the hazard to the citizens and property in the area. Based on the information from CERI, the probability of an earthquake is rated as moderate and the severity is rated high.

New Madrid earthquake damage covers over more than 20 times the area of the typical California earthquake because of the underlying geology in the Midwest. Ground shaking affects structures close to the earthquake epicenter but also can damage structures far away. Certain types of buildings at a significant distance from the earthquake epicenter, such as unreinforced masonry structures, tall structures without adequate lateral resistance, and poorly maintained structures are specifically susceptible to large earthquakes.

While the Richter Scale is a measurement of the energy released by an earthquake, the effects of an earthquake will vary from place to place. The Modified Mercalli Intensity Scale is used by seismologists to describe the effects of an earthquake, at a given place, on the natural environment, the built environment and people. An abbreviated description of the Modified Mercalli Intensity Scale is noted below:

I. Not felt except by a very few under especially favorable conditions.
II. Felt only by a few persons at rest, especially on upper floors of buildings.
III. Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV. Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI. Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII. Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI. Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII. Damage total. Lines of sight and level are distorted. Objects thrown into the air.

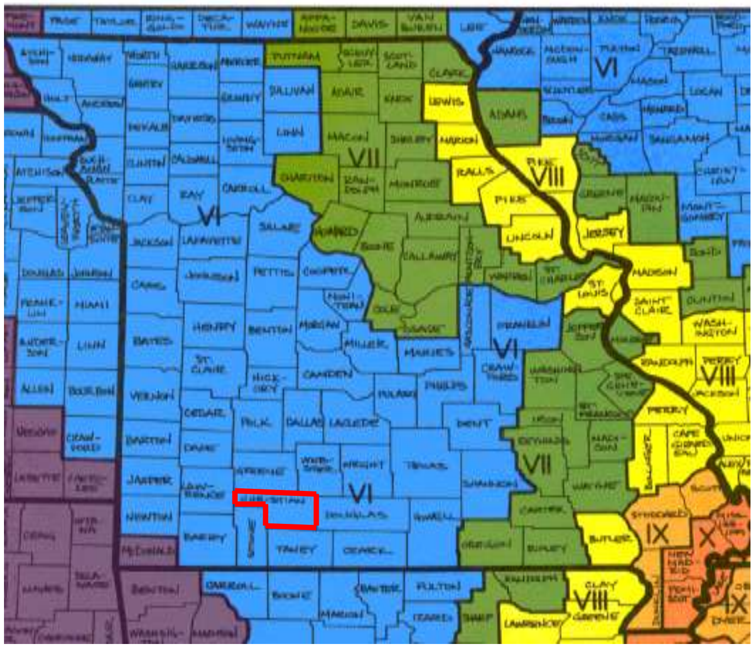
Source: Abridged from *The Severity of an Earthquake*. U. S. Geological Survey Series General Interest Publication. http://pubs.usgs.gov/gip/earthq4/severitygip.html

Indirect hazards may also occur at great distances from large earthquakes. Liquefaction (disintegration of alluvial soils), landslides and life-line disruptions will most affect areas closest to the epicenter, but may occur at significant distances. Secondary effects of such an earthquake could include fire, building collapse, utility disruption, flooding, hazardous materials release, environmental impacts and economic disruptions/losses.

SEMA's Projected Earthquake Intensities indicate Christian County is at risk for a Level V impact on the Modified Mercalli Intensity Scale from a 6.7 magnitude earthquake; Level VI from a 7.6 magnitude earthquake; or Level VII in the event of an 8.6 magnitude earthquake centered within the New Madrid Fault.

Figure 3-8 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.

Figure 3-8: Projected Earthquake Intensities, 7.6 Magnitude



Based on the Projected Earthquake Intensities map and Modified Mercalli damage scale, the future probable severity for each level is shown in Table 3-46.

Table 3-46: Earthquake Probable Severity	
Modified Mercalli levels	**Future Probable Severity**
I-V	Negligible
VI	Limited
VII	Critical
VIII-XII	Catastrophic

The impact on the general public, businesses, life-line services, and the infrastructure may be radically lessened if precautions are undertaken at multiple levels. Increased education and subsequent action can reduce the potential effects of earthquakes, and this can be done in conjunction with preparations for other natural hazards. A public information program that educates the public on the risks and potential impacts of earthquake would be the most beneficial to Christian County residents and businesses.

Individuals and all levels of government have roles in reducing risk to earthquake hazards. Individuals can reduce their own vulnerability by taking some simple and inexpensive actions within their own households. Local government can take action to lower the threat through the proper regulation of at risk sites, assuring that vital or important structures (police, fire, medical) resist hazards, and developing infrastructure in a way that decreases risk. State agencies and the legislature can assist other governmental levels by providing incentives for minimizing hazards.

Since Christian County is located a distance away from the New Madrid Fault, the likely impact of a 6.0 magnitude earthquake would be negligible to limited. A higher magnitude earthquake would cause more adverse effects on the county. The following evaluation presumes the impact of a Level V, magnitude 6.0 earthquake on Christian County:

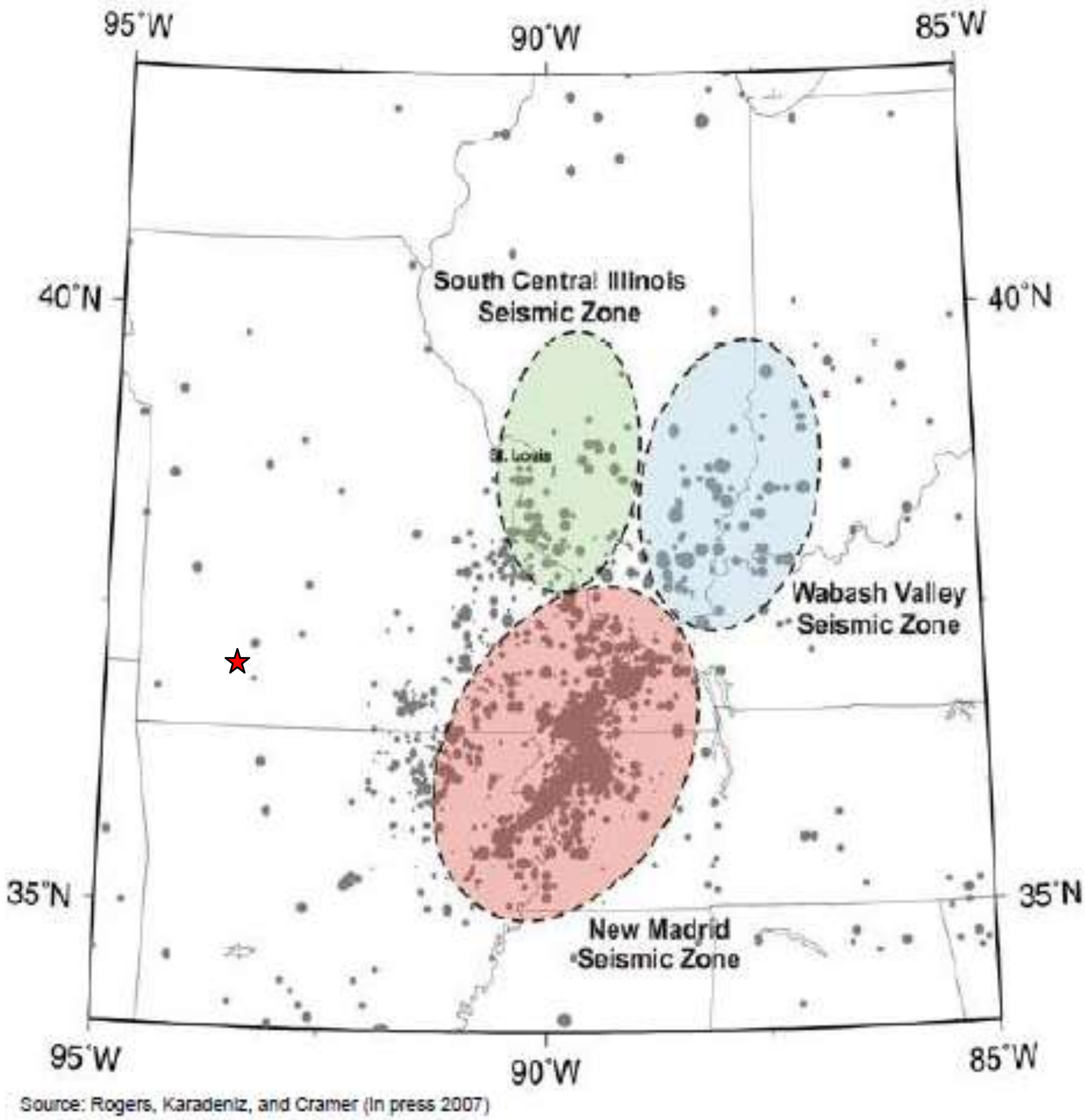
Past Occurrences

Four earthquake source zones -- the New Madrid Fault, the Wabash Valley Fault, the Illinois Basin and the Nemaha Uplift -- could affect Christian County because of their close proximity. The New Madrid fault poses the greatest threat and has the longest history of activity. This fault runs from north Arkansas through southeast Missouri, western Tennessee and Kentucky to the Illinois side of the Ohio River Valley. During the winter of 1811-1812, three earthquakes estimated to have been of a magnitude 7.5 or greater were centered on the New Madrid fault in southeast Missouri. Thousands of aftershocks continued for years. Since 1811, 35 events of magnitude 5.0 or greater have affected Missouri and several surrounding states.

Significant earthquakes, each about magnitude 6, occurred in 1843 near Marked Tree, Arkansas, and on October 31, 1895 near Charleston, Missouri. In November 1968, a magnitude 5.5 earthquake centered in southeastern Illinois caused moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. The afflicted areas included all or portions of 23 states. Smaller earthquakes have occurred throughout southeastern parts of Missouri. While the magnitude of the earthquakes may not be as great, they are still destructive and dangerous. Several smaller earthquakes can weaken structures and foundations, placing such structures in danger of collapse during an earthquake of greater magnitude.

The Figure 3-9 was taken from the Missouri State Hazard Mitigation Plan and shows the Christian County's, the red star, geographical relationship to the Wabash Valley, South Central Illinois and the New Madrid Seismic zones. The dots represent historic seismic activity and the diameter of the dot represents the strength of the activity.

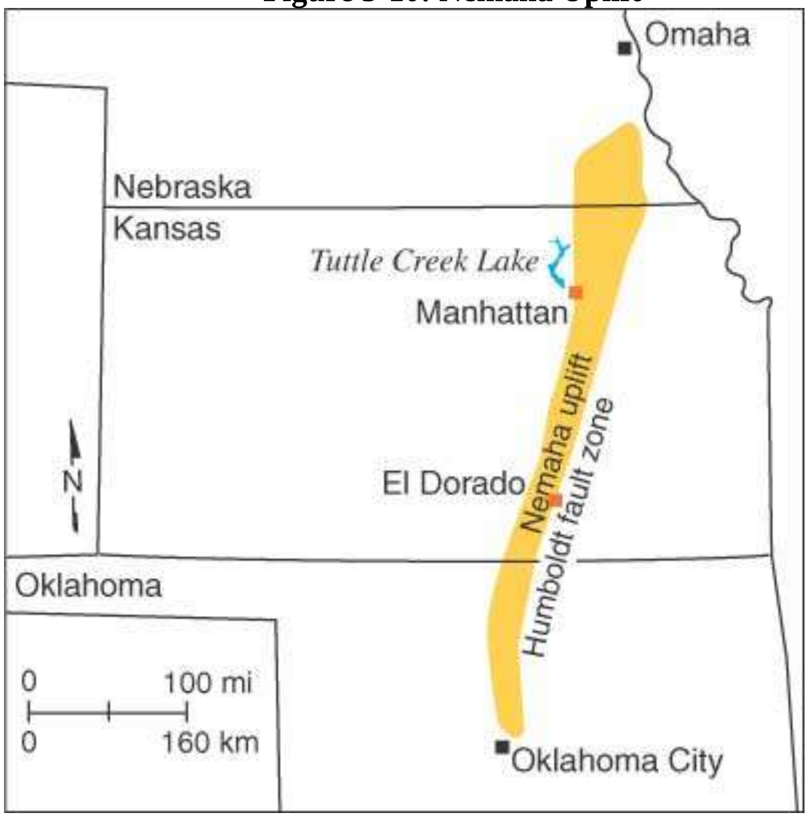
Figure 3-9: Wabash Valley, Central Illinois and New Madrid Earthquakes



Source: Missouri State Hazard Mitigation Plan, 2010

Figure 3-10 was taken from the Kansas Geological Survey and shows the location of the Nemaha Uplift.

Figure 3-10: Nemaha Uplift



Source: http://www.kgs.ku.edu/Publications/GeoRecord/2001/vol7.3/Page1.html

Probability

Current estimates of the recurrence intervals of the large 1811-1812 earthquakes are about 500 years. Most persons are not aware of this risk because the last significant earthquake occurred in the early 19th century. However, small quakes along this fault continue to occur in Missouri about every eight days.

Based on the history of seismic activity in the New Madrid Fault zone and the forecasts developed by the USGS and CERI, there is a 25-40 percent chance that Christian County will experience the effects an earthquake of magnitude 6.0 or greater from the New Madrid Fault within the next 50 years. Since Christian County lies a distance from the New Madrid Fault, low impact level earthquakes usually are not noticeable. The more severe threat stems from an earthquake producing Modified Mercalli levels of VIII-XII. See Table 3-47.

Table 3-47: Probable Risk of Earthquake

Modified Mercalli Levels	Risk
I-V	Unlikely
VI	Likely
VII	Possible
VIII-XII	Possible

Dam Failure

Hazard Identification

A dam is defined by the National Dam Safety Act as an artificial barrier that impounds or diverts water and (1) is at least 6 feet high and stores at least 50 acre-feet of water, or (2) is at least 25 feet high and stores at least 15 acre-feet. Of the 80,000-plus dams in the United States, less than 5% are under the control of the federal government.

According to the Missouri Department of Natural Resources Dam and Reservoir Safety Program, Missouri had some 5,239 recorded dams in October 2009, the largest number of man-made dams of any state in the country. Missouri's topography allows lakes to be built easily and inexpensively, which accounts for the high number of dams. Despite such a large number, only about 679 Missouri dams (13%) fall under state regulations, while another 85 dams are federally controlled. A non-federal dam can be anything from a large farm pond to Bagnell Dam which created the Lake of the Ozarks. The great majority of non-federal dams are privately owned structures that were built either for agriculture or recreational use. Missouri also has some 600 dams which were built as small watershed projects under Public Law-566 (Watershed Protection and Flood Prevention Act of 1953).

These dams serve many functions, including flood control, erosion control, recreation, fish and wildlife habitat, water supply, and water quality improvement. Many are nearing the end of their 50-year lifespan and are in need of repair. Another group of older dams in the state were originally built by railroads to create drinking water reservoirs for the towns where the railroads were built.

Within the State of Missouri, the Department of Natural Resources maintains a Dam and Safety Program within the Division of Geology and Land Survey. The objective is to ensure that the dams are safely constructed, operated, and maintained pursuant to Chapter 236 Revised Statutes of Missouri. Under state statute, a dam must be 35 feet or higher to be state regulated. These dams are surveyed by state inspectors at least every five years. However, the majority of Missouri dams are less than 35 feet high and thus, not regulated. While the State has for many years encouraged dam owners to do owner inspections for those dams not under the law, the condition of many of these dams is deteriorating.

The Department of Natural Resources Geological Survey and Resources Assessment Division resumed inspecting regulated dams effective July 1, 2004. Because of budget cuts in FY'03, dam owners were required to hire private professional engineers to conduct dam surveys for required permits.

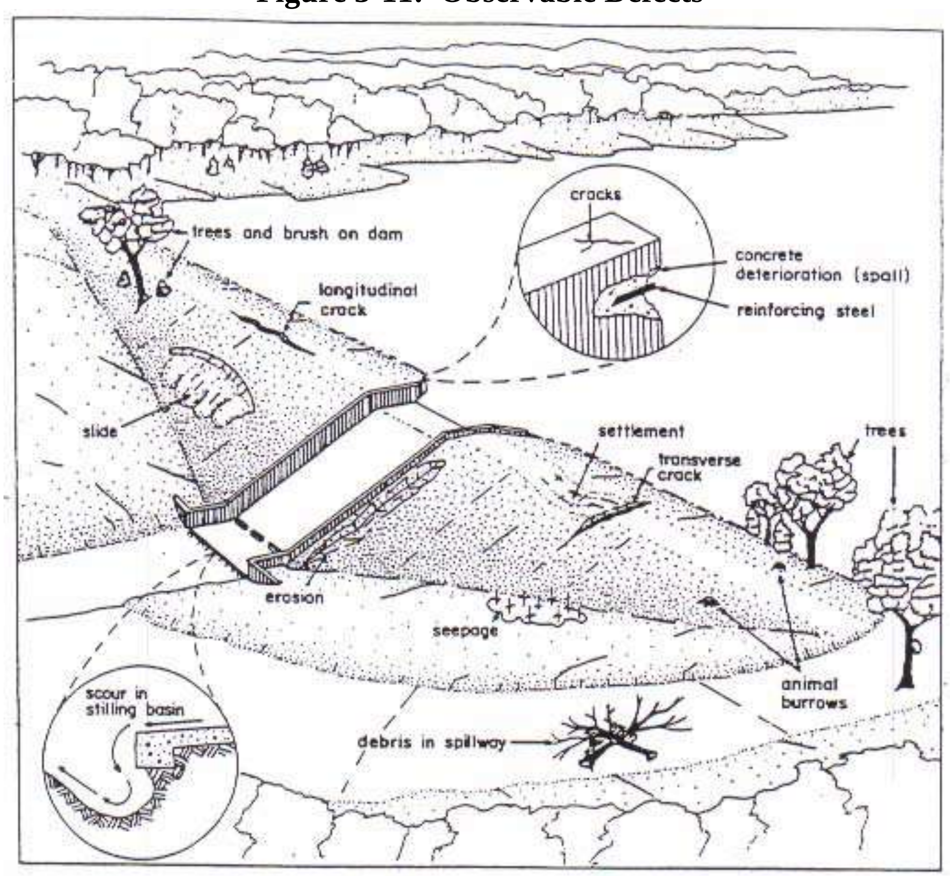
Dam owners have primary responsibility for the safe design, operation and maintenance of their dams. They are responsible for providing early warning of problems at the dam, for developing an effective emergency action plan, and for coordinating that plan with local officials. The state has ultimate responsibility for public safety and many states regulate construction, modification, maintenance, and operation of dams. MDNR's Dam Safety Division maintains a database of all dams regardless of federal, state, local or private ownership.

Oversight is extremely valuable to the owners as well as those people living downstream of the dam who could be flooded in the event the dam should fail. Dams can fail for many reasons. The most common are:

- 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.
- Structure Failure: caused by an earthquake, slope instability or faulty construction.

These failure types often are interrelated. For example, erosion, either on the surface or internal, may weaken the dam or lead to structural failure. Additionally, a structural failure may shorten the seepage path and lead to a piping failure. Figure 3-11 shows observable defects that could be evidence of a dam failure.

Figure 3-11: Observable Defects



Location

The four recorded dams in Christian County are in rural sections of the county. There are no communities, schools or otherwise vulnerable or critical facilities that lie within the likely downstream environment zones of these dams. Figure 3-12 illustrates the mapped locations and downstream environment classes of recorded dams in the county.

Extent (*Magnitude/Severity****)***

Although Christian County has not experienced a dam failure, existing dams continue to age, the likelihood of failure grows with each passing year. The National Inventory of Dams categorizes dam failure hazard as:

> **High Hazard** - If the dam were to fail, lives would be lost and extensive property damage could result.
>
> **Significant Hazard** - Failure could possibly result in the loss of life and appreciable property damage.
>
> **Low Hazard** - Failure results in only minimal property damage.

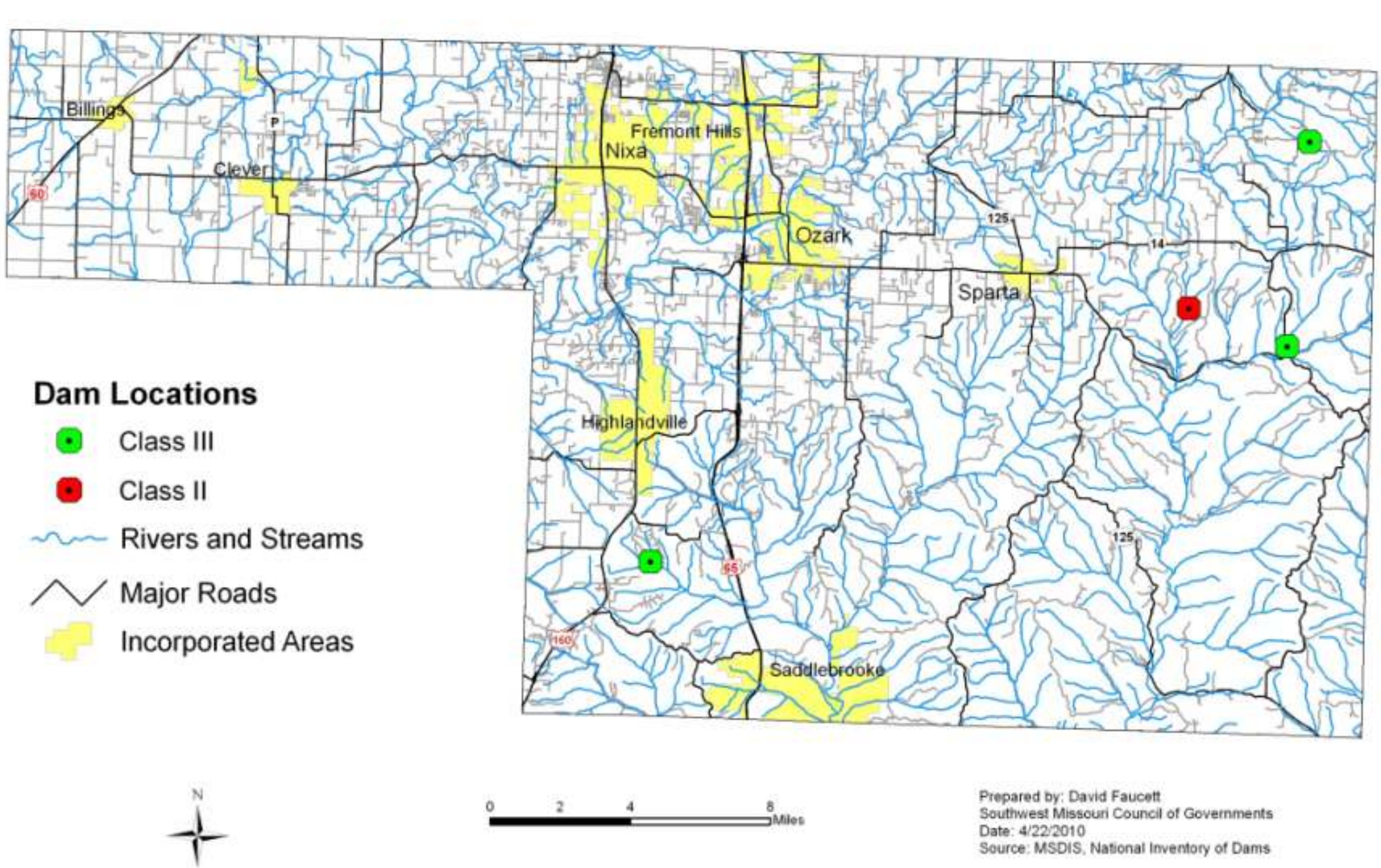
There are four dams in Christian County, but only one is over 35 feet in height. The Liars Lake dam is considered a significant hazard while the other three are considered low hazard. The dams are used primarily for recreation. All Christian County dams are of earthen construction, are on private property, and fall under private ownership (National Weather Service Forecast Office website). Table 3-48 summarizes the attributes of the dams in Christian County obtained from the National Inventory of Dams while Figure 3-12 displays the location of these dams.

Table 3-48: Christian County Dams

Dam #	Official Name	River/Stream	Year Built	Ht.	Res. Area	State Reg.	Hazard Level
1	Stoneshire Lake #2 Dam	Camp Creek	0	25	5	No	L
2	Liars Lake Dam	Elkhorn Creek	1966	39	16	Yes	S
3	Sugar Camp Creek Dam	Swan Creek	0	34	38	No	L
4	Paul's Lake Dam	Finley Creek	1980	25	3	No	L

Source: Missouri Department of Natural Resources. Dam Safety Program.

Figure 3-12: Christian County Dam Locations



The Missouri Dam and Reservoir Safety Council Rules and Regulations uses three classes of downstream environmental zone used when considering permits. The downstream environment zone is the area below the dam that would become inundated should the dam fail. Inundation is defined as water two feet or more over the submerged ground outside of the stream channel. These classes are based on the number of structures and types of development contained within the inundation area as presented in Table 3-49. The downstream environment zone classification is also used to prescribe the frequency of inspection.

Table 3-49: Classes of Downstream Environment Zone	
Class I	The area downstream from the dam that would be affected by inundation contains ten (10) or more permanent dwellings or any public building. Inspection of these dams must occur every two years
Class II	The area downstream from the dam that would be affected by inundation contains one to nine permanent dwelling, or one (1) or more campgrounds with permanent water, sewer and electrical services or one (1) or more industrial buildings. Inspection of these dams must occur once every three years.
Class III	The area downstream from the dam that would be affected by inundation does not contain any of the structures identified for Class I or Class II dams. Inspection of these dams must occur once every five years
Source: http://floodplain.sema.dps.mo.gov/MitPlan/docs.aspx?link=modamreg94	

Aerial photography from the National Agricultural Imagery Program was utilized along with a digital assessor's parcel file from the Christian County GIS database to inspect the downstream environmental zones or likely inundation areas coincident with the four dam locations in the county. Using this method it was determined that the Liars Lake Dam in Elkhorn Creek qualified as a Class II dam while the other three revealed themselves to be Class III dams. Table 3-50 shows the probable severity for a dam failure in Christian County.

Table 3-50: Dam Failure Probable Severity	
Downstream Environment Zone	**Future Probable Severity**
Class III	Negligible
Class II	Limited

Past Occurrences

Dam failures in the United States have resulted in death, injuries and billions of dollars in property damage. Dam failure events in Missouri include dams in Lawrenceton in 1968, Washington County in 1975, Fredericktown in 1977, and a near failure in Franklin County in 1978, and Lesterville in 2005. There has not been a reported incident of dam failure in Christian County thus far.

A large scale example of a dam failure in Missouri occurred at the Tom Sauk in 2005. The stone retaining wall around the huge mountaintop reservoir near the town of Lesterville collapsed before daybreak releasing a billion-gallon torrent of water that swept away at least two homes and several vehicles and critically injured three children according to authorities. After the breach opened up, within minutes the 50-acre reservoir had emptied itself out with terrifying effect, turning the surrounding area into a landscape of flattened trees and clay-covered grass and temporally evacuating the city of Lesterville. (National Weather Service)

Probability

The age and ownership of the dams are the largest factors in the risk of failure. Only one of Christian County's dams is state regulated, and without exact information on the design, operation and maintenance of these dams, it is difficult to assess the risk. The likelihood of a dam failure is possible, but the amount of damage downstream that might result is the most critical consideration.

According to Stanford University's National Performance of Dams Program, between 1975 and 2001 there were 17 dam failures in Missouri. These data translate into a 65% probability that there will be a dam failure in any given year statewide. However, with over 5,000 dams across the state the probability that a dam failure would occur at one of the four recorded dams in Christian County is very low; therefore, it is unlikely that an event of this type will happen in the county.

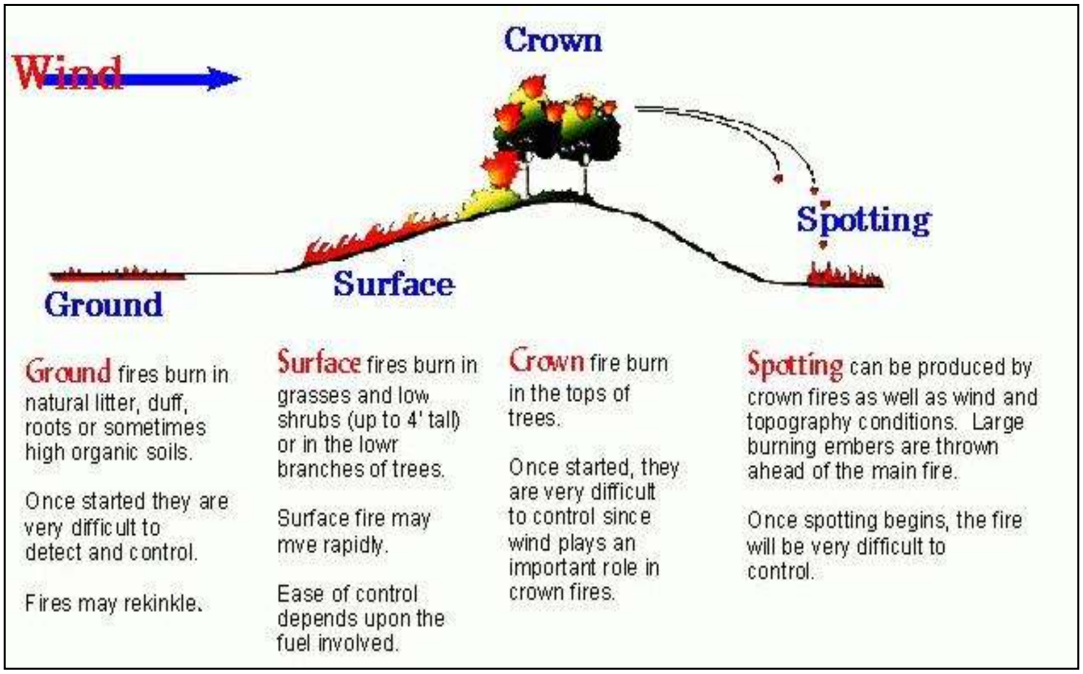
Wildfire

Hazard Identification

Forest and grassland fires can occur any day throughout the year. Each year, an average of about 3,700 wildfires burn more than 55,000 acres of forest and grassland in Missouri. Most of the fires occur during the spring season, normally between February 15 and May 10. The length and severity of burning periods largely depend on the weather conditions. Spring in Missouri is noted for its low humidity and high winds. These conditions, together with below-normal precipitation and high temperatures, result in extremely high fire danger. In addition, due to the continued lack of moisture throughout many areas of the State, conditions are likely to increase the risk of wildfires. Drought conditions can also hamper firefighting efforts, as decreasing water supplies may not provide for adequate firefighting suppression. Spring is when many rural residents burn their garden spots, brush piles, and other areas. Some landowners also believe it is necessary to burn their forests in the spring to promote grass growth, kill ticks, and reduce brush. Therefore, with the possibility of extremely high fire dangers and the increased opportunities for fires, the spring months are the most dangerous for wildfires.

The second most critical period of the year is fall. Depending on the weather conditions, a sizeable number of fires may occur between mid-October and late November. In 2009, there were a total of 3,779 wildfires reported and a total of 42,486 acres burned across the State (MDC). Figure 3-13 notes types of wildfires that may occur.

Figure 3-13: Types of Wildfire



Source: Missouri Department of Conservation

The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from the destructive effects of wildfires. To accomplish this task, eight forestry regions have been established in the State to assist with the quick suppression of fires. The Forestry Division works closely with volunteer fire departments and federal partners to assist with fire suppression activities. Currently, more than 900 rural fire departments have mutual aid agreements with the Forestry Division to obtain assistance in wildfire protection if needed; a cooperative agreement with the Mark Twain National Forest is renewed annually.

A necessary ingredient for combustion in wildfire events is the fuel or vegetative density enabling the fire to spread. As the land cover statistics indicate in Table 3-51, there is an abundance of grassland and forested area within the county. For an indication of the relationship of this kind of land cover to developed areas please refer to the USGS Land Use Land Cover map in chapter II on page 2-21.

Table 3-51: Land Cover in Christian County

Land Cover Type	Acres	% Coverage of County
Non-Native, Cool-Season Grasslands	172,616.27	47.86
Deciduous Upland Mixed Oak Forest	95,479.36	26.47
Mixed Evergreen-Deciduous Shortleaf Pine-Oak Forest	22,738.74	6.30
Deciduous Upland Mixed Hardwood Forest	11,946.60	3.31
Land cover type - includes top four types of estimated land coverage.		
Source: MoWIN: http://outreach.missouri.edu/mowin/counties2/christian.html		

Location

Wildland Urban Interface

According to the SILVIS Lab, in the Department of Forest & Wildlife Ecology at the University of Wisconsin- Madison, the Wildland-Urban Interface (WUI) is defined as the area where structures and other human development meet and intermingle with undeveloped wildland. The SLVIS lab uses thresholds of housing density and a percent of vegetative coverage in an area to model where development and fuel meet and to map the threat of wildfire events. The data used to create this model is gathered from the 2000 U.S. Census, at the Census block level, and the National Land Cover Dataset (NLCD), satellite data based on 1992/93 imagery. From the 2000 Census data, housing densities are derived for all Census blocks and are measured as the number of housing units per square kilometer. Data from the NLCD is used to identify wildlands, which are defined as forests, native grasslands, shrubs, wetlands, and transitional lands, most often clear-cuts.

The SILVIS Lab then defines two types of Wildland-Urban classes; interface and intermix. The interface class is an area were housing is in the vicinity of contiguous vegetation. The area must have more than one house per 40 acres, have less than 50% vegetation, and be within 1.5 miles of a area over 1,325 acres that is more than 75% vegetated. The model specifies 1.5 miles because, according to the California Fire Alliance, that is the distance a firebrand can be blown from a wildland fire to a home and catch the home on fire. The intermix class is an area where housing and vegetation intermingle. The area must have at least one house per 40 acres, have continuous vegetation, and be more than 50% vegetation. For each type of WUI, there are three subtypes: low density, medium density and high density. Each subtype is defined in Table 3-52.

Table 3-52: Classification of Wildland Urban Interface

Sub Type	**Description**
Low Density Interface	Housing Density ≥ 6.2 housing units/km^2 and < 49.4 housing units /km^2 Vegetation ≤ 50% within 2.4km of an area with ≥75% vegetation
Medium Density Interface	Housing Density ≥ 49.4 housing units/km^2 and < 741.3 housing units /km^2 Vegetation ≤ 50% within 2.4km of an area with ≥75% vegetation
High Density Interface	Housing Density ≥ 741.3 housing units/km^2 Vegetation ≤ 50% within 2.4km of an area with ≥75% vegetation
Low Density Intermix	Housing Density ≥ 6.2 housing units/km^2 and < 49.4 housing units /km^2 Vegetation > 50%
Medium Density Intermix	Housing Density ≥ 49.4 housing units/km^2 and < 741.3 housing units /km^2 Vegetation > 50%
High Density Intermix	Housing Density ≥ 49.4 housing units/km^2 and < 741.3 housing units /km^2 Vegetation > 50%

Source: http://silvis.forest.wisc.edu/library/WUIDefinitions2.asp

Application of WUI

The map in Figure 3-14 is meant to illustrate the likely locations of wildfire in Christian County. The map is a combination of land classified as either forest or grassland in the 2005 USGS Land Use Land Cover 30 meter resolution grid and an overlay of 2000 census blocks classified by SILVIS Lab's Wildland Urban Interface methodology. Although the threat of wildfire is countywide, the WUI demonstrates where this hazard would most likely present a danger to people and property. The WUI classes of interface and intermix for each level were combined creating three levels of high, medium and low density development in largely vegetated areas.

Extent (*Magnitude/Severity****)***

A major wildfire within the buffer areas could cause damage to an entire community. However, most wildfires in Christian County tend to be small and of limited severity, due to early detection and quick response by firefighters. Yet wildfires can flare out of control, often with catastrophic results. Grass grows back quickly with little damage, but fires in forests and croplands are costly. A major wildfire can leave a large amount of scorched and barren land. These areas may not return to pre-fire conditions for decades. If the wildfire destroyed the ground cover, then erosion becomes one of several potential problems. Once ground cover has been burned away, little is left to hold soil in place on steep slopes and hillsides. If heavy rains follow a fire, other natural disasters can occur, including landslides and mudflows. Fatalities occasionally can result from wildfires, usually due to overexertion or heart attack.

The overall future probable severity of wildfires (forest, prairie and grassland) in Christian County is considered limited. As residential areas expand into relatively untouched wildlands, people living in these communities are increasingly threatened by forest fires. Protecting structures in these more isolated locations poses special problems and can stretch firefighting resources to the limit. Wildfire fuel includes combustible material in the form of vegetation such as grass, leaves, ground litter, plants, shrubs and trees. The grasslands, croplands and forested areas in Christian County combined with certain weather conditions create the potential risk for wildfire within the county. Table 3-53 notes the future probable severity of wildfire hazard, based on Christian County's supply of wildfire fuel and Wildland Urban Interface subtype.

Figure 3-14: Wildfire Prone Areas in Christian County

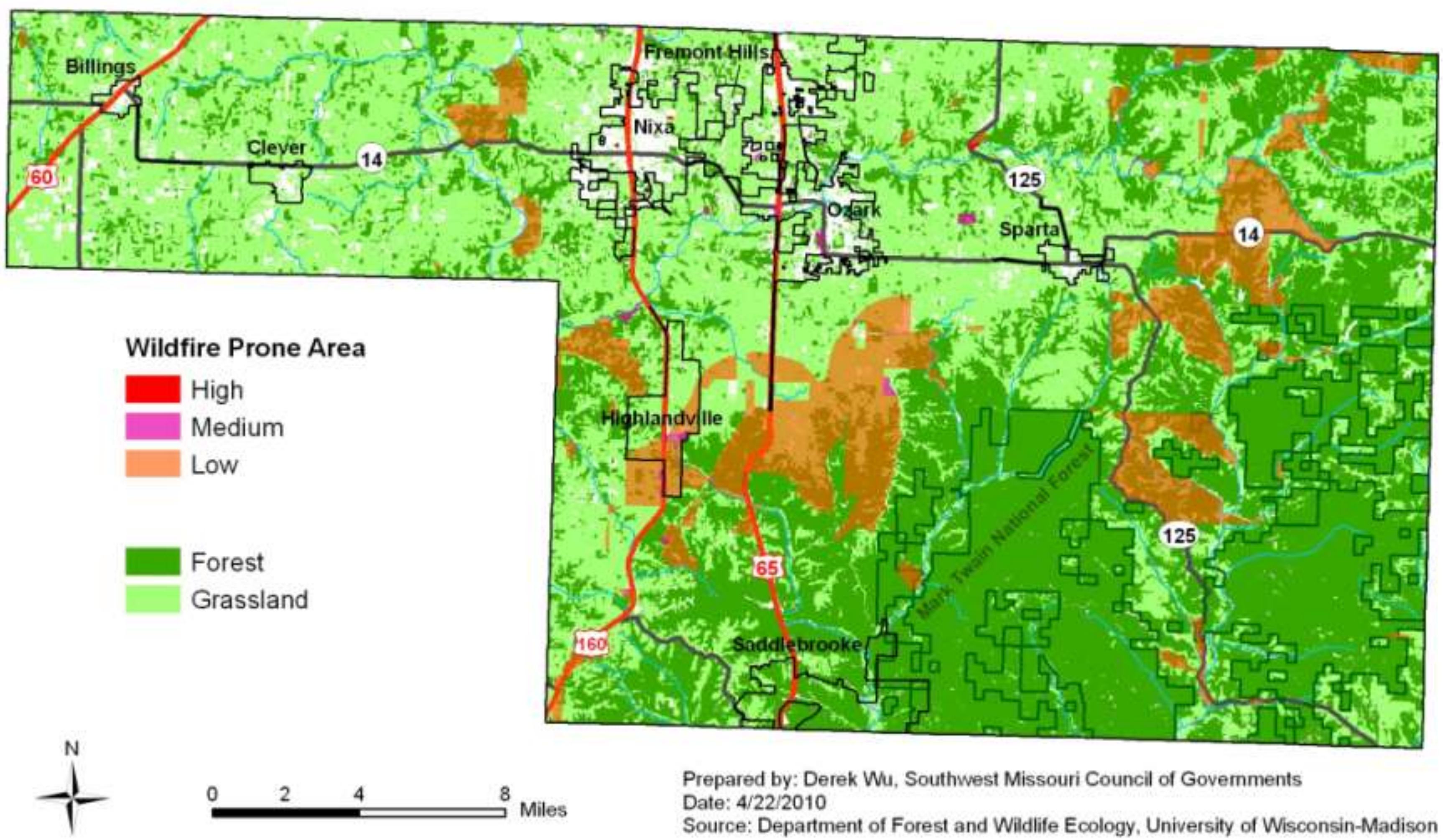


Table 3-53: Future Probable Severity of Wildfire	
Location	**Probable Severity**
Wildland Urban Interface Subtype	
High Density Interface	Limited
High Density Intermix	Critical
Medium Density Interface	Limited
Medium Density Intermix	Critical
Low Density Interface	Limited
Low Density Intermix	Limited
USGS Land Use Land Cover Type	
Forests	Limited
Grasslands/Croplands	Limited

Past Occurrences

No Missouri fires are listed among the significant wildfires in the U.S. since 1825. Each year, about 3,700 wildfires burn more than 55,000 acres of forest and grassland on average in Missouri. On April 5, 2000, Christian County experienced a countywide wildfire resulting in $5,000 worth of property damage. Several counties in the area experienced similar fires on the same day. The Missouri Department of Conservation wildfire data for Christian County over the past five years indicates that there are over a dozen reported wildfires in any given year. During this period there were 71 reported fires that burned 571 acres. In March of 2007, one residence was damaged and another destroyed near Highlandville. This wildfire was reportedly caused by faulty equipment use and was the only instance that resulted in residential damage. Other structures have been damaged in these events but have been limited to outbuildings. There is no injury or death information associated with the data. Table 3-54 summarizes the MDC data by cause.

Table 3-54: Christian County Wildfire Statistics by Cause, 2005-2010				
Cause	**# of Fires**	**Structures Damaged 0r Destroyed**	**Residences Threatened**	**Acres Burned**
Smoking	5	1	3	21
Debris Burning	47	2	30	275
Arson	4	0	4	88
Equipment Use	5	2	12	51
Miscellaneous	4	0	0	52
Unknown	6	0	0	84
Total	71	5	37	571
Source: MDC: http://www.conservation.state.mo.us/ forest/fire/stats.htm				

Probability

The risk of occurrence of wildfires in Christian County is considered likely overall, but may increase to highly likely during certain periods, such as spring, late fall, or under conditions of excessive heat, dryness, and/or drought. The occurrence of a disastrous wildfire in Christian County is unlikely. The risk of wildfire occurrence, based on the MDC's fire danger index, is shown in Table 3-55.

Table 3-55: Likelihood of Future Wildfire Occurrence

Level	Probable Risk of Occurrence
Low Fire Danger	Highly Likely
Moderate Fire Danger	Likely
High Fire Danger	Possible
Extreme Fire Danger	Possible

Source: http://www.mdc.state.mo.us/forest/fire/adject.htm

Sinkhole (bowl-shaped, collapse)

Hazard Identification

A sinkhole is an area of ground that has no natural external surface drainage—when it rains, all of the water stays inside the sinkhole and typically drains into the subsurface. Sinkholes can vary from a few feet to hundreds of acres and from less than 1 to more than 100 feet deep (USGS, Sinkhole Fact Sheet, p. 1). Some are shaped like shallow bowls whereas others have vertical walls; some hold water and form natural ponds, while others do not hold water. Typically, sinkholes form so slowly that little change is seen in one's lifetime, but they can form suddenly when a collapse occurs. Such a collapse can have a dramatic effect if it occurs in an urban setting.

Sinkholes form in karst terrain, which is a region where the bedrock can be dissolved by ground water. Bedrock in a karst area typically is composed of carbonate (limestone/dolomite) or evaporite (gypsum) rock. Topographic features such as springs, caves, and sinkholes all form because water that is slightly acidic, from absorbing carbon dioxide from the air and soil, dissolves the bedrock along horizontal and vertical cracks and crevices, and forms pathways and channels in the rock. These pathways are like underground plumbing that carries water from the surface to springs located in valleys. Eventually, these cracks and crevices, which are the beginning of a conduit system, become large enough to start transporting small soil particles, see Figure 3-15. As these small particles of soil are carried off, the surface of the soil above the conduit starts slumping down gradually, and a small depression forms on the surface of the ground. This small depression acts like a funnel and gathers even more water, which makes the conduit larger and washes more soil into the conduit, making the depression both wider and deeper.

There are two general types of sinkholes – collapse and bowl-shaped. Collapse sinkholes are much less common than the bowl-shaped type. Collapses form in essentially the same way as the more common bowl-shaped sinkholes. However, when the soil particles start washing into the conduit, the soil closer to the ground surface does not slump down, but starts forming a bridge, see Figure 3-16. A void forms where the soil keeps washing into the conduit and, eventually, several things can happen that can cause the bridge to collapse to form a sinkhole. One, the void can grow large enough that the soil above it can no longer bridge it. Two, the soil bridge dries out and collapses due to loss of cohesion. Three, the bridge collapses due to an excess load applied on top of it. Or four, vibration in the adjacent area due to traffic, construction, or even weather can loosen the soil in the bridge.

The process of forming a conduit and a soil bridge can take many years to decades to even centuries to form and can be aggravated by human activities. Since the process of forming a sinkhole depends on water to carry away soil particles, anything that increases the amount of water flowing into the subsurface can facilitate this process. Parking lots, streets, altered drainage from construction, and roof guttering are some things that can increase runoff; even weather can make a difference.

Between 1970 and 2007, MDNR examined more than 160 collapses statewide that were reported by the public. Most of these collapses were small—less than 10 feet in diameter and 10 feet deep (USGS, Sinkhole Fact Sheet, p. 1); some, however, are quite large and spectacular. Sinkhole collapses drained a lake in the St. Louis, Missouri, area (St. Louis Post Dispatch, June 11, 2004), drained the West Plains, Missouri, sewage lagoon (Gillman et al, 2007), partially drained the Springfield, Missouri, treated sewage lagoon (Vineyard and Feder, 1982), and another in Nixa, Missouri swallowed a car along with the garage it was parked in (Gouzie and Pendergrass, 2009).

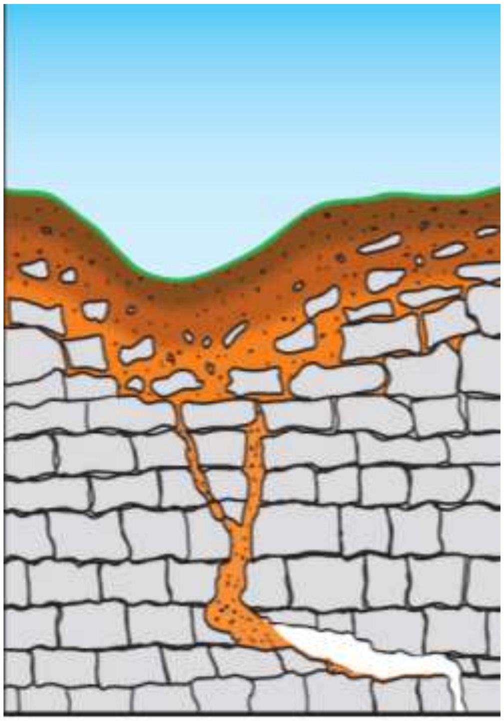


Figure 3-15: Bowl-shaped Sinkhole

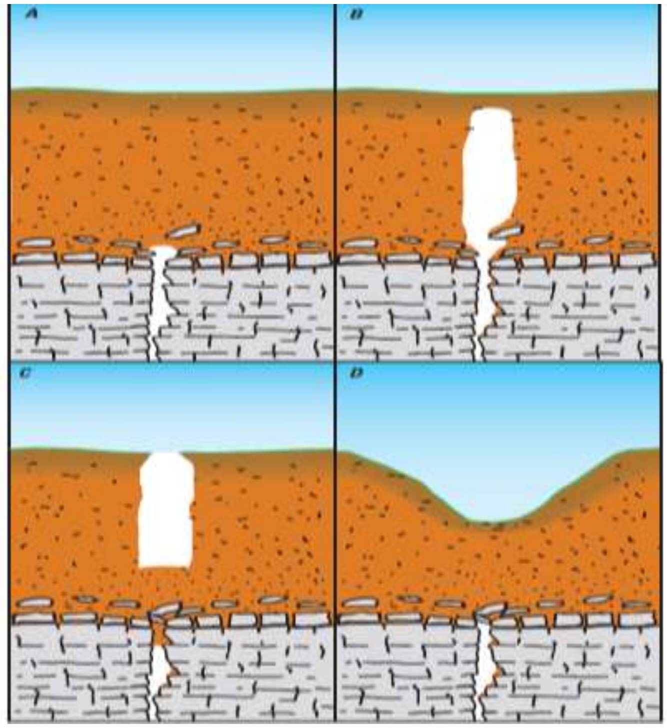


Figure 3-16: Formation of Collapse

Soil bridges gap where sediment has been washing into a solution enlarged fracture, *A*. Over time, the void migrates upward through the soil, *B*. After the bridge thins, a sudden collapse, *C*, often plugs the drain and erosion will, after many years, transform the collapse into a more bowl-shaped sinkhole, *D*.

Source: USGS Sinkhole Fact Sheet 2007-3060

Location

Christian County is underlain primarily by carbonate rocks containing mainly limestone and some dolomite bedrock. These types of bedrock are extremely sensitive to water dissolution along joints and fractures within the rock. Areas along natural drainage paths tend to be more susceptible to sinkhole formation as well, due to increased water flow into the subsurface.

Figures 3-17 and 3-18 illustrate the geology for Christian County giving the geologic series names. The following list better summarizes the types of rock within each series:

Kindherhookian – shale underlain with limestone
Osagean – limestone, cherty limestone, and dolomite
Jefferson City – mainly dolomite
Channel Sands – channelized sandstones

.

Figure 3-17: Christian County Geologic Map Showing Locations of Sinkholes (CARES)

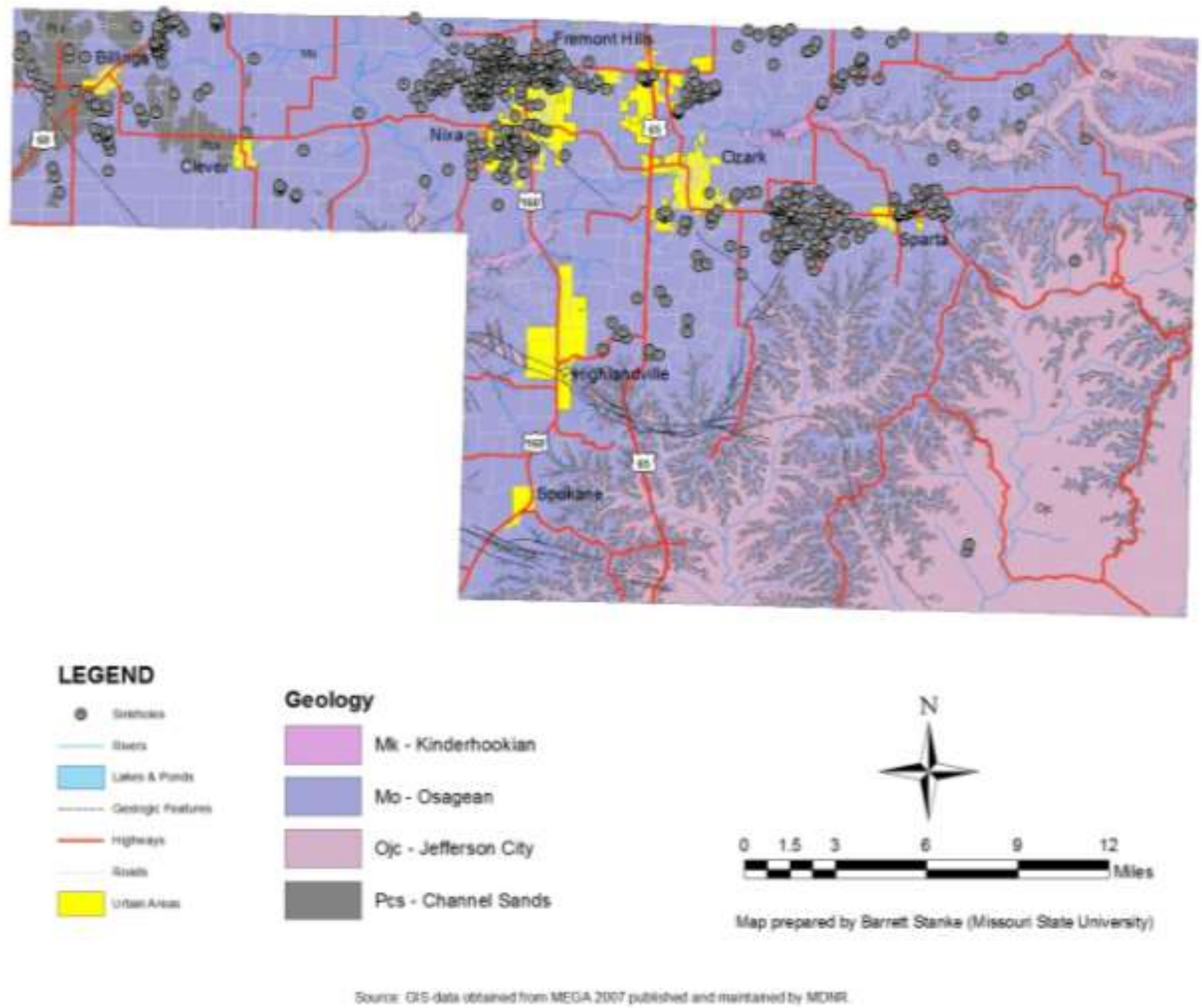
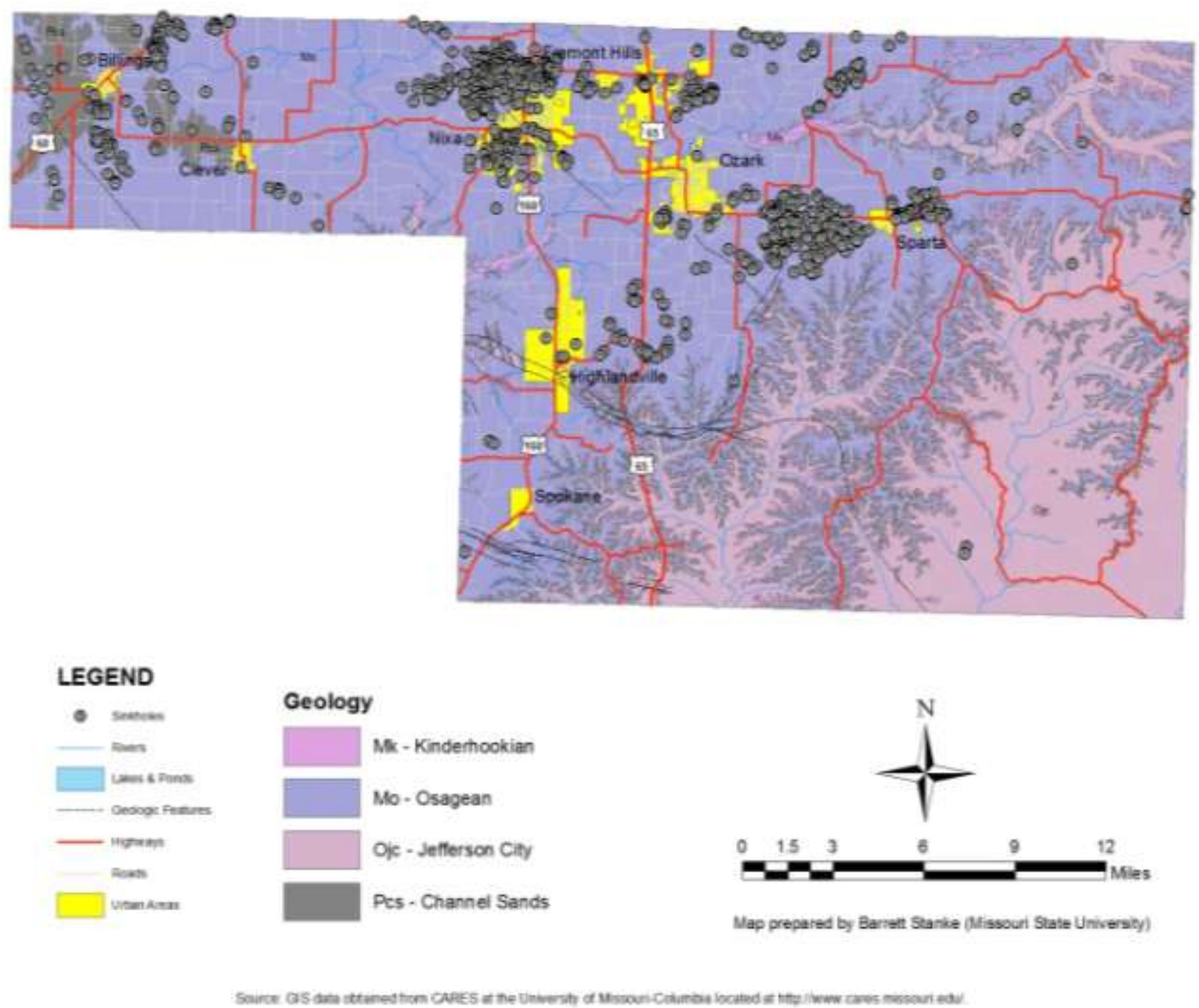


Figure 3-18: Christian County Geologic Map Showing Locations of Sinkholes (MEGA)



Extent (**Magnitude/Severity**)

Formation of sinkholes can and will affect Christian County. However, the impact of past sinkholes is statistically negligible. Since sinkhole formation occurs on a localized scale, property damage is limited to the negligible category depending on structures immediately within or adjacent to the sinkhole area.

An occurrence of a bowl-shaped sinkhole is unlikely to cause much damage, if any, to structures since it is a very slow process that occurs over many years. Structures can be altered or relocated as necessary during the formational process. However, an occurrence of a collapse sinkhole could cause significant damage to structures in the localized area.

As referenced in the *State of Missouri Hazard Mitigation Plan*, 2010, the Emergency Management Accreditation Program (EMAP) has completed an Impact Analysis of Potential for Detrimental Impacts of Hazards. One of the hazards that they looked at was Land Subsistence/ Sinkholes. The report analyzed the different aspects of normal life might be affected by a land subsistence/ sinkholes. Table 3-56 contains information from that analysis of Land Subsidence/ Sinkholes.

Table 3-56: EMAP Impact Analysis: Land Subsidence/Sinkholes

Subject	**Detrimental Impact**
Health and Safety of Persons in the Area at Time of Incident	Localized impact expected to be moderate to severe for incident areas.
Health and Safety of Personnel Responding to the Incident	Limit impacts to personnel responding to the incident.
Continuity of Operations	Limited, unless facility is impacted.
Property, Facilities, and Infrastructure	Localized impact to facilities and infrastructure in the area of the incident. Some severe damage possible.
Delivery of Services	Localized disruption of roads and/or utilities may postpone delivery of some services.
The Environment	Localized impact expected to be moderate for incident area.
Economic and Financial Condition	Limited. Local economy and finances may be adversely affected, depending on damage.
Regulatory and Contractual Obligations	Regulatory waivers may be needed locally. Impact may temporarily reduce deliveries.
Reputation of or Confidence in the Entity	Localized impact expected to primarily adversely affect property owner(s) confidence in local entities development policies.

Source: Missouri State Hazard Mitigation Plan, 2010.

Past Occurrences

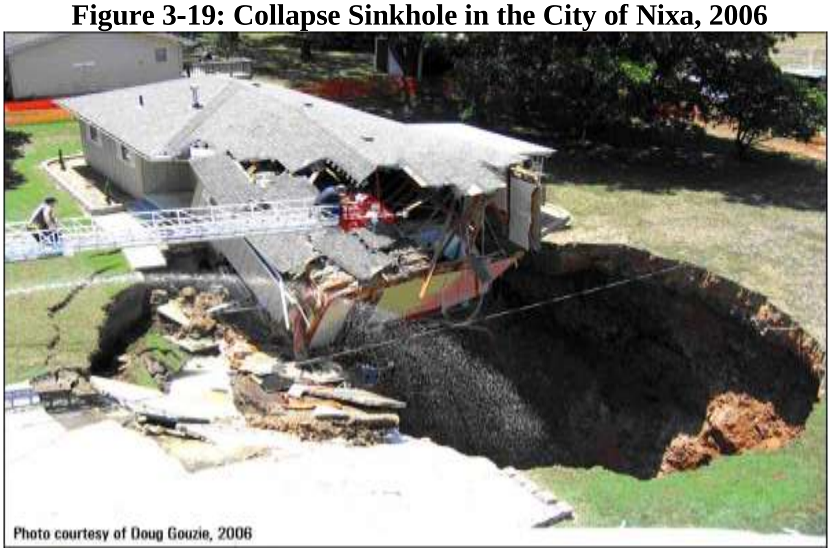
There are currently two spatial mapping database systems publicly available in the State of Missouri for the purpose of identifying geologic sinkhole features. These systems are the Center for Applied Research and Environmental Systems (CARES) operated by the University of Missouri at Columbia, and the Missouri Environmental Geology Atlas (MEGA) operated by the Division of Geology and Land Survey (DGLS) within MDNR.

MEGA is the preferred system for sinkhole hazards mapping due to consistent updating and review of its map layers by MDNR, and their process of eliminating unlikely sinkhole locations. The accompanying figures (Figure 3-17 and 3-18) show approximate locations of existing sinkholes from both database systems.

Since 1879, when the USGS first began topographic mapping, there have been 540 sinkholes reported in Christian County (MEGA, 2007). The presence of these sinkholes are derived from USGS digital raster graphics (DRG) 7.5 minute quadrangle maps, interpolated from aerial photography, or field identified with locations recorded using recreational handheld global positioning system (GPS) receivers. The majority of sinkhole locations are widely scattered throughout the northern half of the county. The northern half of Christian County is predominately underlain by limestone compared to the dolomite of the southern half. Most sinkholes appear to be located near populous areas of Nixa, Ozark, Sparta, and Billings, while other smaller clusters of sinkholes appear near Clever and Highlandville.

Since 1970, Christian County has had 10 occurrences of collapsed sinkholes reported to DGLS-MDNR by the public. No structural damage was recorded on 8 of 10 of those reports. The sinkholes that recorded no structural damage were present on the property adjacent to structures, but not underneath the structures. However, one sinkhole was located near an area proposed for a sewer line expansion for the City of Nixa; extra care had to be taken for proper construction of the sewer expansion due to this sinkhole. Two of 10 reported collapsed sinkholes did report structural damage. The first of these two occurred in August 2006 beginning its collapse under the attached garage with a car inside of a house located in the City of Nixa, continued collapse of this sinkhole lead to it spreading laterally under the living room of the home as well (Figure 3-19). The sinkhole eventually stabilized and was backfilled with graded material. The home has since been demolished and the property currently sits as an open lot. The second structurally damaging collapsed sinkhole reported was in August 2007 in the City of Ozark. A sinkhole had appeared under the corner of a house here causing cracking in the walls of a utility room. No further damage was reported.

Figure 3-19: Collapse Sinkhole in the City of Nixa, 2006



Probability

The risk of sinkhole formation in Christian County is moderate based on the carbonate bedrock in the area and the number of existing sinkholes reported throughout the county. Since map-based record keeping began, only 540 sinkholes have formed and have been mapped in Christian County. Using a buffer of 30 feet (9 meters) around existing sinkholes, this buffer area currently comprises only 0.00941% of the total land area in the county, which can be considered negligible.

Sinkhole formation in urban areas compared to rural areas has the potential to be expedited due to human interaction with the subsurface through construction of facilities and infrastructure. Natural drainage patterns are altered, which can increase water volume and flow to areas more susceptible to sinkhole formation, thus increasing the potential for mobilization of sediment in the subsurface or increasing amount of dissolution of the underlying bedrock.

A secondary problem that can arise once sinkhole formation has already occurred is flooding. During periods of excessive rainfall in the watershed of an existing sinkhole can cause water levels to rise faster than it can infiltrate into the ground through the soil of the sinkhole. When this happens, water can temporarily "back-up" to fill the sinkhole and may even "spill-over" into surrounding low-lying areas. In some cases, homes with "walk-out" basements are built along the sides of a sinkhole and, in those cases, the walk-out basement may become the low-lying "spill-over" area.

The likelihood of future sinkhole hazards is shown in the Table 3-57. It is likely that the more common bowl-shaped sinkhole may occur once a year on average. Of course, it is always possible that a new sinkhole hazard will be of the collapse sinkhole type.

Table 3-57: Likelihood of Future Risk - Sinkhole Hazard

Event Type	**Future Occurrence**
Bowl-shaped Sinkhole	Likely
Collapse Sinkhole	Possible

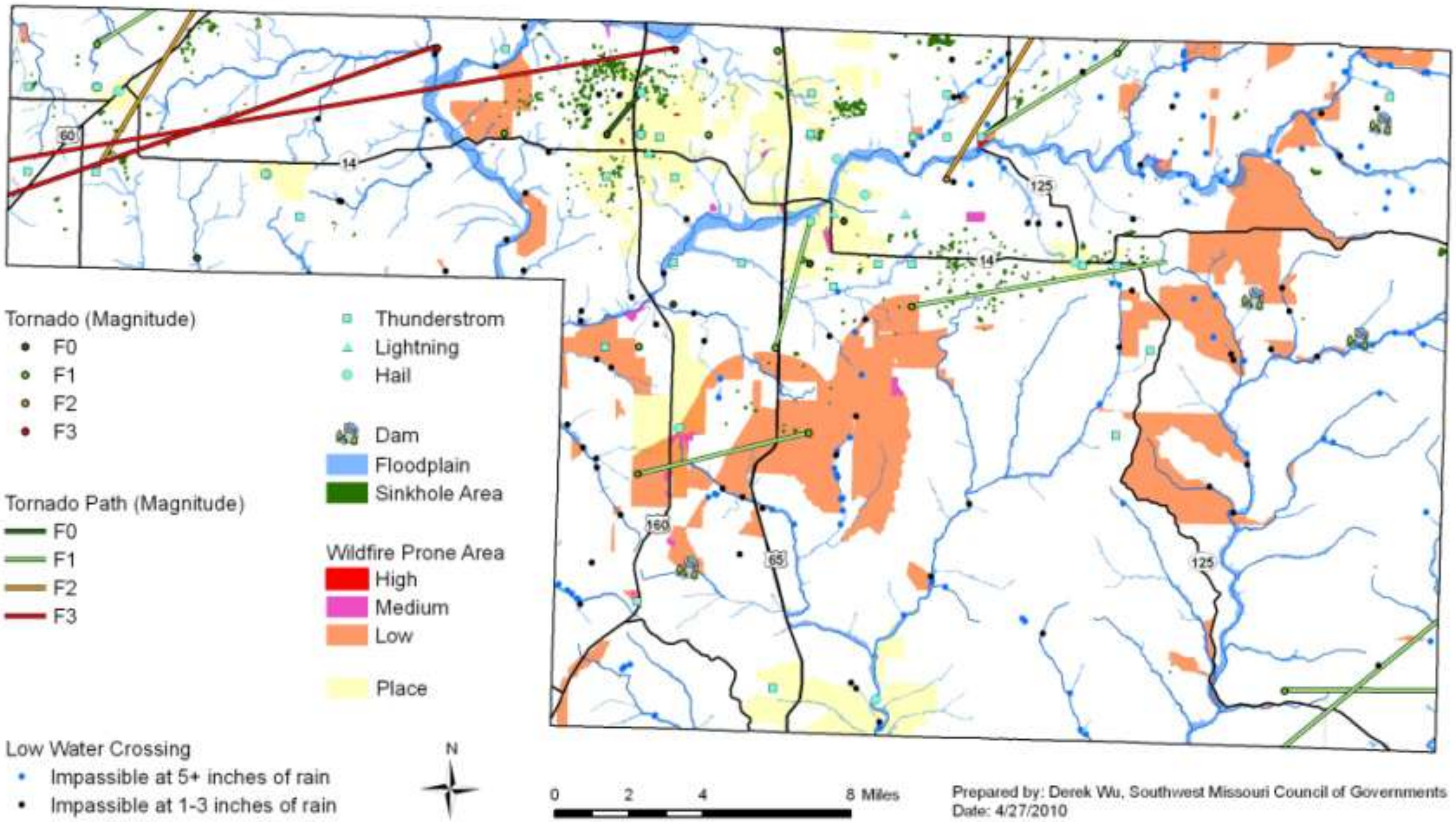
Disaster Declarations

Between 2002 and 2009 there were 11 disaster declarations in Christian County. See Table 3-58 below. Reviewing the disaster declarations allows the county to be better prepared for natural disasters in the future by learning what damage each event may cause. All of these declarations covered multiple counties; therefore, the damage assessment reflects damage done to all counties.

Table 3-58: Disaster Declarations--Christian County 2002-2009

Number	Type of Assistance	Description	Date Declared	Damage Assessment
1847	Individual Assistance	Severe Storms, Tornadoes, and Flooding	06/19/2009	Damage Assessment
1809	Public Assistance	Severe Storms, Flooding, & a Tornado	11/13/2008	Damage Assessment
1773	Public Assistance	Severe Storms and Flooding	06/25/2008	Damage Assessment
1749	Individual and Public Assistance	Severe Storms & Flooding	03/19/2008	Damage Assessment
1748	Public Assistance	Severe Winter Storms and Flooding	03/12/2008	Damage Assessment
3281	Public Assistance	Severe Winter Storms	12/12/2007	
1676	Public Assistance	Severe Winter Storms & Flooding	01/15/2007	
1631	Individual and Public Assistance	Severe Storms, Tornado, and Flooding	03/16/2006	
3232	Public Assistance (Category B)	Hurricane Katrina Evacuation	09/10/2005	
1463	Individual and Public Assistance	Severe Storms, Tornadoes, & Flooding	05/06/2003	
1412	Individual and Public Assistance	Severe Storms & Tornadoes	05/06/2002	
Source: http://www.fema.gov/femaNews/disasterSearch.do				

Figure 3-20: Christian County Hazard Composite Map



The hazards of severe winter weather, earthquake, heat wave and drought are not mapped because the threats of these are countywide.

Geographic Specific Hazards Composite Maps by Jurisdiction

Figure 3-21: Billings Hazards Composite Map

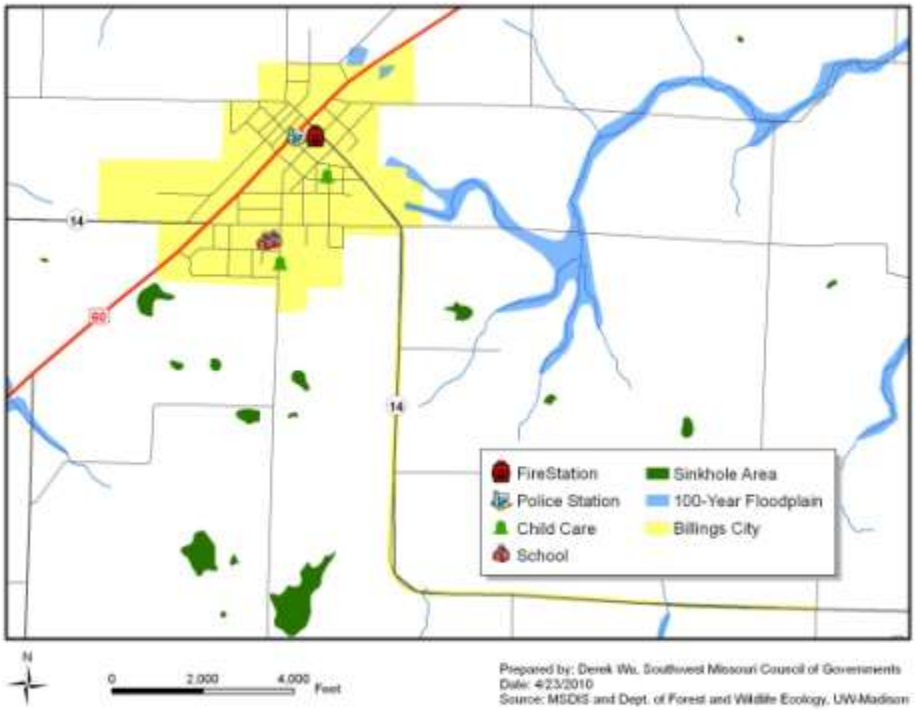


Figure 3-22: Clever Hazards Composite Map

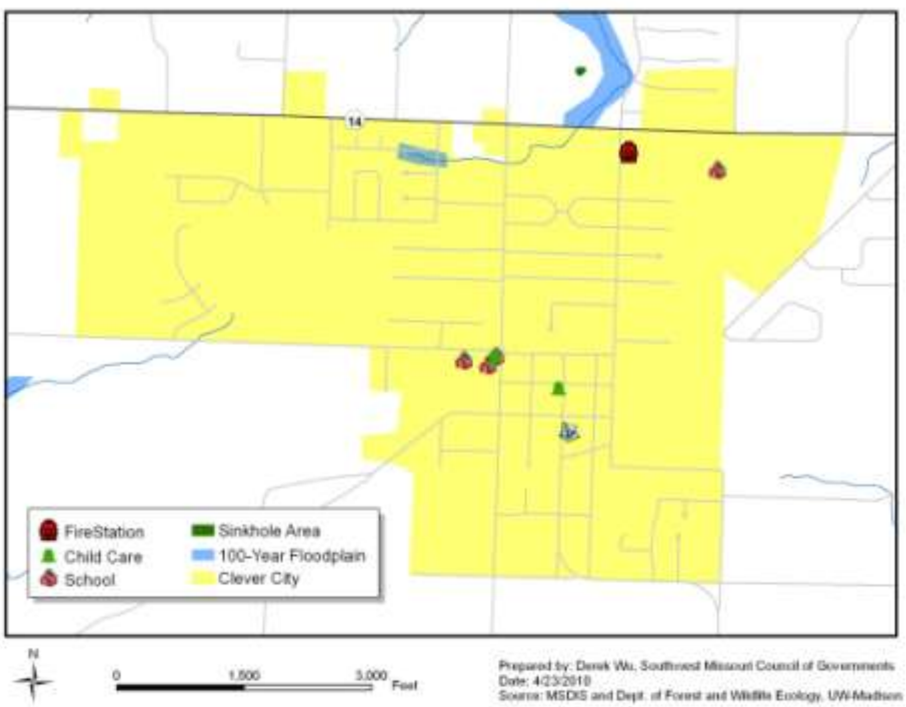


Figure 3-23: Fremont Hills Hazards Composite Map

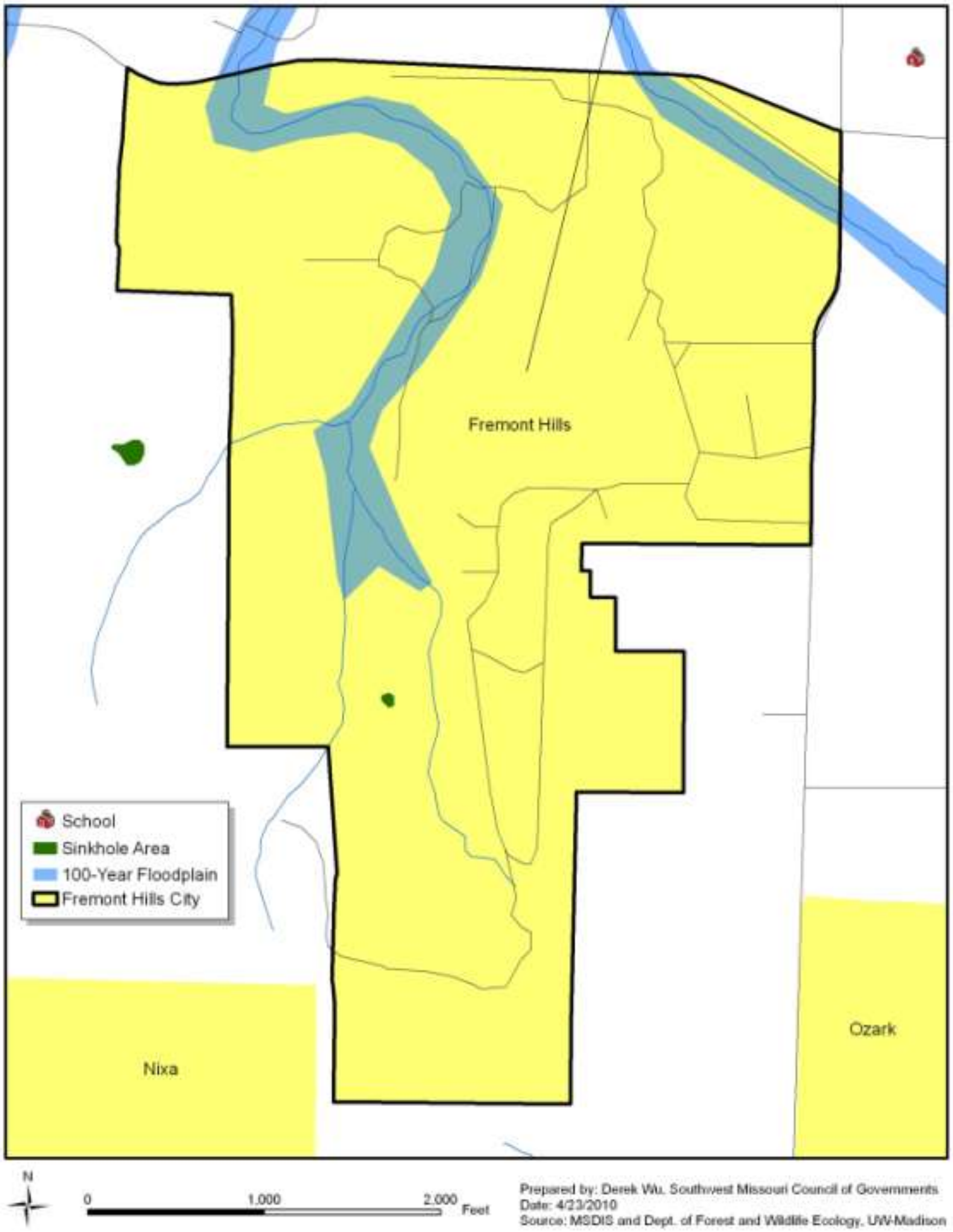


Figure 3-24: Highlandville Hazards Composite Map

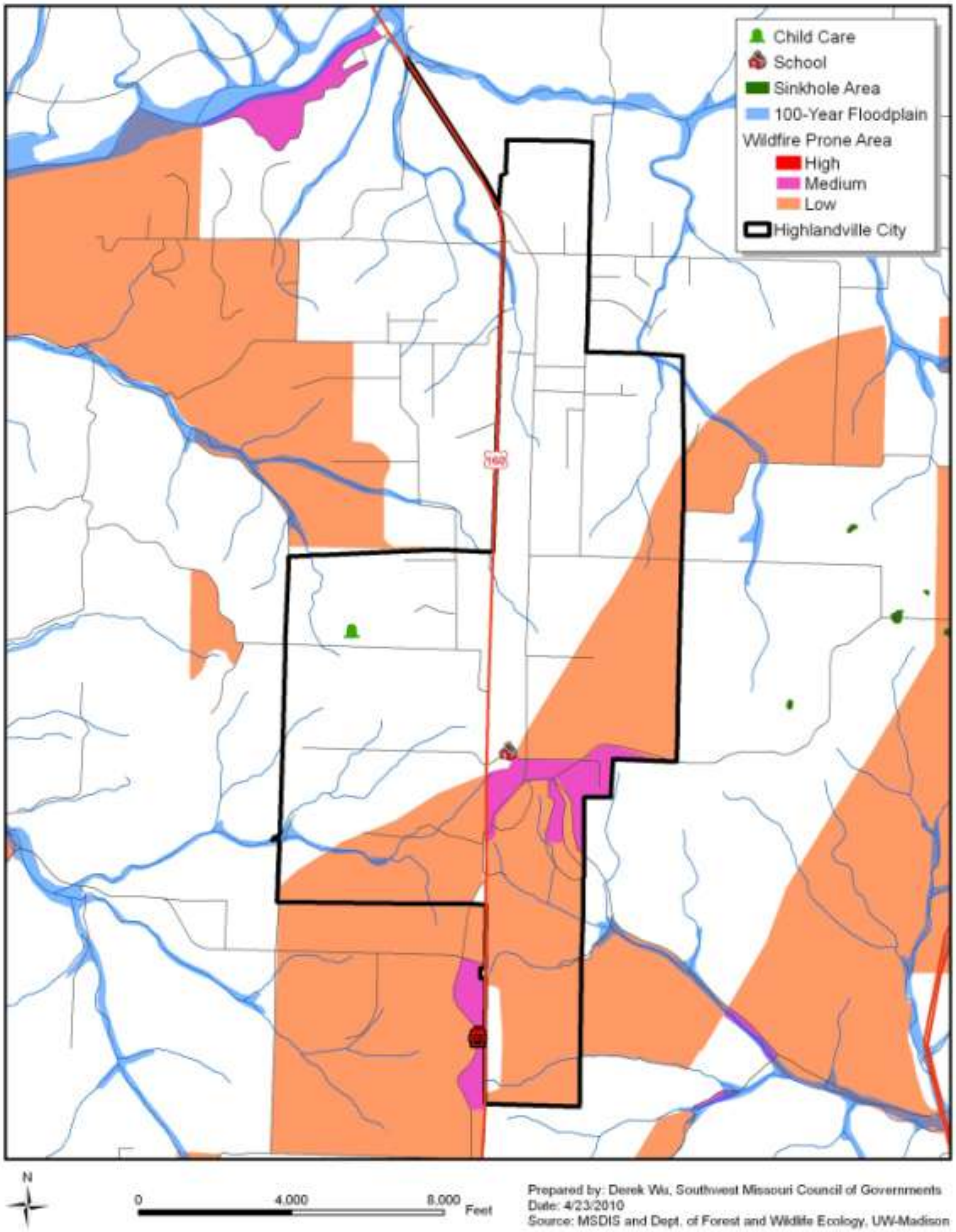
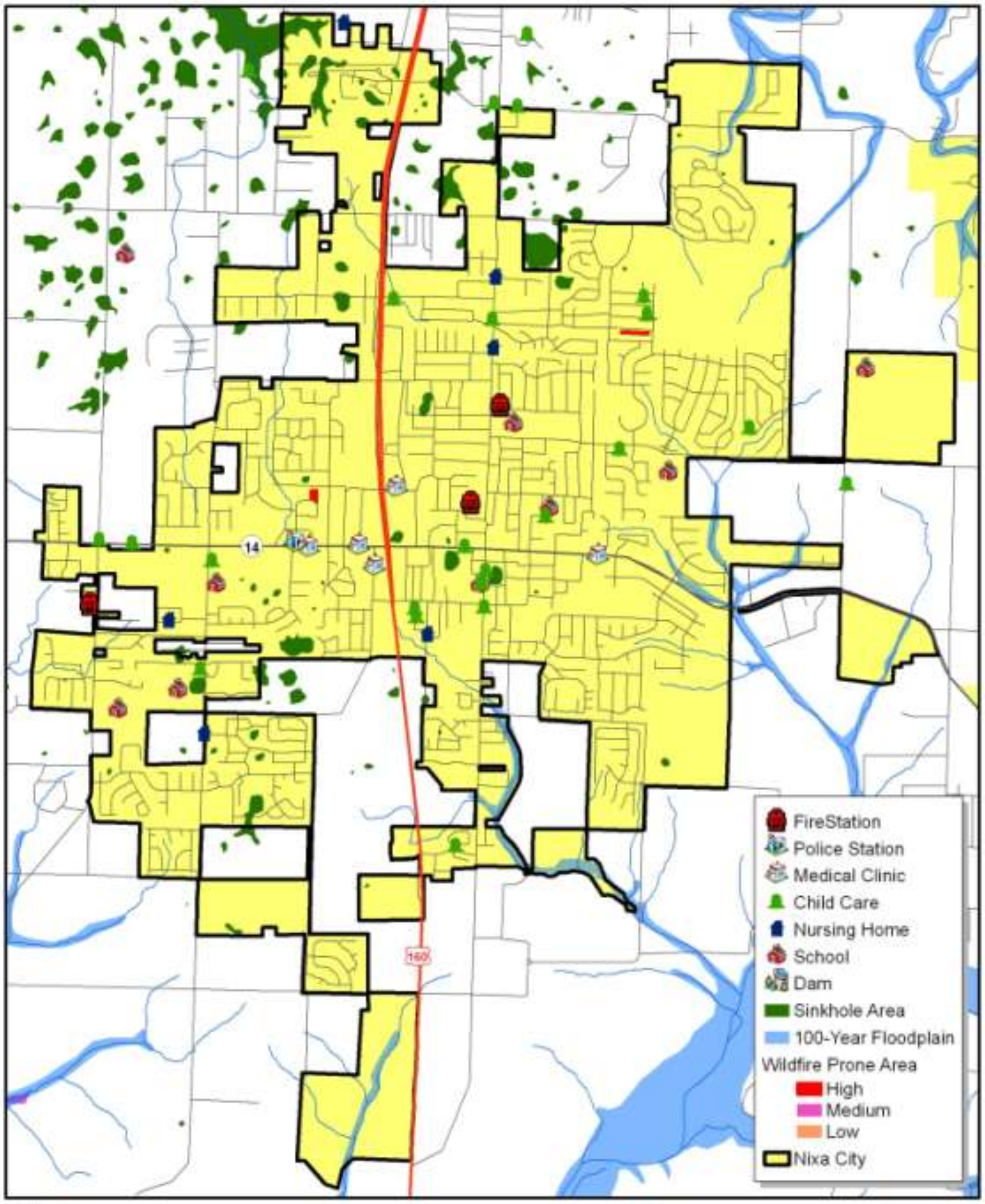


Figure 3-25: City of Nixa Hazards Composite Map



N

0 3,000 6,000 Feet

Prepared by: Derek Wu, Southwest Missouri Council of Governments
Date: 4/23/2010
Source: MSDIS and Dept. of Forest and Wildlife Ecology, UW-Madison

Figure 3-26: City of Ozark Hazards Composite Map

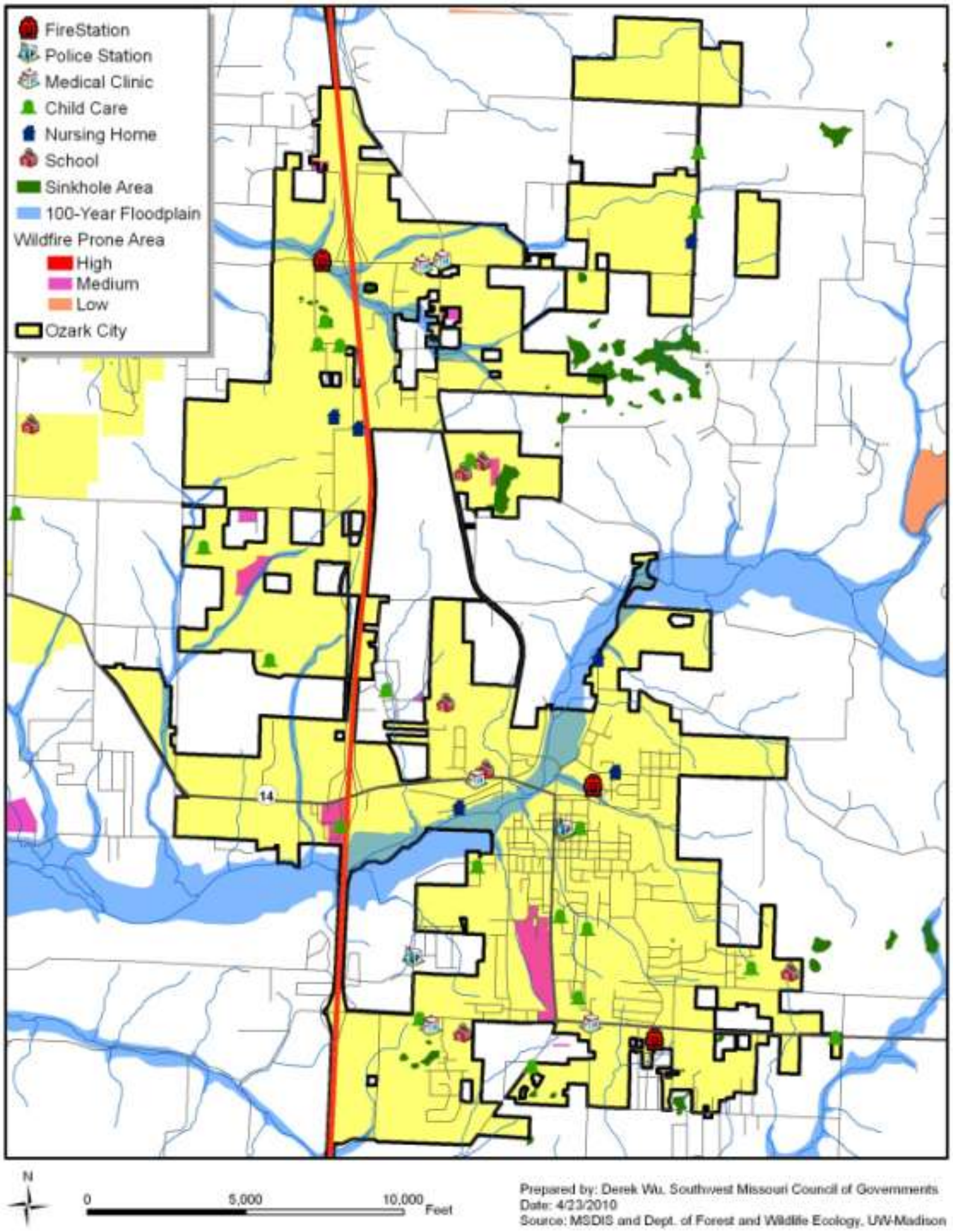
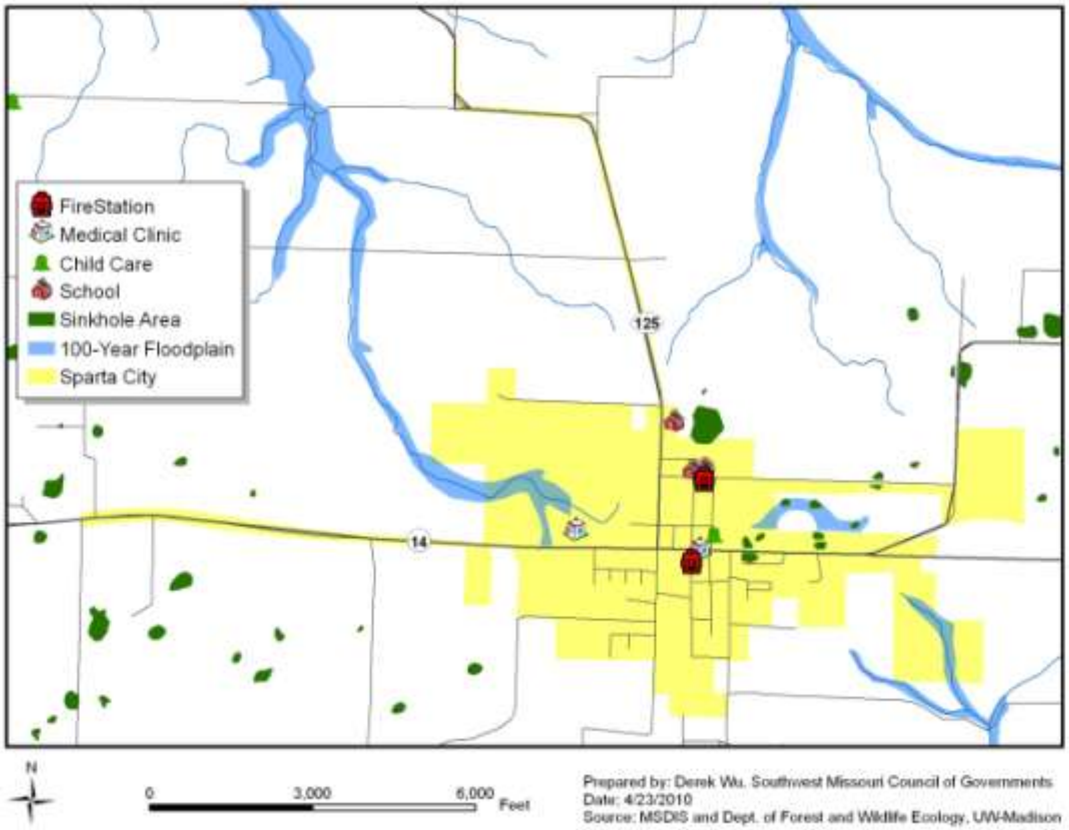


Figure 3-27: City of Sparta Hazards Composite Map



Multi-Jurisdictional Risk Assessment

The multi-jurisdictional risk assessment developed in this plan includes a hazard identification and analysis by jurisdiction. This analysis is an attempt to delineate the threat level of all natural hazards that can affect each participating jurisdiction in Christian County. Likely locations of some hazards can be identified in each of the lengthy hazard profiles previously presented in this section of the plan and in the composite hazard maps, as was their intent. Other regional hazards defy assigning variability to geographically dispersed communities. A method was developed, which capitalized on the data available from the NCDC regarding past events for each hazard. In many cases, a particular jurisdiction was identified as the location associated with individual events. A multi-criteria evaluation of the data was used to develop the hazard identification and analysis described in the plan. In the end, the analysis did not solely rely on these data but was subjected to a common sense review by representatives from each jurisdiction. School districts were surveyed and self-reported the threat of each of these hazards based on specialized knowledge of their own facilities and boundaries.

The second component of the risk assessment is a vulnerability assessment based on estimates of potential loss by jurisdiction. This assessment defines vulnerability in terms of the general type and number of existing buildings and critical facilities located within each jurisdiction. The estimates of potential loss are based on a percentage of damage relating to the threat level developed in the risk identification and analysis by jurisdiction and summarized in the Overall Summary of Hazard Vulnerability by Jurisdiction in Table 3-59.

Natural Hazards Risk Identification and Analysis by Jurisdiction

In order to identify and assess variability of the risk of natural hazards that can affect each jurisdiction in Christian County, data for each recorded hazard events on the National Oceanic and Atmospheric Administration (NOAA) website and ranking of what constitutes a low, medium or high probability and severity of an event from the 2007 State Hazard Mitigation Plan were used in a multi-criteria assessment. Based on the NOAA records, data for past events were divided into categories of crop and other damage resulting from the event, number of causalities and injuries due to the event, and the probability of the event based on the number of occurrences divided by the number of years in the timeframe from the first documented event to the year of the last recorded event. The numeric values for these categories were collapsed in the three ordered classes of low, medium and high based on the following definitions from the 2007 *State of Missouri Hazard Mitigation Plan*:

Probability—The likelihood that the hazard will occur.

- **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).

Severity—The deaths, injuries, or damage (property or environmental) that could result from the hazard.

- **Low**—Few or minor damage or injuries are likely.
- **Moderate**—Injuries to personnel and damage to property and the environment is expected.
- **High**—Deaths and major injuries and damage will likely occur

Damages per Event

The damages in dollar amounts reported for each type of hazard event for each jurisdiction associated with that event were added together and then divided by the number of events creating the value for damages per event. For the purposes of this analysis; low damage equaled $0 - $49,000, moderate equaled $50,000 - $99,000 and high equaled $100,000 or more.

Injuries and Deaths per Event

Similar to damages per event, a total of all injuries and deaths associated with all events associated with certain jurisdictions were divided by the number of those events. This number was reclassified into low; 0-1 person affected, moderate; 1.1-4 persons affected and high; 4.1 or more persons affected.

Probability of Future Events

This criterion was broken down according to the definitions used in the State Plan where low equaled less than 1%, medium equaled 1%-10% and high was a value greater than 10%.

In order to sum and divide the classes of low, medium and high, these ordered levels were assigned a value of 1 for low, 2 for medium and 3 for high. For each jurisdiction, the value of 1, 2, or 3 corresponding to each category were added together and divided by 3 creating a cumulative ranking of threat level for individual jurisdictions. These values were then converted back to ordered statements of low, moderate and high based on the values of less than 1.6, 1.6 – 2.0 and greater than 2.0 respectively. Finally, this information was presented to the Plan Review and Advisory Committee meeting for a common sense review in a format similar to Table 3-59. It was explained to the committee that the NOAA data may not be comprehensive, meaning that not all events may have been reported, and that there were some serious issues in the method used and the definitions of the classes. Based on input from representatives from the local jurisdictions many values were changed to where they made more sense. For instance, it was determined that the impact of sinkholes in the City of Nixa should be elevated from low to moderate as they have spent thousands of dollars on remediation over the past year. The results are presented in the Overall Summary of Hazard Vulnerability by Jurisdiction in Table 3-59.

Table 3-59: Overall Summary of Hazard Vulnerability by Jurisdiction										
Hazards / Jurisdiction	Tornado	Severe T-storm	Flood (riverine, Flash)	Severe Winter Weather	Drought	Heatwave	Earthquake	Dam Failure	Wildfire	Sinkhole
Christian County	H	H	H	H	M	M	L	L	M	L
Municipalities										
Billings	H	H	M	H	M	M	L	N/A	L	L
Clever	H	M	L	H	M	M	L	N/A	L	L
Fremont Hills	L	L	L	H	M	M	L	N/A	L	L
Highlandville	M	M	L	H	M	M	L	N/A	M	L
Nixa	M	M	M	H	M	M	L	N/A	L	M
Ozark	M	M	H	H	M	M	L	N/A	L	L
Sparta	L	M	L	H	M	M	L	N/A	L	L
School Districts										
Billings R-IV	H	H	H	H	M	M	L	N/A	L	L
Chadwick R-I	L	M	L	H	M	M	L	N/A	L	L
Clever R-V	H	H	L	M	L	L	L	N/A	L	L
Nixa R-II	M	M	M	H	M	M	L	N/A	L	M
Ozark R-VI	M	M	M	M	L	L	L	N/A	L	L
Spokane R-VII	H	H	H	M	M	M	M	N/A	L	M
Colleges										
OTC Richwood	H	H	L	M	L	M	M	N/A	L	M

Vulnerability Assessment and Estimates of Potential Loss by Jurisdiction

<u>Methodology</u>

The vulnerability assessment further defines and quantifies populations, buildings, critical facilities, and other community assets at risk to natural hazards by jurisdiction. The vulnerability assessment for this plan is based on the methodology described in the FEMA publication *Understanding Your Risks—Identifying Hazards and Estimating Losses* (2002). This section describes overall vulnerability and estimates potential losses for buildings, infrastructure and critical facilities located in identified hazard areas. The vulnerability assessment was conducted based on the best available data and the significance of the hazard by jurisdiction in Table 3-59. Data to support the vulnerability assessment was collected from the following sources:

- County Assessor’s GIS parcel data (appraised valuations)
- Missouri United School Insurance Council
- FEMA’s HAZUS-MH loss estimation software
- Insured replacement cost of assets provided by participating jurisdictions
- Existing plans and reports

The methods used to calculate potential losses in dollar amounts vary according to the natural hazard addressed and type of entity or jurisdiction. The methods used to estimate losses for local governments are not the same for school districts. Local government loss estimates were first calculated for identified and profiled hazards that can affect the entire planning area. These hazards include drought, earthquake, extreme heat, tornado/thunderstorms and winter storms. The corresponding values of low, medium and high for each jurisdiction in the Overall Summary of Hazard Vulnerability in Table 3-59 were converted to a damage factor or vulnerability percentage of 1%, %5 and 10% respectively.

The damage factors for individual jurisdictions were applied to a community's inventory of assets by building type. A GIS parcel file with residential, commercial and agricultural appraised valuation was the primary source used to create the total replacement costs for these building types and contents. Critical facilities included in the local government loss estimations are the essential facilities listed in Table 3-47, main government buildings and water treatment facilities. Schools are not included in the local government loss estimates because they are included in the loss estimates for school districts. Day care centers and nursing homes are assumed to have been captured in the total commercial appraised value in the jurisdiction that it is located.

Replacement values for local government critical facilities were based on insured replacement values for buildings and contents provided by local jurisdictions. The corresponding damage factor for each jurisdiction from the Overall Summary of Hazard Vulnerability in Table 3-59 was applied to that jurisdiction's inventory of assets replacement values to create a dollar value of potential losses. Drought and extreme heat are not likely to result in damage to structures but are more likely to affect the contents housed in buildings. Therefore, the damage factors for these two hazards were only applied to the contents values.

After the tables depicting loss estimations for area wide hazards for local governments, local area hazard loss estimates for each participating local government are presented. Local area hazards include dam failure, flooding (riverine and flash), sinkholes and wildfire where certain hazard prone areas can be defined. The loss estimates for local area hazards depict losses to structures in the hazard prone areas only. A brief description of the method used for these hazards is provided here:

- Dam failure loss estimates were included for unincorporated Christian County only due to the only significant hazard dam is located in a rural east central portion of the county. To estimate the losses from the failure of this dam a ten meter buffer of the floodplain up to five miles downstream of the dam was used as a likely inundation area. HAZUS-MR3 census blocks that intersected with the likely inundation area were used to generate a building count within the hazard area. An average replacement value for the type of structures based on appraised valuations in unincorporated Christian County was multiplied by the number of structures in the hazard area to generate the loss estimation for this hazard event.

- Flood loss estimates were developed using a method similar to the one used for dam failure. All HAZUS census blocks situated within 100 feet of the 100 year floodplain were selected to compile building counts by type for each participating municipality and the unincorporated balance of Christian County. It is important to note that this method created building counts for areas well outside the 100 year floodplain but in an effort to depict losses from flash flooding as well, the entire building count for all census blocks within 100 feet of the 100 year floodplain would be more prone to flash flooding due to the proximity to natural drainage features in the area. Average replacement values for each community were then applied to the HAZUS building counts before the damage factor for the community was applied to create a loss estimate for both types of flood events.

- Sinkhole loss estimates were established using GIS processes and appraised valuations. A sinkhole point shapefile acquired from MSDIS was used to run a point density function in GIS. The output from this function created values for individual pixels based on a count of sinkhole features within a specified radius from each pixel. The values of all pixels were grouped into 3 classes from low to high creating three zones. The zone with the highest pixel values was designated as the hazard prone area for sinkholes. The map layer of the hazard prone area was used as an overlay on the parcel data to generate the loss estimates from this hazard by jurisdiction.

- Wildfire loss estimates were created by overlaying the SILVIS lab Wildland Urban Interface census blocks over the HAZUS census blocks. If the census block was categorized as medium or high interface or intermix, its coincident HAZUS census block was used to generate building counts for each community. The average appraised valuation by building type in each community was applied to the number of structures before the appropriate damage factor was calculated.

Loss estimates for school districts were developed using Missouri United School Insurance Council (MUSIC) replacement values for school district structures and contents. This information was provided by all school districts that participated in the plan. The Hazard Vulnerability to each identified hazard was self reported by each participating school district through a survey instrument. Unlike potential loss estimations for local municipal and the county government, the loss estimations for school districts include a value for the number of building occupants and a projection of losses for future development of district facilities based on the growth percentage of the municipality or unincorporated area of the county which it serves. The growth percentage for communities is based the difference between the 2000 census and 2008 population estimates from Table 2-2 in Part II and accounts for growth over the next eight years.

Describing vulnerability in terms of dollar losses provides communities with a framework to measure the effects of hazards on vulnerable structures and a means to prioritize mitigation strategies to reduce future losses due to natural hazards. Although there may be some limitations in using the loss estimations to apply a rigorous benefit/cost analysis, the methods were applied equally to all jurisdictions.

Critical Facilities and Infrastructure

A critical facility may be defined as one that provides essential public safety or mitigation functions during response or recovery operations. Table 3-60 below gives examples of critical facilities, high potential loss facilities and transportation and lifelines as they are defined for the purposes of this analysis. Table 3-61 describes the number and types of these facilities by jurisdiction. Immediately following Table 3-61 are the potential loss estimates by hazard and by jurisdiction presented in Tables 3-62 through 3-86.

Table 3-60: Critical Facilities, Definitions and Examples

Essential Facilities	**High Potential Loss Failure**	**Transportation and Lifelines**
Hospital and other medical facilities	Power Plants	Railroad and facilities
Police Stations	Dams and Levees	Airports
Fire Stations	Hazardous material sites	Water Treatment facilities
	Schools	Natural gas facilities, Pipelines
	Day Care Centers	Communication facilities
	Nursing Homes	
	Main government buildings	

Source: FEMA HAZUS-MH MR3.

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Table 3-61: Critical Facilities and Infrastructure by Jurisdiction

	Christian County (Unincorporated)	Billings	Clever	Fremont Hills	Highlandville	Nixa	Ozark	Sparta	Total
Medical Clinics	--	--	--	--	--	6	5	2	13
Ambulance Services	--	--	--	--	--	1	1	1	3
Waste Water Treatment	--	1	1	1	1	2	2	1	9
Police Stations	--	1	1	--	1	1	3	1	8
Fire Stations	8	1	1	--	2	2	2	1	17
Schools/Colleges	4	2	4	--	1	9	8	3	31
911 Station	--	--	--	--	--	1	1	--	2
Residential and Skilled Nursing Care	--	--	--	--	--	6	8	--	14
Day Care Centers	--	--	2	--	1	14	11	1	29
Senior Centers	--	--	1	--	--	1	1	--	3
Main Government Buildings	--	1	1	--	1	1	4	1	9
Dams	4	--	--	--	--	--	--	--	4
Total	16	6	11	1	7	44	46	11	142

Area Wide Vulnerability Assessment Tables for Participating Jurisdictions

Table 3-62	**Area Wide Hazard Vulnerability Percentages**					
Unincorporated Christian County	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$1,615,342,400	$97,949,900	$39,982,300	$578,744	$1,753,853,344
Contents	x	$807,671,200	$97,949,900	$39,982,300	$868,116	$1,084,982,460
Building and Contents	x	$2,423,013,600	$195,899,800	$79,964,600	$1,446,860	$2,838,835,804
Estimated Number of buildings		13,835	500	3,539	8	17,936
Hazard						
Drought	5%	$40,383,560	$4,897,495	$1,999,112	$43,406	$47,323,573
Earthquake	1%	$24,230,136	$1,958,999	$799,646	$14,469	$25,240,150
Heatwave	5%	$40,383,560	$4,897,495	$1,999,112	$43,406	$47,323,573
Tornado/T-Storms	10%	$242,301,360	$19,589,990	$7,996,460	$144,686	$270,032,406
Winter Storms	10%	$242,301,360	$19,589,990	$7,996,460	$144,686	$270,032,406

Table 3-63	**Area Wide Hazard Vulnerability Percentages**					
City of Clever	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$79,489,000	$7,916,300	$104,300	$2,810,816	$90,320,416
Contents	x	$39,744,500	$7,916,300	$104,300	$4,216,224	$51,981,324
Building and Contents	x	$119,233,500	$15,832,600	$208,600	$7,027,040	$142,301,740
Estimated Number of buildings		864	53	15	5	937
Hazard						
Drought	5%	$1,987,225	$395,815	$5,215	$210,811	$2,599,066
Earthquake	1%	$1,192,335	$158,326	$1,043	$70,270	$1,421,974
Heatwave	5%	$1,987,225	$395,815	$5,215	$210,811	$2,599,066
Tornado/T-Storms	5%	$5,961,675	$791,630	$5,215	$351,352	$7,109,872
Winter Storms	10%	$11,923,350	$1,583,260	$10,430	$702,704	$14,219,744

Table 3-64	**Area Wide Hazard Vulnerability Percentages**					
City of Fremont Hills	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$87,874,500	$1,471,600	$0	$2,229,700	$91,575,800
Contents	x	$43,937,250	$1,471,600	$0	-	$45,408,850
Building and Contents	x	$131,811,750	$2,943,200	$0	$2,229,700	$136,984,650
Estimated Number of buildings		370	2	0	1	373
Hazard						
Drought	5%	$2,196,863	$73,580	$0	$0	$2,270,443
Earthquake	1%	$1,318,118	$29,432	$0	$22,297	$1,369,847
Heatwave	5%	$2,196,863	$73,580	$0	$0	$2,270,443
Tornado/T-Storms	1%	$1,318,118	$29,432	$0	$22,297	$1,369,847
Winter Storms	10%	$13,181,175	$294,320	$0	$222,970	$13,698,466

Table 3- 65	**Area Wide Hazard Vulnerability Percentages**					
City of Highlandville	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$26,789,300	$2,800,500	$65,949	$1,987,212	$31,642,961
Contents	x	$13,394,650	$2,800,500	$65,949	$2,980,818	$19,241,917
Building and Contents	x	$40,183,950	$5,601,000	$131,898	$4,968,030	$50,884,878
Estimated Number of buildings		390	28	47	5	470
Hazard						
Drought	5%	$669,733	$140,025	$3,297	$149,041	$962,096
Earthquake	1%	$401,840	$56,010	$1,319	$49,680	$508,849
Heatwave	5%	$669,733	$140,025	$3,297	$149,041	$962,096
Tornado/T-Storms	5%	$2,009,198	$280,050	$6,595	$248,402	$2,544,245
Winter Storms	10%	$4,018,395	$560,100	$13,190	$496,803	$5,088,490

Table 3-66	**Area Wide Hazard Vulnerability Percentages**					
City of Nixa	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$825,727,000	$118,282,300	$512,800	$36,070,880	$980,592,980
Contents	x	$412,863,500	$118,282,300	$512,800	$54,106,320	$585,764,920
Building and Contents	x	$1,238,590,500	$236,564,600	$1,025,600	$90,177,200	$1,566,357,900
Estimated Number of buildings		6,697	316	84	35	7,132
Hazard						
Drought	5%	$20,643,175	$5,914,115	$25,640	$2,705,316	$29,288,246
Earthquake	1%	$12,385,905	$2,365,646	$10,256	$90,17720	$23,779,527
Heatwave	5%	$20,643,175	$5,914,115	$25,640	$2,705,316	$29,288,246
Tornado/T-Storms	5%	$61,929,525	$11,828,230	$51,280	$4,508,860	$78,317,895
Winter Storms	10%	$123,859,050	$23,656,460	$102,560	$9,017,720	$156,635,790

Table 3-67	**Area Wide Hazard Vulnerability Percentages**					
City of Ozark	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$732,685,600	$182,629,000	$1,674,800	$47,787,220	$964,776,620
Contents	x	$366,342,800	$182,629,000	$1,674,800	$71,680,830	$622,327,430
Building and Contents	x	$1,099,028,400	$365,258,000	$3,349,600	$119,468,050	$1,587,104,050
Estimated Number of buildings		5,544	514	185	35	6,278
Hazard						
Drought	5%	$18,317,140	$9,131,450	$83,740	$2,705,316	$31,116,372
Earthquake	1%	$10,990,284	$3,652,580	$3,350	$1,194,681	$15,840,895
Heatwave	5%	$18,317,140	$9,131,450	$83,740	$2,705,316	$31,116,372
Tornado/T-Storms	5%	$54,951,420	$18,262,900	$167,480	$5,973,403	$79,355,203
Winter Storms	10%	$109,902,840	$36,525,800	33,496	$11,946,805	$158,408,950

Table 3-68	**Area Wide Hazard Vulnerability Percentages**					
City of Sparta	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Building Only	x	$49,601,300	$5,953,400	$81,700	$2,853,930	$58,490,330
Contents	x	$24,800,650	$5,953,400	$81,700	$4,280,895	$35,116,645
Building and Contents	x	$74,401,950	$11,906,800	$163,400	$7,134,825	$93,606,975
Estimated Number of buildings		642	57	17	8	724
Hazard						
Drought	5%	$1,240,033	$297,670	$4,085	$214,045	$1,755,833
Earthquake	1%	$744,020	$119,068	$817	$71,348	$935,253
Heatwave	5%	$1,240,033	$297,670	$4,085	$214,045	$1,755,833
Tornado/T-Storms	5%	$3,720,098	$595,340	$4,085	$356,741	$4,676,264
Winter Storms	10%	$7,440,195	$1,190,680	$1,870	$713,483	$9,346,228

Local Area Hazard Vulnerability Tables for Participating Jurisdictions

Table 3-69	**Local Area Hazard Vulnerability Percentages**					
Unincorporated Christian County	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Dam Failure	**1%**	**$50,790**	**$3,918**	**-**	**-**	**$54,708**
Building Only	x	$3,385,982	$195,900	-	-	$3,581,882
Contents	x	$1,692,991	$195,000	-	-	$1,887,991
Building and Contents	x	$5,078,973	$391,800	-	-	$5,470,773
Estimated Number of buildings		29	1	0	0	30
Flooding	**10%**	**$1,507,496**	**$2,238,860**	**$3,282,200**	**$90,429**	**$7,118,985**
Building Only	x	$241,780,900	$11,194,300	$15,141,100	$361,715	$268,478,015
Contents	x	$241,780,900	$11,194,300	$15,141,100	$542,573	$268,658,873
Building and Contents	x	$483,561,800	$22,388,600	$30,282,200	$904,287	$537,136,887
Estimated Number of buildings		1,920	55	953	5	2,933
Sinkhole	**1%**	**$4,650,195**	**$1,206,946**	**$65,082**	**$362**	**$5,922,585**
Building Only	x	$310,013,000	$60,347,300	$3,254,100	$144,686	$373,759,086
Contents	x	$155,006,500	$60,347,300	$3,254,100	$217,029	$218,824,929
Building and Contents	x	$465,019,500	$120,694,600	$6,508,200	$361,715	$592,584,015
Estimated Number of buildings		2,335	237	538	2	3,112
Wildfire	5%	**$3,870,517**	**$783,599**	**$1,129**	**-**	**$4,655,245**
Building Only	x	$51,606,891	$7,835,992	$11,298	-	$59,454,181
Contents	x	$25,803,446	$7,835,992	$11,298	-	$33,650,736
Building and Contents	x	$77,410,337	$15,671,984	$22,596	-	$93,104,917
Estimated Number of buildings		442	40	1	0	483

Table 3-70	Local Area Hazard Vulnerability Percentages					
City of Clever	Hazard Value	Building Types				Totals
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**1%**	**$114,543**	**$5,975**	**$139**	**-**	**$120,657**
Building Only	x	$7,636,166	$298,730	$6,954	-	$7,941,850
Contents	x	$3,818,083	$298,730	$6,954	-	$4,123,767
Building and Contents	x	$11,454,249	$597,460	$13,908	-	$12,065,617
Estimated Number of buildings		83	2	1	0	86
Sinkhole	**1%**	**-**	**-**	**-**	**-**	**-**
Building Only	x	-	-	-	-	-
Contents	x	-	-	-	-	-
Building and Contents	x	-	-	-	-	-
Estimated Number of buildings		-	-	-	-	-
Wildfire	**1%**	**-**	**-**	**-**	**-**	**-**
Building Only	x	-	-	-	-	-
Contents	x	-	-	-	-	-
Building and Contents	x	-	-	-	-	-
Estimated Number of buildings		-	-	-	-	-

Table 3-71	**Local Area Hazard Vulnerability Percentages**					
City of Fremont Hills	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**1%**	**$491,623**	**$29,432**	**-**	**$22,297**	**$543,352**
Building Only	x	$32,774,862	$1,471,600	-	$2,229,700	$36,466,162
Contents	x	$16,387,431	$1,471,600	-	-	$17,859,031
Building and Contents	x	$49,162,293	$2,943,200	-	$2,229,700	$54,335,193
Estimated Number of buildings		138	2	0	1	143
Sinkhole	1%	**$548,340**	**-**	**-**	**-**	**$548,340**
Building Only	x	$36,556,000	-	-	-	$36,556,000
Contents	x	$18,278,000	-	-	-	$18,278,000
Building and Contents	x	$54,834,000	-	-	-	$54,834,000
Estimated Number of buildings		116	-	-	-	116
Wildfire	1%	-	-	-	-	-
Building Only	x	-	-	-	-	-
Contents	x	-	-	-	-	-
Building and Contents	x	-	-	-	-	-
Estimated Number of buildings		-	-	-	-	-

Table 3-72	**Local Area Hazard Vulnerability Percentages**					
City of Highlandville	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**1%**	**$438,186**	**$8,002**	**$57**	**$39,745**	**$485,990**
Building Only	x	$29,212,377	$400,072	$2,808	$1,589,772	$31,205,029
Contents	x	$14,606,189	$400,072	$2,808	$2,384,658	$17,393,727
Building and Contents	x	$43,818,566	$800,144	$5,616	$3,974,430	$48,598,756
Estimated Number of buildings		123	4	2	4	133
Sinkhole	**1%**	-	-	-	-	-
Building Only	x	-	-	-	-	-
Contents	x	-	-	-	-	-
Building and Contents	x	-	-	-	-	-
Estimated Number of buildings		-	-	-	-	-
Wildfire	**5%**	**$159,705**	**$20,000**	**-**	**-**	**$179,705**
Building Only	x	$2,129,406	$200,004	-	-	$2,328,410
Contents	x	$1,064,703	$200,004	-	-	$1,264,707
Building and Contents	x	$3,194,109	$400,008	-	-	$3,594,117
Estimated Number of buildings		31	2	0	0	33

Table 3-73	**Local Area Hazard Vulnerability Percentages**					
City of Nixa	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**5%**	**$8,276,379**	**$1,384,951**	**$1,832**	**$525,299**	**15,706,351**
Building Only	x	$110,351,710	$13,849,507	$18,315	$4,122,388	128,341,920
Contents	x	$55,175,855	$13,849,507	$18,315	$6,183,582	75,227,259
Building and Contents	x	$165,527,565	$27,699,014	$36,630	$10,305,970	203,569,179
Estimated Number of buildings		895	37	3	4	939
Sinkhole	5%	**$39,207,278**	**$11,213,740**	**$59,070**	**$2,962,965**	**$53,443,052.15**
Building Only	x	$522,763,700	$112,137,400	$590,700	$23,703,708	$659,195,508
Contents	x	$261,381,850	$112,137,400	$590,700	$35,555,585	$409,665,535
Building and Contents	x	$784,145,550	$224,274,800	$1,181,400	$59,259,293	$1,08,861,043
Estimated Number of buildings		4,354	300	48	23	4,725
Wildfire	1%	**$33,293**	**-**	**-**	**-**	**$33,293**
Building Only	x	$2,219,634	-	-	-	$2,219,634
Contents	x	$1,109,682	-	-	-	$1,109,682
Building and Contents	x	$3,329,316	-	-	-	$3,329,316
Estimated Number of buildings		18	-	-	-	18

Table 3-74	**Local Area Hazard Vulnerability Percentages**					
City of Ozark	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**10%**	**$11,537,481**	**$5,471,774**	**$5,432**	**$1,365,350**	**$18,380,037**
Building Only	x	$76,916,538	$27,358,870	$27,159	$5,461,400	$109,763,967
Contents	x	$38,458,269	$27,358,870	$27,159	$8,192,096	$74,036,394
Building and Contents	x	$115,374,807	$54,717,740	$54,318	$13,653,496	$183,800,361
Estimated Number of buildings		1,164	77	3	4	1,248
Sinkhole	**1%**	**$3,063,941**	**$1,912,036**	**$2,944**	**$443,738**	**$5,422,659**
Building Only	x	$204,262,700	$95,601,800	$147,200	$17,749,491	$317,761,191
Contents	x	$102,131,350	$95,601,800	$147,200	$26,624,312	$224,504,662
Building and Contents	x	$306,394,050	$191,203,600	$294,400	$44,373,849	$542,265,899
Estimated Number of buildings		1301	192	31	13	1537
Wildfire	**1%**	**$188,326**	**$7,106**	**-**	**-**	**$195,432**
Building Only	x	$12,555,038	$355,309	-	-	$12,910,347
Contents	x	$6,277,519	$355,309	-	-	$6,632,828
Building and Contents	x	$18,832,557	$710,618	-	-	$19,543,175
Estimated Number of buildings		95	14	0	0	109

Table 3-75	**Local Area Hazard Vulnerability Percentages**					
City of Sparta	**Hazard Value**	**Building Types**				**Totals**
	%	**Residential** Contents Valued at 50%	**Commercial** Contents Valued at 100%	**Agriculture** Contents Valued at 100%	**Critical Facilities** Contents Valued at 150%	
Hazard						
Flooding	**5%**	**$525,375**	**$62,667**	**-**	**-**	**$588,042**
Building Only	x	$5,253,748	$626,674	-	-	$5,880,422
Contents	x	$5,253,748	$626,674	-	-	$5,880,422
Building and Contents	x	$10,507,496	$1,253,347	-	-	$11,760,843
Estimated Number of buildings		68	6	0	0	74
Sinkhole	**1%**	**$481,809**	**$103,350**	**$1,582**	**$35,674**	**$622,415**
Building Only	x	$32,120,600	$5,167,500	$79,100	$1,426,964	$38,794,164
Contents	x	$16,060,300	$5,167,500	$79,100	$2,140,448	$23,447,348
Building and Contents	x	$48,180,900	$10,335,000	$158,200	$3,567,412	$62,241,512
Estimated Number of buildings		441	48	31	4	524
Wildfire	**1%**	-	-	-	-	-
Building Only	x	-	-	-	-	-
Contents	x	-	-	-	-	-
Building and Contents	x	-	-	-	-	-
Estimated Number of buildings		-	-	-	-	-

Vulnerability Assessment Tables for all Christian County School Districts

Table 3-76	**Tornado: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Tornado/Severe T-Storm	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	52	1	$1,359,785	54	1	$1,420,975
Chadwick R-I	3	1	$57,740	3	0	$59,472
Clever R-V	107	1	$3,435,486	173	1	$5,531,133
Nixa R-II	287	1	$5,657,662	445	1	$8,769,377
Ozark R-VI	250	2	$6,468,592	468	3	$12,096,266
Spokane R-VII	84	1	$2,402,862	87	1	$2,474,948

Table 3-77	**Severe T-Storm: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Tornado/Severe T-Storm	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	52	1	$1,359,785	54	1	$1,420,975
Chadwick R-I	3	1	$57,740	3	0	$59,472
Clever R-V	107	1	$3,435,486	173	1	$5,531,133
Nixa R-II	287	1	$5,657,662	445	1	$8,769,377
Ozark R-VI	250	2	$6,468,592	468	3	$12,096,266
Spokane R-VII	84	1	$2,402,862	87	1	$2,474,948

Table 3-78	**Flood: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Flood	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	52	1	$1,359,785	54	1	$1,420,975
Chadwick R-I	3	0	$57,740	3	0	$59,472
Clever R-V	11	0	$343,549	17	0	$553,113
Nixa R-II	287	1	$5,657,662	445	1	$8,769,377
Ozark R-VI	250	1	$6,468,592	467	2	$12,096,266
Spokane R-VII	84	0	$2,402,862	86	0	$2,474,948

Table 3-79	**Winter Storm: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Severe Winter Storm	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	52	1	$1,359,785	54	1	$1,420,975
Chadwick R-I	27	1	$577,397	28	1	$594,719
Clever R-V	54	1	$1,717,743	87	1	$2,765,567
Nixa R-II	574	1	$11,315,324	890	2	$17,538,754
Ozark R-VI	250	2	$6,468,592	468	3	$12,096,266
Spokane R-VII	42	1	$1,201,431	44	1	$1,237,474

Table 3-80	**Drought: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Drought	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	26	1	$679,892	27	1	$710,487
Chadwick R-I	14	1	$288,699	14	1	$297,360
Clever R-V	11	1	$343,549	17	1	$553,113
Nixa R-II	287	1	$5,657,662	445	1	$8,769,377
Ozark R-VI	50	1	$1,293,718	94	1	$2,419,253
Spokane R-VII	42	1	$1,201,431	44	1	$1,237,474

Table 3-81	**Heat Wave: Christian County School Districts Vulnerability Assessment** Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Heat Wave	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	26	1	$679,892	27	1	$710,487
Chadwick R-I	14	1	$288,699	14	1	$297,360
Clever R-V	11	0	$343,549	17	0	$553,113
Nixa R-II	287	1	$5,657,662	445	1	$8,769,377
Ozark R-VI	50	0	$1,293,718	94	1	$2,419,253
Spokane R-VII	42	1	$1,201,431	44	1	$1,237,474

Table 3-82	Earthquake: Christian County School Districts Vulnerability Assessment Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Earthquake	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	5	1	$135,978	5	1	$142,097
Chadwick R-I	3	1	$57,740	3	1	$59,472
Clever R-V	11	1	$343,549	17	1	$553,113
Nixa R-II	57	1	$1,131,532	89	1	$1,752,625
Ozark R-VI	50	1	$1,293,718	94	1	$2,419,253
Spokane R-VII	42	1	$1,201,431	44	1	$1,237,474

Table 3-83	Wildfire: Christian County School Districts Vulnerability Assessment Estimates based on High/Medium/Low Risk factors for each district outlined in Table 3-42					
Wildfire	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	5	1	$135,978	5	1	$142,097
Chadwick R-I	3	0	$57,740	3	0	$59,472
Clever R-V	11	0	$343,549	17	0	$553,113
Nixa R-II	57	0	$1,131,532	89	0	$1,753,875
Ozark R-VI	50	0	$1,293,718	93	0	$2,419,253
Spokane R-VII	8	0	$240,286	9	0	$247,495

Table 3-84	Sinkhole: Christian County School Districts Vulnerability Assessment Estimates based on Low Risk factors for each district outlined in Table 3-42					
Sinkhole	**Current Facilities**			**Future Growth**		
	# People	**# Bldgs**	**Est. Value**	**# People**	**# Bldgs**	**Est. Value**
Billings R-IV	5	1	$135,978	5	1	$142,097
Chadwick R-I	3	0	$57,740	3	0	$59,472
Clever R-V	11	0	$343,549	17	0	$553,113
Nixa R-II	57	0	$1,131,532	89	0	$1,753,875
Ozark R-VI	50	1	$1,293,718	93	1	$2,419,253
Spokane R-VII	8	0	$240,289	9	0	$247,495