3 Risk Assessment

DRAFT

DRAFT

44 CFR Requirement §201.6(c)(2): [The plan shall include] A risk assessment that provides the factual basis for activities proposed in the strategy to reduce losses from identified hazards. Local risk assessments must provide sufficient information to enable the jurisdiction to identify and prioritize appropriate mitigation actions to reduce losses from identified hazards.

The goal of the risk assessment is to estimate the potential loss in the planning area, including loss of life, personal injury, property damage, and economic loss, from a hazard event. The risk assessment process allows communities and school/special districts in the planning area to better understand their potential risk to the identified hazards. It will provide a framework for developing and prioritizing mitigation actions to reduce risk from future hazard events.

This chapter is divided into four main parts:

- **Section 3.1 Hazard Identification** identifies the hazards that threaten the planning area and provides a factual basis for elimination of hazards from further consideration.
- **Section 3.2 Assets at Risk** provides the planning area's total exposure to natural hazards, considering critical facilities and other community assets at risk.
- **Section 3.3 Future Land Use and Development** discusses areas of planned future development
- **Section 3.4 Hazard Profiles and Vulnerability Analysis** provides more detailed information about the hazards impacting the planning area. For each hazard, there are three sections: 1) Hazard Profile provides a general description and discusses the threat to the planning area, the geographic location at risk, potential severity/magnitude/extent, previous occurrences of hazard events, probability of future occurrence, risk summary by jurisdiction, impact of future development on the risk; 2) Vulnerability Assessment further defines and quantifies populations, buildings, critical facilities, and other community/school or special district assets at risk to natural hazards; and 3) Problem Statement briefly summarizes the problem and develops possible solutions.

3.1 Hazard Identification

Requirement §201.6(c)(2)(i): [The risk assessment shall include a] description of the type…of all natural hazards that can affect the jurisdiction.

The primary phase in the development of a hazard mitigation plan is to identify specific hazards which may impact the planning area. To initiate this process, the Hazard Mitigation Planning Committee (HMPC) reviewed a list of natural hazards provided by the Federal Emergency Management Agency (FEMA). From that list, the HMPC selected pertinent natural hazards of concern that have the potential to impact Washington County. These selected natural hazards are further profiled and analyzed in this plan.

3.1.1 Review of Existing Mitigation Plans

Within the State of Missouri, local hazard mitigation plans customarily include only natural hazards, as only natural hazards are required by federal regulations. Nevertheless, there is an opportunity to include man made or technical hazards within the plan. However, it was decided that only natural hazards were appropriate for the purpose of this plan. Based on past history and future probability, the Hazard Mitigation Planning Committee (HMPC) determined that the following potential hazards would be included in the Washington County Hazard Mitigation Plan:

- Dam Failure
- Drought
- Earthquake
- Extreme Temperatures
- Fires
- Flooding (Riverine and Flash)
- Land Subsidence/Sinkholes
- Severe Thunderstorms Including High Winds, Hail, and Lightning
- Tornado
- Severe Winter Weather

Hazards not occurring in the planning area or considered insignificant were eliminated from this plan. **Table 3.1** outlines the hazards eliminated from the plan and the reasons for doing so. Additionally, some hazards were combined in the Washington County Plan to match the hazards listed in the Missouri State Hazard Mitigation Plan.

Table 3.1. Table 3.1 Hazards Not Profiled in the Plan

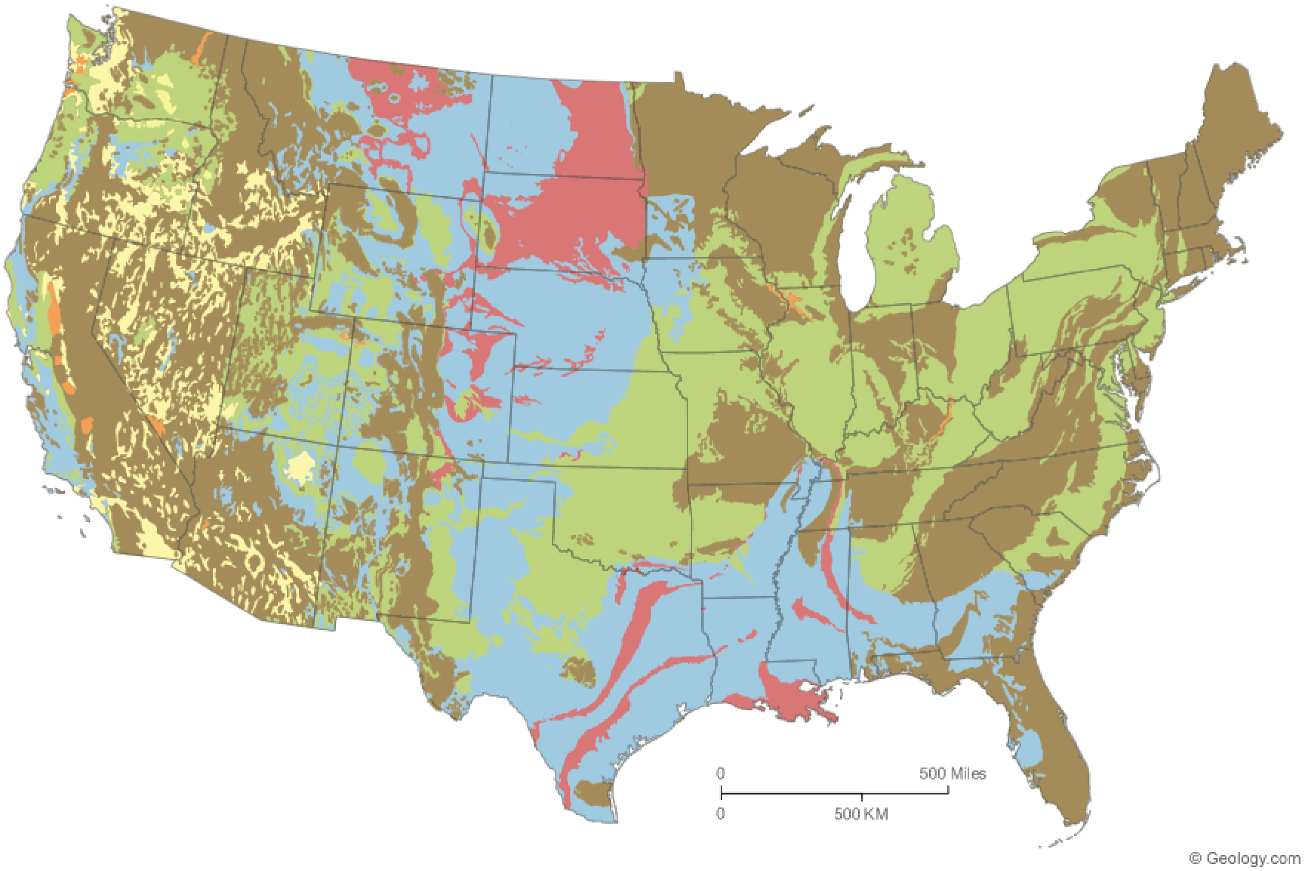
Hazard	Reason for Omission
Avalanche	No mountains in the planning area.
Coastal Erosion	Planning area is located in the Midwest, not on any coast.
Coastal Storm	Planning area is located in the Midwest, not on any coast.

Hazard	Reason for Omission
Debris Flow	There are no mountainous areas in the planning area where this type of event occurs.
Expansive Soils	No expansive soils exist within the planning area. According to the USGS National Geologic Map Database[1], the planning area is underlain by soils with little to no clays with swelling potential (**Figure 3.1**).
Hurricane	Planning area is located in the Midwest, not on any coast.
Levee Failure	According to the US Army Corps of Engineers' National Levee Database [2], and local officials, there are no levees located in the planning area. However, low-head agricultural levees could be present. Unfortunately, no data could be found indicating damages in the event of failure.
Volcano	There are no volcanic areas in the county.

DRAFT

[1] http://ngmdb.usgs.gov/Prodesc/proddesc_10014.htm
[2] http://nld.usace.army.mil/egis/f?p=471:1:0::NO

Figure 3.1. Swelling clays map of the conterminous United States



Over 50 percent of these areas are underlain by soils with abundant clays of high swelling potential.

Less than 50 percent of these areas are underlain by soils with clays of high swelling potential.

Over 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.

Less than 50 percent of these areas are underlain by soils with abundant clays of slight to moderate swelling potential.

These areas are underlain by soils with little to no clays with swelling potential.

Data insufficient to indicate the clay content or the swelling potential of soils.

Source: http://ngmdb.usgs.gov/Prodesc/proddesc_10014.htm

3.1.2 Review Disaster Declaration History

In order to assess risk, it was logical to review the disaster declaration history for the State of Missouri and specifically for Washington County. Federal and State disaster declarations are granted when the severity and magnitude of a hazard event surpasses the ability of local government to respond and recover. Disaster assistance is supplemental and sequential. When the local government's capacity has been surpassed, a state disaster declaration may be issued, allowing for the provision of state assistance. If the disaster is so severe that both the local and state governments' capacities are exceeded; a federal emergency or disaster declaration may be issued allowing for the provision of federal assistance.

FEMA also issues emergency declarations, which are more limited in scope and do not include the long-term federal recovery programs of major disaster declarations. Determinations for declaration type are based on scale and type of damages and institutions or industrial sectors affected.

There are three agencies through which a federal disaster declaration can be issued – FEMA, the U.S. Department of Agriculture (USDA) and/or the Small Business Administration. A federally declared disaster generally includes long-term federal recovery programs. The type of declaration is determined by the type of damage sustained during a disaster and what types of institutions or industries are affected.

A declaration issued by USDA indicates that the affected area has suffered at least a 30 percent loss in one or more crops or livestock industries. This type of declaration provides those farmers affected with access to low-interest loans and other programs to assist with disaster recovery and mitigation.

Missouri has been especially hard hit by natural disasters in the recent past. The state has had 72 federally declared disasters since 1953. Of those, 35 have occurred since 2002. Most of these disasters have been weather related – severe wind and rainstorms, tornadoes, flooding, hail, ice storms and winter storms. **Table 3.2** lists the federal disaster declarations for Washington County from 2001 through 2020.

Table 3.2. FEMA Disaster Declarations that included Washington County, Missouri, 2001-2020

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-1412	Missouri Severe Storms & Tornadoes	Incident Period: April 24, 2002-June 10, 2002 Declaration Date: May 06, 2002	PA
DR-1463	Missouri Severe Storms, Tornadoes, and Flooding	Incident Period: May 04, 2003-May 30, 2003 Declaration Date: May 06, 2003	IA, PA
EM-3232	Missouri Hurricane Katrina Evacuation	Incident Period: August 29, 2005-October 01, 2005 Declaration Date: September 10, 2005	PA

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
EM-3267	Missouri Severe Storms	Incident Period: July 19, 2006-July 21, 2006 Declaration Date: July 21, 2006	PA
DR-1631	Missouri Severe Storms, Tornadoes, and Flooding	Incident Period: March 08, 2006-March 13, 2006 Declaration Date: March 16, 2006	PA
DR-1673	Missouri Severe Winter Storms	Incident Period: November 30, 2006-December 02, 2006 Declaration Date: December 29, 2006	PA
EM-3281	Missouri Severe Winter Storms	Incident Period: December 08, 2007-December 15, 2007 Declaration Date: December 12, 2007	PA
DR-1749	Missouri Severe Storms & Flooding	Incident Period: March 17, 2008-May 09, 2008 Declaration Date: March 19, 2008	IA, PA
DR-1847	Missouri Severe Storms, Tornadoes, and Flooding	Incident Period: May 08, 2009-May 16, 2009 Declaration Date: June 19, 2009	IA, PA
EM-3303	Missouri Severe Winter Storms	Incident Period: January 26, 2009-January 28, 2009 Declaration Date: January 30, 2009	PA
DR-1980	Missouri Severe Storms, Tornadoes, and Flooding	Incident Period: April 19, 2011-June 06, 2011 Declaration Date: May 09, 2011	PA
EM-3317	Missouri Severe Winter Storm	Incident Period: January 31, 2011-February 05, 2011 Declaration Date: February 03, 2011	PA
DR-4238	Missouri Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Incident Period: May 15, 2015-July 27, 2015 Declaration Date: August 07, 2015	PA
EM-3374	Missouri Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Incident Period: December 22, 2015-January 09, 2016 Declaration Date: January 02, 2016	PA
DR-4250	Missouri Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Incident Period: December 23, 2015-January 09, 2016 Declaration Date: January 21, 2016	PA

DRAFT

Disaster Number	Description	Declaration Date Incident Period	Individual Assistance (IA) Public Assistance (PA)
DR-4317	Missouri Severe Storms, Tornadoes, Straight-line Winds, and Flooding	Incident Period: April 28, 2017-May 11, 2017 Declaration Date: June 02, 2017	PA
EM-3482	Missouri COVID-19	Declaration Date: March 13, 2020 Incident Period: January 20, 2020, and continuing	PA
DR-4490	Missouri COVID-19 Pandemic	Declaration Date: March 26, 2020 Incident Period: January20, 2020, and continuing	IA, PA

Source: Federal Emergency Management Agency: http://www.fema.gov/disasters

3.1.3 Research Additional Sources

List of the additional sources of data on locations and past impacts of hazards in the planning area:

- Missouri Hazard Mitigation Plans (2013, 2018)
- Federal Emergency Management Agency (FEMA)
- Missouri Department of Natural Resources (MDNR)
- National Drought Mitigation Center Drought Reporter
- US Department of Agriculture's (USDA) Risk Management Agency Crop Insurance Statistics
- National Agricultural Statistics Service (Agriculture production/losses)
- Data Collection Questionnaires completed by each jurisdiction
- State of Missouri GIS data
- Environmental Protection Agency
- Flood Insurance Administration
- Hazards US (HAZUS)
- Missouri Department of Transportation
- Missouri Division of Fire Marshal Safety
- Missouri Public Service Commission
- National Fire Incident Reporting System (NFIRS)
- National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI);
- Pipeline and Hazardous Materials Safety Administration
- County and local Comprehensive Plans to the extent available
- County Emergency Management
- County Flood Insurance Rate Map, FEMA
- Flood Insurance Study, FEMA

DRAFT

- SILVIS Lab, Department of Forest Ecology and Management, University of Wisconsin
- U.S. Army Corps of Engineers
- U.S. Department of Transportation
- United States Geological Survey (USGS)
- Various articles and publications available on the internet (sources are cited in the body of the Plan)

Remarkably, the only centralized source of data for many of the weather-related hazards is the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI). Although it is usually the best and most current source, there are limitations to the data which should be noted. The NCEI documents the occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. In addition, it is a partial record of other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occurs in connection with another event. Some information appearing in the NCEI may be provided by or gathered from sources outside the National Weather Service (NWS), such as the media, law enforcement and/or other government agencies, private companies, individuals, etc. An effort is made to use the best available information but because of time and resource constraints, information from these sources may be unverified by the NWS. Those using information from NCEI should be cautious as the NWS does not guarantee the accuracy or validity of the information.

The NCEI damage amounts are estimates received from a variety of sources, including those listed above in the Data Sources section. For damage amounts, the NWS makes a best guess using all available data at the time of the publication. Property and crop damage figures should be considered as a broad estimate. Damages reported are in dollar values as they existed at the time of the storm event. They do not represent current dollar values.

The database currently contains data from January 1950 to March 2014, as entered by the NWS. Due to changes in the data collection and processing procedures over time, there are unique periods of record available depending on the event type. The following timelines show the different time spans for each period of unique data collection and processing procedures.

1. Tornado: From 1950 through 1954, only tornado events were recorded.
2. Tornado, Thunderstorm Wind and Hail: From 1955 through 1992, only tornado, thunderstorm wind and hail events were keyed from the paper publications into digital data. From 1993 to 1995, only tornado, thunderstorm wind and hail events have been extracted from the Unformatted Text Files.
3. All Event Types (48 from Directive 10-1605): From 1996 to present, 48 event types are recorded as defined in NWS Directive 10-1605.

Injuries and deaths caused by a storm event are reported on an area-wide basis. When reviewing a table resulting from an NCEI search by county, the death or injury listed in connection with that county search did not necessarily occur in that county.

3.1.4 Hazards Identified

Table 3.3 lists the hazards that significantly impact each jurisdiction within the planning area and were chosen for further analysis in alphabetical order. “X” indicates the jurisdiction is impacted by the hazard, and a "-" indicates the hazard is not applicable to that jurisdiction. As Washington County is predominately rural, limited variations occur across the county. However, jurisdictions with a high percentage of housing comprised of mobile homes, for example, could be more at risk to damages from a tornado.

Table 3.3. Hazards Identified for Each Jurisdiction

Jurisdiction	Dam Failure	Drought	Earthquake	Extreme Temperatures	Flooding (River and Flash)	Land Subsidence/Sinkholes	Thunderstorms/High Winds/ Lightning/Hail	Severe Winter Weather	Tornado	Wildfires
Washington County	x	x	x	x	x	x	x	x	x	x
Caledonia	x	x	x	x	x	x	x	x	x	x
Irondale	x	x	x	x	x	x	x	x	x	x
Mineral Point	x	x	x	x	x	x	x	x	x	x
Potosi	x	x	x	x	x	x	x	x	x	x
School Districts										
Kingston K-14	x	x	x	x	x	x	x	x	x	x
Potosi R-III	x	x	x	x	x	x	x	x	x	x
Richwoods R-VII	x	x	x	x	x	x	x	x	x	x
Valley R-VI	x	x	x	x	x	x	x	x	x	x

3.1.5 Multi-Jurisdictional Risk Assessment

For this multi-jurisdictional hazard mitigation plan, each hazard is profiled in which the risks are assessed on a planning area wide basis. Some hazards, such as dam failure, vary in risk across the county. If variations exist within the planning area, discussion is included in each profile. Washington County is uniform across the county in terms of climate, topography, and building construction characteristics. Weather-related hazards will impact the entire county in much the same fashion, as do topographical/geological related hazards such as earthquake. Sinkholes appear throughout the county and are localized in their effects. The focal area of urbanization includes the cities and villages of Caledonia, Irondale, Mineral Point, and Potosi. Urbanized areas have more assets at a greater density, and therefore have greater vulnerability to weather-related hazards. Rural areas include agricultural assets (livestock/crops) that are also vulnerable to damages. Differences among jurisdictions for each hazard will be discussed in greater detail in the vulnerability section of each hazard.

3.2 Assets at Risk

This section assesses the planning area's population, structures, critical facilities, infrastructure, and other important assets that may be at risk to hazards.

3.2.1 Total Exposure of Population and Structures

Unincorporated County and Incorporated Cities

In the following three tables, population data is based on 2020 Census Bureau data. Building counts values are based on parcel data provided by the 2018 Missouri State Hazard Mitigation Plan, which can be found at the following website, https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf.

Table 3.4. Maximum Population and Building Exposure by Jurisdiction

Jurisdiction	2020 Population	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Unincorporated Washington County	20,246	14,690	$921,201,000	$482,800,000	$1,404,001,000
Caledonia	131	106	$9,968,000	$6,571,000	$16,539,000
Irondale	368	194	$20,681,000	$11,552,000	$32,413,000
Mineral Point	231	128	$13,780,000	$7,108,000	$20,888,000
Potosi	2,538	1,163	$130,847,000	$47,673,000	$207,381,000
Total	23,514	16,288	$1,097,306,000	$584,999,000	$1,682,304,000

Sources: U.S. Census Bureau Decennial Redistricting Data, 2018 Missouri State Hazard Mitigation Plan

DRAFT

Table 3.5. Building Value/Exposure by Usage Type

Jurisdiction	Agriculture	Commercial	Education	Government	Industrial	Residential	Total
Washington County	$3,390	$79,525	$16,142	$7,309	$25,644	$1,271,990	$1,404,001
Caledonia	$8	$6,101	$0	$261	$0	$10,169	$16,539
Irondale	$1	$3,704	$0	$783	$0	$27,926	$32,413
Mineral Point	$0	$872	$0	$0	$0	$20,016	$20,888
Potosi	$3	$51,419	$7,122	$3,394	$2,426	$143,018	$207,381
Total	**$3,402**	**$142,056**	**$23,264**	**$11,747**	**$28,070**	**$1,473,765**	**$1,682,304**

Source: FEMA HAZUS, Missouri State Hazard Mitigation Plan
* All values in 1,000s of dollars.

Table 3.6. Building Counts by Usage Type

Jurisdiction	Residential Counts	Commercial Counts	Industrial Counts	Agricultural Counts	Other	Total
Washington County	7,880	365	74	6,309	62	14,690
Caledonia	63	28	0	14	1	106
Irondale	173	17	0	1	3	194
Mineral Point	124	4	0	0	0	128
Potosi	6	236	7	6	28	1,163
Total	9,130	652	81	6331	94	16,288

Source: 2018 MO State Hazard Mitigation Plan

Table 3.7 below, provides additional information for school districts, including the number of buildings, building values (building exposure) and contents value (contents exposure). These numbers will represent the total enrollment and building count for the public-school districts regardless of the county in which they are located.

Table 3.7. Population and Building Exposure by Jurisdiction-Public School Districts

Public School District	Enrollment	Building Count	Building Exposure ($)	Contents Exposure ($)	Total Exposure ($)
Kingston K-14	873	4	26,271,848	3,892,679	30,164,527
Potosi R-III	2,046	4	78,315,194	13,061,787	91,376,981
Richwoods R-VII	149	1	5,957,754	1,288,404	7,246,157
Valley R-VI	415	2	16,664,587	5,670,153	22,334,740

Source: https://apps.dese.mo.gov/MCDS/Reports/SSRS_Print.aspx?ReportId=152b1d45-e617-4184-acf3-82b9287ae2b4 ; 2022 Data Collection Questionnaire

DRAFT

3.2.2 Critical and Essential Facilities and Infrastructure

This section will include information from the Data Collection Questionnaire and other sources concerning the vulnerability of participating jurisdictions' critical, essential, high potential loss, and transportation/lifeline facilities to identified hazards. Definitions of each of these types of facilities are provided below.

- Critical Facility: Those facilities essential in providing utility or direction either during the response to an emergency or during the recovery operation.
- Essential Facility: Those facilities that if damaged, would have devastating impacts on disaster response and/or recovery.
- High Potential Loss Facilities: Those facilities that would have a high loss or impact on the community.
- Transportation and lifeline facilities: Those facilities and infrastructure critical to transportation, communications, and necessary utilities.

The table below (**Table 3.8**) provides information for critical facilities in the planning area. Specific information includes a Hazus ID if applicable, jurisdiction, building name/owner, and address. Facilities addressed include emergency, fire department, law enforcement, medical, and schools.

DRAFT

Table 3.8. Table 3.8 Washington County Critical Facilities by Type and Jurisdiction

HazusID	Jurisdiction	Building Name	Address	City	State	Zip
Emergency Facilities						
	Washington Co.	Emergency Management Director	23117 State Highway P	Belgrade	MO	63622
	Washington Co.	Washington Co. E-911	12252 N State Highway 21	Cadet	MO	63630
Fire Department Facilities						
MO000138	Belgrade	Belgrade Volunteer Fire Dept.	14126 State Hwy C	Belgrade	MO	63622
MO000715	Caledonia	Caledonia Fire Protection Dist.	155 Webster Road	Caledonia	MO	63631
	Irondale	Irondale Community Vol. Fire Dept.	107 West Pine St.	Irondale	MO	63648
MO000517	Potosi	Potosi Fire Prot. Dist., No. 1	313 East Jefferson St.	Potosi	MO	63664
	Potosi	Potosi Fire Prot. Dist., No. 2	10441 State Hwy AA	Potosi	MO	63664
	Potosi	Potosi Fire Prot. Dist., No. 3	10047 Tiff Road	Cadet	MO	63630
	Potosi	Potosi Fire Prot. Dist., No. 4	19076 North State Hwy 21	Cadet	MO	63630
	Potosi	Potosi Fire Prot. Dist., No. 5	10051 Jeff City Road	Potosi	MO	63664
MO000137	Richwoods	Richwoods Fire Prot. Dist.	10015 Turtle Road	Richwoods	MO	63071
	Sullivan	Sullivan Fire Protection District, Station 2	11890 Mine Road	Sullivan	MO	63080
Law Enforcement Facilities						
	Potosi	Potosi Police Department	1 Police Plaza	Potosi	MO	63664
	Washington Co.	Washington County Sheriff's Department	116 West High Street	Potosi	MO	63664
Medical Facilities						
MO000099	Potosi	Washington Co. Memorial Hospital	300 Health Way	Potosi	MO	63664
	Washington Co.	Washington Co. Health Dept.	520 Purcell Drive	Potosi	MO	63664
School Facilities						
	Cadet	Kingston Primary	10047 Diamond Road	Cadet	MO	63630
MO001824	Cadet	Kingston Elem.	10047 Diamond Road	Cadet	MO	63630
MO001825	Cadet	Kingston Middle	10047 Diamond Road	Cadet	MO	63630
MO001120	Cadet	Kingston High	10047 Diamond Road	Cadet	MO	63630
MO000822	Potosi	Potosi Elem.	205 State Hwy P	Potosi	MO	63664
MO000825	Potosi	Trojan Intermediate	367 Intermediate Drive	Potosi	MO	63664
MO000823	Potosi	John A. Evans Middle	303 S Lead St.	Potosi	MO	63664
MO000824	Potosi	Potosi High	1 Trojan Drive	Potosi	MO	63664

HazusID	Jurisdiction	Building Name	Address	City	State	Zip
MO000173	Potosi	Citadel School	400 S Mine	Potosi	MO	63664
MO001177	Richwoods	Richwoods Elem.	10788 State Hwy A	Richwoods	MO	63071
MO001827	Caledonia	Caledonia Elem.	1 Viking Drive	Caledonia	MO	63631
MO001828	Caledonia	Valley High	1 Viking Drive	Caledonia	MO	63631
Childcare Facilities						
	Mineral Point	East Missouri Action Agency, Inc	512 State St.	Mineral Point	MO	63660
	Potosi	Happy Days Preschool	10079 Simmental LN	Potosi	MO	63664
	Potosi	Kids Zone	402 N. Missouri	Potosi	MO	63664
	Potosi	Little Learners Academy	10965 Hwy. 185	Potosi	MO	63664
	Caledonia	Martin, Kimberly	10350 Webster Rd.	Caledonia	MO	63631
	Potosi	Mim's Just Like Home, LLC	10405 State Hwy P	Potosi	MO	63664
	Potosi	Randall, Sandra Kay	303 College St.	Potosi	MO	63664
	Potosi	Tammy's Tiny Tots	606 Raymond	Potosi	MO	63664
	Potosi	Wilson, Dena Mae	10271 Outer Rd.	Potosi	MO	63664
Nursing Homes						
	Potosi	Georgian Gardens Center for Rehab and Healthcare	1 Georgian Gardens Dr.	Potosi	MO	63664
	Mineral Point	Hillside Living Center	10109 Restoration Circle	Mineral Point	MO	63660
	Potosi	Potosi Manor	307 S. Hwy. 21	Potosi	MO	63664
	Mineral Point	South Haven Residential Care Center, LLC	10462 Airport Road	Mineral Point	MO	63664

Source: 2020 Data Collection Questionnaires, Missouri DHSS
https://healthapps.dhss.mo.gov/childcaresearch/, https://healthapps.dhss.mo.gov/showmeltc/default.aspx

Table 3.9 includes a summary of the inventory of critical and essential facilities and infrastructure in the planning area. The list was compiled from the 2020 Data Collection Questionnaire, the Meramec Regional Hazardous Materials Emergency Response Plan and the National Bridge Inventory.

Table 3.9. Inventory of Critical/Essential Facilities and Infrastructure by Jurisdiction

	Airport Facility	Bus Facility	Childcare Facility	Communications Tower	Electric Power Facility	Emergency Operations	Fire Service	Government	Housing	Shelters	State & Non-State Structures (Bridge)	Hospital/Health Care	Military	Pipeline/Pump Station	Nursing Homes	Police Station	Potable Water Facility	Rail	Sanitary Pump Stations	School Facilities	Stormwater Pump Stations	Tier II Chemical Facility	Wastewater Facility	Total
Unincorporated Washington County	0	0	0	-	-	1	2	28	2	0	143	0	0	-	0	1	-	1	2	4	0	16	0	200
Caledonia	1	0	1	-	-	0	1	1	-	0	0	0	0	-	0	0	-	0	5	2	-	2	-	13
Irondale	0	0	0	-	-	0	1	3	205	0	2	0	0	-	0	0	-	1	10	0	1	1	-	224
Mineral Point	1	0	1	-	1	0	0	0	-	0	2	0	0	-	2	0	-	2	-	0	-	6	-	15
Potosi	1	0	7	-	1	0	1	13	2	0	9	3	0	1	2	1	-	0	0	4	0	15	2	62
Totals	3	0	9	-	2	1	5	45	209	0	156	3	0	1	4	2	-	4	17	10	1	40	2	514

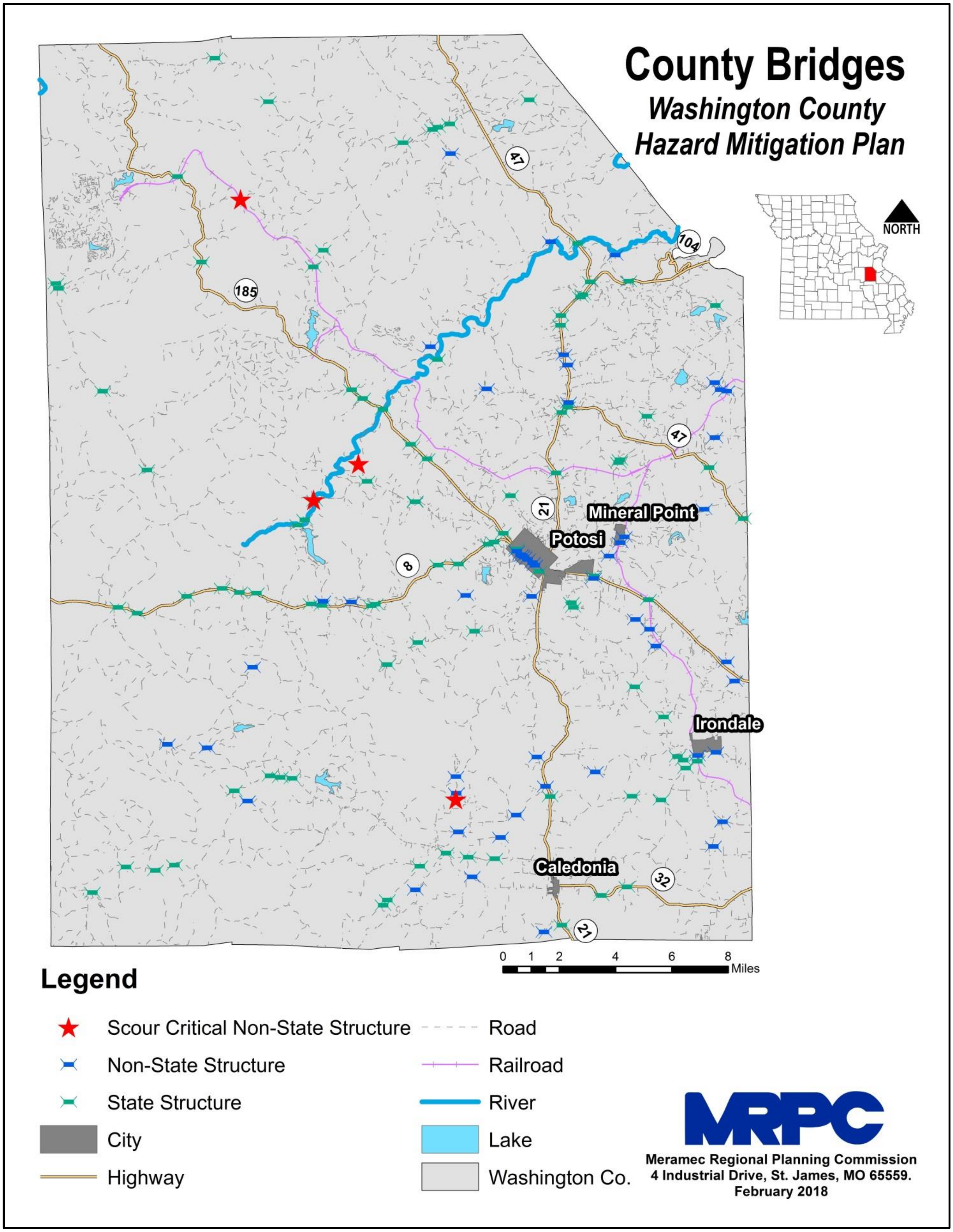
Source: 2022 Data Collection Questionnaires, National Bridge Inventory, 2021 MREPC Hazardous Materials Emergency Response Plan

According to the National Bridge Inventory there are a total of 156 bridges in Washington County[3]. **Figure 3.2** shows the locations of State regulated bridges and non-State bridges in the planning area. Scour critical bridges were also examined. Scour critical refers to one of the database elements in the National Bridge Inventory. This element is quantified using a "scour index", which is a number indicating the vulnerability of a bridge to scour during a flood. Bridges with a scour index between 1 and 3 are considered "scour critical", or a bridge with a foundation determined to be unstable for the observed or evaluated scour condition. There are four scour critical bridge within Washington County. The Goose Creek Rd. bridge spanning the Indian Creek, the Floyd Tower Rd. bridge over Fourche Renault creek, the Delbridge Rd. bridge over Clear Creek, and the Fourche Renault Rd bridge over the Little Fourche A Renault all have scour index ratings of 3[4].

DRAFT

[3] http://www.fhwa.dot.gov/bridge/nbi/no10/county.cfm
[4] https://infobridge.fhwa.dot.gov/Data/BridgeDetail/21918012#!#OverviewTab

Figure 3.2. Washington County Bridges



Source: MSDIS, MoDOT, MRPC

3.2.3 Other Assets

Assessing the vulnerability of the planning area to disaster also requires data on the natural, historic, cultural, and economic assets of the area. This information is important for many reasons.

- These types of resources warrant a greater degree of protection due to their unique and irreplaceable nature and contribution to the overall economy.
- Knowing about these resources in advance allows for consideration immediately following a hazard event, which is when the potential for damages is higher.
- The rules for reconstruction, restoration, rehabilitation, and/or replacement are often different for these types of designated resources.
- The presence of natural resources can reduce the impacts of future natural hazards, such as wetlands and riparian habitats which help absorb floodwaters.
- Losses to economic assets like these (e.g., major employers or primary economic sectors) could have severe impacts on a community and its ability to recover from disaster.

Threatened and Endangered Species: **Table 3.10** depicts Federally Threatened, Endangered, Proposed and Candidate Species in the county.

Table 3.10. Threatened and Endangered Species in Washington County

Common Name	Scientific Name	Status
Amphibians		
Eastern Hellbender	*Cryptobranchus alleganiensis*	Endangered (S)(Proposed F)
Clams		
Scaleshell Mussel	*Leptodea leptodon*	Endangered (F)
Snuffbox Mussel	*Epioblasma triquetra*	Endangered (F)
Spectaclecase	*Cumberlandia monodonta*	Endangered (F)
Sheepnose Mussel	*Plethobasus cyphyus*	Endangered (F)
Crustaceans		
Big Creek Crayfish	*Faxonius peruncus*	Threatened (Proposed F)
St. Francis River Crayfish	*Faxonius quadruncus*	Threatened (Proposed F)
Fishes		
Mountain Madtom	*Noturus eleutherus*	Endangered (S)
Taillight Shiner	*Notropus maculatus*	Endangered (S)
Birds		
Northern Harrier	*Circus cyaneus*	Endangered (S)
Flowering Plants		
Mead's Milkweed	*Asclepias meadii*	Endangered (S)
Eastern prairie fringed orchid	*Plantanthera leucophaea*	Endangered (S)
Mammal		
Gray bat	*Myotis grisescens*	Endangered (F) (S)
Indiana bat	*Myotis sodalis*	Endangered (F) (S)
Northern long-eared bat	*Myotis septentrionalis*	Threatened (F)

Eastern spotted skunk	*Spilogale putorius*	Endangered (S)

Note: S = State, F = Federal
Source: U.S. Fish and Wildlife Service, https://ecos.fws.gov/ecp/;
MDC, https://nature.mdc.mo.gov/status/endangered

Natural Resources: The Missouri Department of Conservation (MDC) provides a database of lands owned, leased, or managed for public use. **Table 3.11** provides the names and locations of parks and conservation areas in Washington County.

Table 3.11. Conservation Areas in Washington County

Area Name	Address	City
Bismark Conservation Area	From Caledonia, take Highway 32 east 10 miles, then right onto County Road 533, then left onto County Road 532, then right onto Bismark Lake Road.	Caledonia
Bootleg Access	From Potosi, take Highway 21 south 10 miles to Big River.	Potosi
Buford Mountain Conservation Area	From Caledonia, take Highway 21 south for 13 miles, turn left onto Highway U.	Caledonia
Hughes Mountain NA	From Potosi, take Highway 21 south 11 miles, then Route M east 5 miles to parking lot on south side of road 200 yards east of Cedar Creek Road (CR 541).	Potosi
Kingston Access	From the main entrance of Washington State Park, take Highway 21 west 3 miles, then Dugout Road north 2 miles to the area.	-
Little Indian Creek CA	North entrance: From Highway 30, take Route K south across the Meramec River, then Old Route K left 0.50 mile, then Little Indian Creek Road 3 miles to the area sign. South entrance to new shooting range: From I-44, take Highway 185 south 7 miles, then Route A east 6 miles to the area sign.	-

DRAFT

MO DNR (Washington State Park Access)	The Washington State Park Access (MO DNR) is north off of Highway 21 between De Soto and Old Mines. The access is located on the west side of the Big River.	-
Pea Ridge CA	Pea Ridge Conservation Area consists of several tracts and is marked with a sign on Highway 185 between Sullivan and Potosi.	Potosi
Potosi (Roger Bilderback Lake)	In Potosi City Park, located along Route P.	Potosi

Source: https://nature.mdc.mo.gov/discover-nature/find/places?area_name=&counties=All&location%5Bdistance%5D=50&location%5Borigin%5D=

Table 3.12 provides information pertaining to community owned/operated parks within Washington County.

Table 3.12. Community Owned Parks in Washington County

Park Name	Address	City
Townsend St. City Park	Townsend St., Caledonia, MO	Caledonia
Irondale City Park	Ash St., Irondale, MO 63648	Irondale
Bilderback Park	Clara Ave, Potosi, MO 63664	Potosi
Cresswell Park	South Lead St., Potosi, MO 63664	Potosi
Heritage Park	S Mine St. Potosi, MO 63664	Potosi
Howell Park	Stone St., Potosi, MO 63664	Potosi
Potosi City Park	Park Dr., Potosi, MO 63664	Potosi
Thurman Park	E Jefferson St., Potosi, MO 63664	Potosi

Source: Google Search

Historic Resources: The National Register of Historic Places is the official list of registered cultural resources worthy of preservation. It was authorized under the National Historic Preservation Act of 1966 as part of a national program. The purpose of the program is to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archeological resources. The National Register is administered by the National Park Service under the Secretary of the Interior. Properties listed in the National Register include districts, sites, buildings, structures, and objects that are significant in American history, architecture, archeology, engineering, and culture. **Table 3.13** provides information in regards to properties on the National Register of Historic Places in Washington County.

Table 3.13. Washington County Properties on the National Register of Historic Places

Property	Address	City	Date Listed
Caledonia Historic District	roughly bounded by Patrick, College, and Alexander Sts., and MO 21 on Main St., Caledonia	Caledonia	10/27/86
Cresswell Petroglyph Archaeological Site	address restricted	-	2/12/71
Cresswell, George, Furnance	MO F, Potosi vicinity	Potosi	5/23/88

DRAFT

Land Archaeological Site	address restricted	-	5/05/72
Lost Creek Pictograph Archaeological Site	address restricted	-	1/25/71
Palmer Historic Mining District	address restricted	-	11/29/10
Queen, Harrison, House	Hwy C, 1.3 mi. W of MO 21, Caledonia vicinity	Caledonia	6/27/02
Susan Cave	address restricted	-	7/08/89
Washington County Courthouse	102 N. Missouri St., Potosi	Potosi	10/25/11
Washington State Park CCC Historic District	Potosi vicinity	Potosi	3/04/85
Washington State Park Petroglyph Archaeological Site	Fertile vicinity	-	4/03/70

Source: Missouri Department of Natural Resources – Missouri National Register Listings by County http://dnr.mo.gov/shpo/mnrlist.htm

Economic Resources: **Table 3.14** provides major non-government employers in the planning area. There are approximately 350 employer establishments within the county, employing on average 11 individuals each[5].

Table 3.14. Major Non-Government Employers in Washington County

Employer Name	Product or Service	Employees
Potosi Correctional Center	Corrections	250-499
Washington Co. Memorial Hospital	Hospital	250-499
Red Wing Shoe Store	Retail	100-249
Purcell Tire Co.	Tire	100-499
Pyramid Homemaker Service	Services	100-249
Walmart Supercenter	Retail	100-249
YMCA Trout Lodge	Youth Organizations & Centers	250-499

Source: https://meric.mo.gov/industry/business-locator, 2022 Data Collection Questionnaires

Agriculture plays an important role in Washington County. However, the Agribusiness Employment Location Quotient for the county is 0.70; meaning that there is a relatively low share of agribusiness employment to its share of total national employment[6]. In addition, there were 86 individuals working in the agriculture industry, comprising 0.87% of the total workforce in 2020[7]. Furthermore, the market value of products sold in 2017 was $21,818,000 million; 88% from livestock sales and 12% from crop sales[8].

[5] https://www.census.gov/quickfacts/fact/table/washingtoncountymissouri,dentcountymissouri,crawfordcountymissouri/HSG650219
[6] Missouri Economic Research Information Center
[7] https://data.census.gov/table?text=S2405&g=0500000US29221&tid=ACSST5Y2020.S2405
[8] https://www.nass.usda.gov/Quick_Stats/CDQT/chapter/2/table/1/state/MO/county/065/year/2017

3.3 Future Land Use and Development

Table 3.15 provides population growth statistics for Washington County.

Table 3.15. Washington County Population Growth, 2010-2020

Jurisdiction	2010 Population	2020 Population	2010-2020 # Change	2010-2020 % Change
Unincorporated Washington County	20,696	20,246	-450	-2.17%
Caledonia	130	131	1	0.77%
Irondale	445	368	-77	-17.30%
Mineral Point	351	231	-120	-34.19%
Potosi	2,482	2,538	56	2.26%

Source: U.S. Bureau of the Census 2020 Decennial Redistricting Data, Census 2010 Summary File 1

Typically, population growth or decline is generally accompanied by an increase or decrease in the number of housing units. **Table 3.16** provides the change in numbers of housing units in the planning area from 2010-2019.

Table 3.16. Change in Housing Units, 2010-2020

Jurisdiction	Housing Units 2010	Housing Units 2020	2010-2020 # Change	2010-2020 % change
Unincorporated Washington	9,388	9,193	-195	-2.08%
Caledonia	76	74	-2	-2.63%
Irondale	192	160	-32	-16.67%
Mineral Point	131	99	-32	-24.43%
Potosi	1,230	1,193	-37	-3.01%

Source: U.S. Census Bureau 2020 Decennial Redistricting Data, U.S. Bureau of the Census, Census 2010 Summary File 1

Jurisdictions reported anticipated future developments within the next five years (2021-2026). The cities of Potosi, Mineral Point, and Caledonia did not anticipate any major future developments within the next five years nor did the Richwoods R-VII school district.

Washington County reported the recent development of two residential sub-division just outside the city limit of Potosi, increasing growth in the area industrial park, and preparations to construct a new park and amphitheater to be located in Potosi.

The city of Irondale is demolishing their recreation center to construct a new recreation center that will double as a community disaster shelter.

Valley R-VI recently completed several projects to include roof repairs and HVAC system improvements. They are designed the high school entryway to include interior locking doors a waiting area, and a window into the office. They also labelled all interior and exterior doors to improve communication with first responders during emergency situations. Finally, a new property was acquired and converted into a pre-school facility. There are no current plans for future construction at this time. The district does not have any FEMA certified tornado safe rooms.

Potosi R-III School District just completed the construction of certified tornado safe room at the elementary and would like to construct another in the next five years to service the Jr. High and High Schools.

Kingston K14 School district plans to construct a new gymnasium and fine arts classrooms at the high school as well as updating the existing cafeteria and some other classrooms. The district has one certified tornado safe room servicing the elementary school. They would like to build a second to serve the Jr. high and high schools.

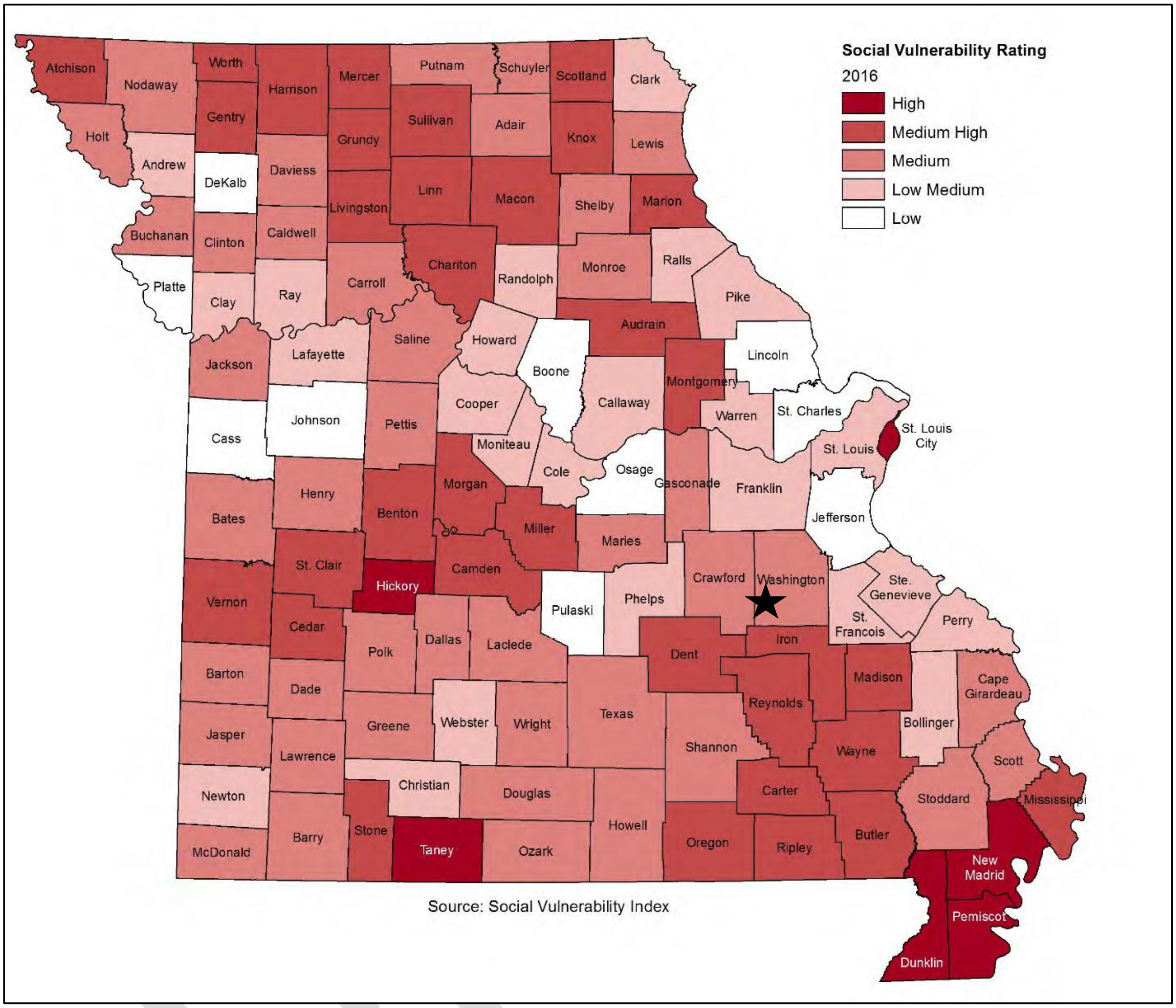
New development can impact a jurisdiction's vulnerability to natural hazards. As the number of buildings, critical facilities, and assets increase, vulnerability increases as well. For example, real estate development can increase storm water runoff, which often increases localized flooding. However, some development such as infrastructure improvements can help reduce vulnerability risks. Unfortunately, quantitative data is not available to further examine each jurisdictions new development and its correlation to natural hazard vulnerabilities.

Socioeconomic Profile

The Missouri State Hazard Mitigation Plan provides ratings for social vulnerability for each of the counties in the state based on 42 socioeconomic and built environment variables that research suggests contribute to a community's ability to prepare for, respond to and recover from hazards. Based on that data, Washington County has a "medium" social vulnerability rating (**Figure 3.3**). Furthermore, business incentives are available in the County including Missouri Works, a program for qualified job creators which enables the retention of withholding tax or tax credits that can be transferrable, refundable and/or saleable; BUILD, a financial incentive for the location or expansion of large business projects; sales tax exemptions exist for qualified manufacturers; and industrial infrastructure grants are available up to $2 million or $20,000 per job created[9].

[9] https://ded.mo.gov/programs/business/missouri-works

Figure 3.3. Social Vulnerability Rating for Washington County



Source: 2018 Missouri State Hazard Mitigation Plan
*Black star indicates Washington County

3.4 Hazard Profiles, Vulnerability, and Problem Statements

Each hazard that has been determined to be a potential risk to Washington County is profiled individually in this section of the plan document. The profile will consist of a general hazard description, location, severity/magnitude/extent, previous events, future probability, a discussion of risk variations between jurisdictions, and how anticipated development could impact risk. At the end of each hazard profile will be a vulnerability assessment, followed by a summary problem statement.

Hazard Profiles

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

Each hazard identified in Section **3.1.4** will be profiled individually in this section in alphabetical order. The level of information presented in the profiles will vary by hazard based on the information available. With each update of this plan, new information will be incorporated to provide better evaluation and prioritization of the hazards that affect the planning area. Detailed profiles for each of the identified hazards include information categorized as follows:

Hazard Description: This section consists of a general description of the hazard and the types of impacts it may have on a community or school/special district.

Geographic Location: This section describes the geographic location of the hazard in the planning area. Where available, use maps to indicate the specific locations of the planning area that are vulnerable to the subject hazard. For some hazards, the entire planning area is at risk.

Severity/Magnitude/Extent: This includes information about the severity, magnitude, and extent of a hazard. For some hazards, this is accomplished with description of a value on an established scientific scale or measurement system, such as an EF2 tornado on the Enhanced Fujita Scale. Severity, magnitude, and extent can also include the speed of onset and the duration of hazard events. Describing the severity/magnitude/extent of a hazard is not the same as describing its potential impacts on a community. Severity/magnitude/extent defines the characteristics of the hazard regardless of the people and property it affects.

Previous Occurrences: This section includes available information on historic incidents and their impacts. Historic event records form a solid basis for probability calculations.

Probability of Future Occurrence: The frequency of recorded past events is used to estimate the likelihood of future occurrences. Probability was determined by dividing the number of recorded events by the number of years and multiplying by 100. This gives the percent chance of the event happening in any given year. For events occurring more than once annually, the probability will be reported 100% in any given year, with a statement of the average number of events annually. For hazards such as drought that may have gradual onset and extended duration, probability can be based on the number of months in drought in a given time-period and expressed as the probability for any given month to be in drought.

The discussion on the probability of future occurrence should also consider changing future conditions, including the effects of long-term changes in weather patterns and climate on the identified hazards. NOAA has a new tool that can provide useful information for this purpose.

- NOAA Climate Explorer, http://toolkit.climate.gov/climate-explorer2/

Vulnerability Assessments

Requirement §201.6(c)(2)(ii): The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community.

Requirement §201.6(c)(2)(ii)(A): The plan should describe vulnerability in terms of the types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas.

Requirement §201.6(c)(2)(ii)(B): The plan should describe vulnerability in terms of an] estimate of the potential dollar losses to vulnerable structures identified in paragraph (c)(2)(i)(A) of this section and a description of the methodology used to prepare the estimate.

Requirement §201.6(c)(2)(ii)(C): The plan should describe vulnerability in terms of] providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.

Requirement §201.6(c)(2)(ii): (As of October 1, 2008) The risk assessment must also address National Flood Insurance Program (NFIP) insured structures that have been repetitively damaged in floods.

DRAFT

Following the hazard profile for each hazard will be the vulnerability assessment. The vulnerability assessment further defines and quantifies populations, buildings, critical facilities, and other community assets at risk to damages from natural hazards. The vulnerability assessments will be based on the best available county-level data, which is in the Missouri Hazard Mitigation Plan (2018). With the 2018 Hazard Mitigation Plan Update, SEMA is pleased to provide online access to the risk assessment data and associated mapping for the 114 counties in the State. Through the web-based Missouri Hazard Mitigation Viewer, local planners or other interested parties can obtain all State Plan datasets. This effort removes from local mitigation planners a barrier to performing all the needed local risk assessments by providing the data developed during the 2018 State Plan Update. The Missouri Hazard Mitigation viewer can be found at this link: http://bit.ly/MoHazardMitigationPlanViewer2018.

The county-level assessments in the State Plan were also based on the following additional sources:

- Statewide GIS data sets compiled by state and federal agencies; and
- FEMA's HAZUS-MH loss estimation software.

The vulnerability assessments in the Washington County plan will also be based on:

- Written descriptions of assets and risks provided by participating jurisdictions;
- Existing plans and reports;
- Personal interviews with planning committee members and other stakeholders; and
- Other sources as cited.

Within the Vulnerability Assessment, the following sub-headings will be addressed:

Vulnerability Overview: This section will include a brief review of the vulnerability of each hazard.

Potential Losses to Existing Development: This section will describe the potential impacts of each hazard – the consequences of the effect of the hazard on the jurisdiction and its assets (including types and numbers, of buildings, critical facilities, etc.).

Future Development: This section will include information on anticipated future development in the county, and how that would impact hazard risk in the planning area.

Previous and Future Development: This section will include information on how changes in development have impacted the community's vulnerability to this hazard. Describe how any changes in development that occurred in known hazard prone areas since the previous plan have increased or decreased the community's vulnerability. Describe any anticipated future development in the county, and how that would impact hazard risk in the planning area.

Problem Statements

Each hazard analysis must conclude with a brief summary of the problems created by the hazard in the planning area, and possible ways to resolve those problems. Additionally, variations in risk between geographic areas will be included.

DRAFT

3.4.1 Dam Failure

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.3, Page 3.148 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Missouri Department of Natural Resources, Dam and Reservoir Safety, https://dnr.mo.gov/land-geology/dam-reservoir-safety
- Stanford University's National Performance of Dams Program; http://npdp.stanford.edu/
- National Inventory of Dams, https://nid.usace.army.mil/#/
- National Resources Conservation Service http://www.nrcs.usda.gov
- DamSafetyAction.org, http://www.damsafetyaction.org/MO/
- Missouri Spatial Data Information Service, http://msdis.missouri.edu
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Total number of Missouri NID dams by County
  - Total number of High, Significant, and Low Hazard dams by County
  - Total number of State Regulated dams by County
  - Total number of Class 1, Class 2, and Class 3 dams by County
  - Total number of structures impacted by USACE dams by County
  - Total number of structures impacted by State dams by County
  - Total value of structures impacted by USACE dams by County
  - Total value of structures impacted by State dams by County
  - Total population impacted by USACE dams by County
  - Total population impacted by State dams by County

Hazard Profile

Hazard Description

A dam is defined as a barrier constructed across a watercourse for the purpose of storage, control, or diversion of water. Dams are typically constructed of earth, rock, concrete, or mine tailings. Dam failure is the uncontrolled release of impounded water resulting in downstream flooding, affecting both life and property. Dam failure can be caused by any of the following:

1. Overtopping: inadequate spillway design, debris blockage of spillways or settlement of the dam crest.
2. Piping: internal erosion caused by embankment leakage, foundation leakage and deterioration of pertinent structures appended to the dam.
3. Erosion: inadequate spillway capacity causing overtopping of the dam, flow erosion, and inadequate slope protection.
4. Structural Failure: caused by an earthquake, slope instability or faulty construction.

Information regarding dam classification systems under both the Missouri Department of Natural Resources (MDNR) and the National Inventory of Dams (NID), which differ, are provided in **Table 3.17** and **Table 3.18**, respectively.

DRAFT

Table 3.17. MDNR Dam Hazard Classification Definitions

Hazard Class	Definition
Class I	Contains 10 or more permanent dwellings or any public building
Class II	Contains 1 to 9 permanent dwellings or 1 or more campgrounds with permanent water, sewer, and electrical services or 1 or more industrial buildings
Class III	Everything else

Source: Missouri Department of Natural Resources, Missouri Geological Survey Rolla Office

Table 3.18. NID Dam Hazard Classification Definitions

Hazard Class	Definition
Low Hazard	A dam located in an area where failure could damage only farm or other uninhabited buildings, agricultural or undeveloped land including hiking trails, or traffic on low volume roads that meet the requirements for low hazard dams.
Significant Hazard	A dam located in an area where failure could endanger a few lives, damage an isolated home, damage traffic on moderate volume roads that meet certain requirements, damage low-volume railroad tracks, interrupt the use or service of a utility serving a small number of customers, or inundate recreation facilities, including campground areas intermittently used for sleeping and serving a relatively small number of persons.
High Hazard	A dam located in an area where failure could result in any of the following: extensive loss of life, damage to more than one home, damage to industrial or commercial facilities, interruption of a public utility serving a large number of customers, damage to traffic on high-volume roads that meet the requirements for hazard class C dams or a high-volume railroad line, inundation of a frequently used recreation facility serving a relatively large number of persons, or two or more individual hazards described for significant hazard dams.

Source: National Inventory of Dams

Geographic Location

Dams in Planning Area

According to the National Inventory of Dams there are 118 recorded dams in Washington County; including 85 high hazard dams; two significant hazard dams; and 31 low hazard dams. The Missouri Department of Natural Resources also tracks dams in the state and has identified forty Class 1 dams, forty-six Class 2 dams, and thirty five Class 3 dams. **Table 3.19** provides the name of the dam, DNR hazard class and NID hazard class for each of the identified dams in Washington County. There are fifty-seven state-regulated dams and two local government dams in Washington County. There is one federally owned dam, however it is owned by the USDA Forest Service. None of the dams are owned or operated by the United States Army Corps of Engineers (USACE). County dams are privately or commercially owned. **Table 3.20** provides the names, locations, and other pertinent information for all NID High Hazard Dams in the planning area.

Table 3.19. Washington County Dams Hazard Risk

Name of Dam	DNR Hazard Class	NID Hazard Class
ARNAULT BRANCH MINE DAM	2	High
ARTESIAN LAKE DAM	2	High
ASHLEY BRANCH DAM	2	High
ASSAF LAKE DAM	3	Low
BAHA TRAIL LAKE DAM	2	High
BELGRADE DAM	2	High
BELL-SETTLE LAKE DAM	1	High
BIG FOUR MINE DAM	1	High
BLACK TAILINGS DAM	1	High
BLACKWELL MINE DAM	1	High
BLUE HERON DAM	2	High
BOTTOM DIGGINS DAM	2	High
BRESSIE LAKE(TOO SMALL)	3	Low
BUST LAKE DAM (BREACHED)	3	Low
CADET MINE TAILINGS DAM	2	High
CADET NO. 1 DAM	2	High
CADET NO. 2 DAM	2	High
CADET NO. 3 DAM	2	High
CARTER LAKE DAM	3	Low
CASEY LAKE DAM (MO30695)	2	High
CASEY LAKE DAM (MO31005)	1	High
CATES LAKE DAM	3	Low
CLICK LAKE DAM	3	Low
CRYSTAL LAKE DAM	2	High
DAVIS LAKE DAM	2	High
DEL LAGO LAKE DAM	3	Low
DEL VISTA LAKE DAM	3	Low
DESOTO MINE PIT & PLANT A DAM	2	High
DESOTO PIT & PLANT B DAM	2	High
DESSIEUX LAKE DAM	1	High
DITCH CREEK DAM	2	High
DORLAC LAKE DAM	2	High
DRESSER #1 DAM	1	High
DRESSER IND. OLD #1	1	High

DRAFT

Name of Dam	DNR Hazard Class	NID Hazard Class
DRESSER MINERALS #7 DAM NORTH(DRY)	2	High
DRESSER MINERALS #7 DAM SOUTH (DRY)	2	High
DRESSER MINERALS DAM SEC 24 (DRY)	3	Low
DRESSER MINERALS NO 7 DAM (DRY)	3	Low
DRESSER NO.4 DAM	1	High
EMERALD LAKE DAM	2	High
ESHBAUGH-MARTIN DAM	2	High
FLOYD LAKE DAM	1	High
FLYING "S" BAR RANCH DAM	1	High
FOREST LAKE DAM	1	High
FOUR WINDS WAY DAM	2	High
GIBSON MEMORIAL DAM	2	High
GUDAITIS LAKE DAM	1	High
GUN CLUB LAKE DAM	2	High
HAHN LAKE DAM/(DRY)	2	High
HEIMOS LAKE DAM	1	High
HEMATITE LAKE DAM (BREACHED)	3	Low
HENPECK HOLLOW DAM	1	High
HILL VIEW LAKE DAM SOUTH	3	Low
HILLVIEW LAKE DAM	3	Low
HOFFMAN LAKE DAM	2	High
HOPKINS LAKE DAM	3	Low
HOWELL MINE DAM	2	High
INDIAN CREEK MINE DAM - UPPER	1	High
INDIAN CREEK MINE DAM-LOWER	1	High
JOHNS DAM	3	Low
JONES LAKE DAM	3	Low
KEUSS DAM	2	High
KEYES BRANCH MINE DAM	1	High
KING ARTHUR'S DAM	2	High
KINGSTON NO. 1 DAM	2	High
KIRKPATRICK LAKE DAM	2	High
LAC SHAYNE DAM	2	High
LAKE 2 DAM	3	Low
LAKE APACHE DAM	2	High

DRAFT

Name of Dam	DNR Hazard Class	NID Hazard Class
LAKE CHEROKEE DAM	1	High
LAKE MELISSA DAM	3	Low
LAKEVIEW DAM	1	High
LITTLE INDIAN CREEK DAM	1	High
LOWER DRESSER NO. 4 DAM	1	High
LUTTRELL LAKE DAM LOWER	3	Significant
LUTTRELL LAKE UPPER DAM	3	Significant
MINERAL POINT #1	1	High
MINERAL POINT #2	1	High
MINNETONKA LAKE DAM	2	High
MONONAME 267	3	Low
MONONAME 551	3	Low
MONONAME 558	3	Low
MONONAME 563	3	Low
MONONAME 582	3	Low
MONONAME 588	3	Low
MONONAME 862	3	Low
MONONAME 875	2	High
MOOSEHORN LAKE DAM	3	Low
NATIONAL LEAD INDUSTRIES DAM	1	High
OLD MINES TAILINGS DAM	1	High
OLD WOLF DAM	1	High
PALMER MINE DAM	1	High
PAROLE MINE DAM	1	High
PEA RIDGE TAILINGS DAM	1	High
PINE TREE LAKE EAST DAM	1	High
PINE TREE LAKE WEST DAM	1	High
PINSON GRAVEL COMPANY DAM	2	High
PIONEER ROD&GUN CLUB DAM	3	Low
PODORSKI LAKE DAM	2	High
POTOSI LAKE DAM	1	High
POWDER SPRING LAKE DAM	1	High
RACOLA TAILINGS DAM	2	High
RICHWOODS MINE B DAM	1	High
RIEFFER LAKE DAM	3	Low
ROGUE CREEK UPPER DAM (IMCOMPLETED)	2	High
RUSSEL ELSEY DAM	1	High
SAMPSON LAKE DAM	3	Low

DRAFT

Name of Dam	DNR Hazard Class	NID Hazard Class
SAYERSBROOK DAM	2	High
SCHNELLE LAKE DAM	2	High
SETTLE MINE DAM #2	2	High
SOMETHING GREEN A DAM	1	High
SOMETHING GREEN B DAM	1	High
SPRING GLEN LAKE DAM	2	High
SPRING LAKE DAM (MO30725)	1	High
SPRING LAKE DAM (MO31838)	3	Low
SUN MINE DAM	2	High
SUNNEN DAM	2	High
THE PLACE LAKE DAM	1	High
TIMBERLANE DAM (FEDERAL)	3	Low
WING LAKE DAM	3	Low
WOODLAND LAKE	3	Low

Source: Missouri Department of Natural Resources, Dam and Reservoir Safety Program; National Inventory of Dams

DRAFT

Table 3.20. NID High Hazard Class Dams in the Washington County Planning Area

Dam Name	NIDID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
ARNAULT BRANCH MINE DAM	MO30716	High	46	582	TRIB-ARNAULT CREEK	OLD MINES	3
ARTESIAN LAKE DAM	MO30470	High	26	195	TR-LITTLE INDIAN CREEK	RICHWOODS	3
ASHLEY BRANCH DAM	MO31857	High	58	1,970	ASHLEY BRANCH CREEK	BOURBON	14
BAHA TRAIL LAKE DAM	MO31306	High	30	433	TR-DRY BR-INDIAN CREEK	SULLIVAN	6
BELGRADE DAM	MO30696	High	55	281	TR-FURNACE CREEK	LEADWOOD	17
BELL-SETTLE LAKE DAM	MO30480	High	33	230	TR-MINE A BRETON CREEK	POTOSI	2
BIG FOUR MINE DAM	MO30729	High	73	1,980	TRIB-CALICO CREEK	FLETCHER	2
BLACK TAILINGS DAM	MO31154	High	70	22	MILL CREEK-OFFSTREAM	MINERAL POINT	0
BLACKWELL MINE DAM	MO30709	High	85	2,100	TRIB MADDEN CREEK	POTOSI	1
BLUE HERON DAM	MO30478	High	51	2,176	POND CREEK	TIFF	7
BOTTOM DIGGINS DAM	MO30750	High	41	300	TR-MILL CREEK	TIFF	3
CADET MINE TAILINGS DAM	MO30715	High	97	103	TR-MILL CREEK	TIFF	3
CADET NO. 1 DAM	MO30704	High	53	264	MILLCREEK TRIB OFFSTREAM	BLACKWELL	7
CADET NO. 2 DAM	MO30707	High	77	33	TR-MILL CREEK	TIFF	4
CADET NO. 3 DAM	MO31830	High	74	765	SHIBBOLETH BRANCH	CADET	4
CASEY LAKE DAM	MO31005	High	57	120	TR-OLD MINES CREEK	MORSE MILL	26
CASEY LAKE DAM	MO30695	High	36	117	TR-CLEAR CREEK	LEADWOOD	20
CRYSTAL LAKE DAM	MO31837	High	65	1,770	HARRIS BRANCH	ANTHONIES MILL	10
DAVIS LAKE DAM	MO31000	High	30	48	TR-TYREY CREEK	MORSE MILL	21
DESOTO MINE PIT & PLANT A DAM	MO30468	High	78	3,700	TRIB-DITCH CREEK	RICHWOODS	2

Dam Name	NIDID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
DESOTO PIT & PLANT B DAM	MO30469	High	54	248	DITCH CREEK	RICHWOODS	2
DESSIEUX LAKE DAM	MO30994	High	28	470	TR BATES CREEK	BATES CREEK CAMP	2
DITCH CREEK DAM	MO30726	High	60	1,500	TR-DITCH CREEK	MORSE MILL	16
DORLAC LAKE DAM	MO30731	High	45	758	TR-MINERAL FORK-BIG RIVER	OLD MINES	6
DRESSER #1 DAM	MO31117	High	30	1,295	RUBENEAU BRANCH - OFFSTREAM	MINERAL POINT	0
DRESSER IND. OLD #1	MO30753	High	45	1,300	RUBENEAU BRANCH-OFFSTREAM	MINERAL POINT	0
DRESSER MINERALS #7 DAM NORTH(DRY)	MO31145	High	15	305	TR-CADET CREEK	CADET	0
DRESSER MINERALS #7 DAM SOUTH (DRY)	MO31147	High	34.6	80	TR-MILL CREEK	BLACKWELL	0
DRESSER NO.4 DAM	MO30474	High	105	4,325	TR-MILL CREEK	TIFF	2
EMERALD LAKE DAM	MO31836	High	46	405	TR HARRIS BRANCH	SULLIVAN	16
ESHBAUGH-MARTIN DAM	MO30711	High	115	81	TR BIG RIVER	MORSE MILL	26
FLOYD LAKE DAM	MO30744	High	21	90	TR-OLD MINES CREEK	OLD MINES	2
FLYING "S" BAR RANCH DAM	MO31124	High	62	127	TR MILL CREEK	TIFF	1
FOREST LAKE DAM	MO30101	High	50	409	SWAN CREEK	LATTY	2
FOUR WINDS WAY DAM	MO30722	High	31	199	TR-MINERAL FORK-BIG RIVER	APTUE	1
GIBSON MEMORIAL DAM	MO32036	High	45	184	ASHLEY BRANCH	SHRILEY	0
GUDAITIS LAKE DAM	MO30702	High	25	158	TR-CLEAR CREEK	IRONDALE	12
GUN CLUB LAKE DAM	MO30476	High	85	1,400	TR-MINE A BRETON CREEK	CRUISE	11

DRAFT

Dam Name	NIDID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
HAHN LAKE DAM/(DRY)	MO31122	High	30	241	TR-SALT MINES CREEK	MORSE MILL	25
HEIMOS LAKE DAM	MO30999	High	37	37	TRIB-LITTLE INDIAN CREEK	RICHWOODS	1
HENPECK HOLLOW DAM	MO31256	High	24	141	TR-COURTOIS CREEK	BERRYMAN	4
HOFFMAN LAKE DAM	MO31484	High	25	134	TR-LITTLE INDIAN CREEK	RICHWOODS	0
HOWELL MINE DAM	MO30700	High	58	1,460	ISHMAEL BR HAZEL CREEK	SHIRLEY	9
INDIAN CREEK MINE DAM - UPPER	MO31036	High	56	791	GOOSE CREEK	SULLIVAN	13
INDIAN CREEK MINE DAM-LOWER	MO30717	High	84	875	GOOSE CREEK	RICHWOODS	5
KEUSS DAM	MO40120	High	45	378	TURKEY CREEK	-	0
KEYES BRANCH MINE DAM	MO30386	High	77	1,192	TRIBUTARY KEYES BRANCH CREEK	TIFF	0
KING ARTHUR'S DAM	MO31825	High	80	2,000	POND CREEK	MINERAL POINT	6
KINGSTON NO. 1 DAM	MO30728	High	85	1,700	TR-MINERAL FK-BIG RIVER	BLISS	2
LAC SHAYNE DAM	MO31835	High	72	2,475	POND CREEK	TERRE DU LAC	6
LAKE APACHE DAM	MO30703	High	41	142	TR DRY CREEK	IRONDALE	1
LAKE CHEROKEE DAM	MO30751	High	27	72	TR DRY CREEK	IRONDALE	1
LAKEVIEW DAM	MO30688	High	68	1,750	TR BATES CREEK	FLETCHER	23
LITTLE INDIAN CREEK DAM	MO30718	High	58	1,280	TR-LITTLE INDIAN CREEK	RICHWOODS	1
LOWER DRESSER NO. 4 DAM	MO31123	High	31	116	TRIBUTAR TO MILL CREEK	TIFF	2
MINERAL POINT #1	MO30705	High	72	2,200	TR-MILL CREEK	BLACKWELL	9
MINERAL POINT #2	MO31158	High	95	1,191	TRIB-MILL CREEK	MINERAL POINT	1
MINNETONKA LAKE DAM	MO30727	High	74	2,500	TRIB-DITCH CREEK	RICHWOODS	1
MONONAME 875	MO31006	High	20	235	SYCAMORE CREEK	BLISS	0

DRAFT

Dam Name	NIDID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
NATIONAL LEAD INDUSTRIES DAM	MO30708	High	99	363	TR-MILL CREEK	BLACKWELL	2
OLD MINES TAILINGS DAM	MO30706	High	61	286	MUD TOWN CREEK	RACOLA	1
OLD WOLF DAM	MO31118	High	48	182	TR CADET CREEK	TIFF	4
PALMER MINE DAM	MO30482	High	76	1,460	TR HAZEL CREEK	SHIRLEY	9
PAROLE MINE DAM	MO30483	High	64	1,000	SPRINGTOWN BRANCH	PAROLE	9
PEA RIDGE TAILINGS DAM	MO30473	High	150	4,100	TR-MARYS CREEK	MORSE MILL	-
PINE TREE LAKE EAST DAM	MO30992	High	33	159	TRIB-FOURCHEARENAULT CREEK	POTOSI	0
PINE TREE LAKE WEST DAM	MO30995	High	28	120	TRIB-FOURCHE A RENAULT CREEK	POTOSI	0
PINSON GRAVEL COMPANY DAM	MO31155	High	79	875	TR-OLD MINES CR	CRUISE MILL	0
PODORSKI LAKE DAM	MO30697	High	26	83	TR-CLEAR CREEK	LEADWOOD	19
POTOSI LAKE DAM	MO30477	High	33	438	TRIB-BIG RIVER	LEADWOOD	10
POWDER SPRING LAKE DAM	MO30749	High	28	195	BUST BRANCH O MILL CREEK	TIFF	2
RACOLA TAILINGS DAM	MO30475	High	78	29	OLD MINES CREEK	RACOLA	1
RICHWOODS MINE B DAM	MO31404	High	48	1,000	TR-DITCH CREEK	RICHWOODS	0
ROGUE CREEK UPPER DAM (IMCOMPLETED)	MO31849	High	17	109	ROGUE CREEK	POTOSI	3
RUSSEL ELSEY DAM	MO30102	High	21	224	NORTH FORK FOURCHE A RENAULT	POTOSI	0
SAYERSBROOK DAM	MO30112	High	67	1,080	ASHLY BRANCH	APTUS	6
SCHNELLE LAKE DAM	MO31329	High	25	134	TR-BIG RIVER	BELGRADE	4

DRAFT

Dam Name	NIDID	Hazard Potential *	NID Height (Ft.)	NID Storage	River	Nearest City *	Distance To City (Mi.) *
SETTLE MINE DAM #2	MO30479	High	68	300	TR-MINE A BRETON CREEK	POTOSI	2
SOMETHING GREEN A DAM	MO30720	High	27	347	ROUGE CREEK	POTOSI	8
SOMETHING GREEN B DAM	MO30719	High	22	118	ROUGE CREEK	POTOSI	9
SPRING GLEN LAKE DAM	MO30698	High	33	194	GOOSE CREEK	LEADWOOD	17
SPRING LAKE DAM	MO30725	High	27	92	TRIB-LITTLE INDIAN CREEK	RICHWOODS	2
SUN MINE DAM	MO30710	High	73	2,100	MADDIN CREEK	POTOSI	11
SUNNEN DAM	MO30111	High	51	5,000	FOURCHE A RENAULT	APTUS	7
THE PLACE LAKE DAM	MO30996	High	16	94	TR-MINE A BRETON CREEK	POTOSI	2

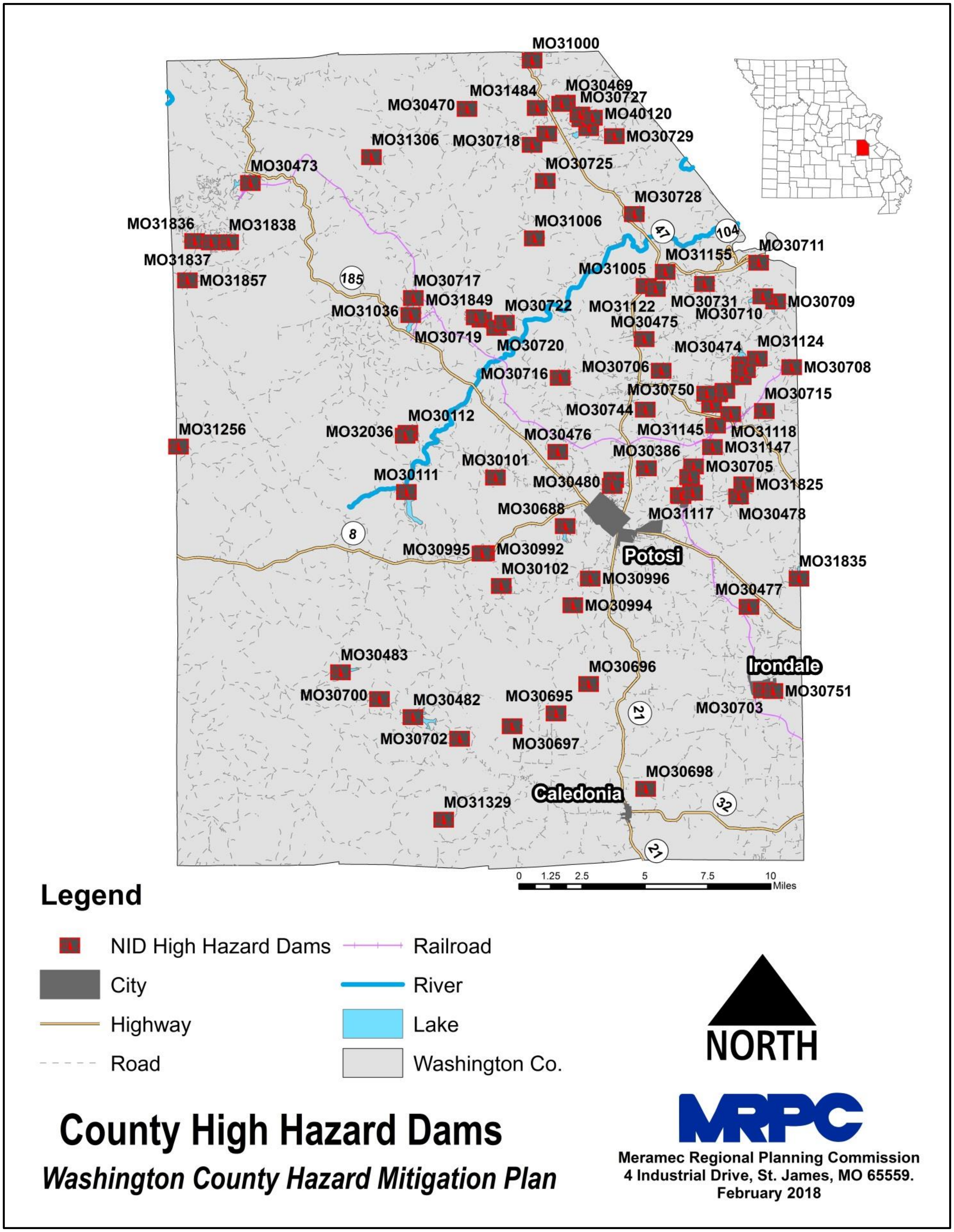
Sources: National Inventory of Dams, http://nid.usace.army.mil/cm_apex/f?p=838:12

Figure 3.4 depicts locations of NID high hazard dams located in the planning area. If a dam failure were to occur in Washington County, depending upon dam and location, the severity would range between negligible to life threatening. Road infrastructure, residential structures, commercial buildings, and public buildings are all vulnerable to losses. There is one area of assembly in dam inundation zones within the county. Kingston K-14 Schools are located between two tailings dams, MO31122 and MO31005. The distance from the dams to school assets are less than 385 yards.

Ten dam inundation maps were available from the Missouri Department of Natural Resources. These Regulated Dams include Ashley Branch Dam, Crystal Lake Dam, Emerald Lake Dam, Forest Lake Dam, Gibson Memorial Dam, Keuss Dam, Lac Shayne Dam, Lake Apache Dam, Sayersbrook Dam, and Sunnen Dam (**Figure 3.5** through **Figure 3.14**). No other dam inundation maps were available for the remaining NID High Hazard Dams in the county.

The Missouri Department of Natural Resources requires certain dams over 35 feet tall to be permitted and submit an emergency action plan. Emergency action plans are on record for an additional forty mine tailing dams that include Mineral Point #1 Dam, Old Mines Dam, Mineral Point #2 Dam, Keys Branch Dam, Desoto A Dam, Desoto B Dam, Pea Ridge Tailings Dam, Racola Tailings Dam, Blue Heron Dam, Settle Mine #2 Dam, Palmer Mine Dam, Parole Mine Dam, Lake View Dam, Casey Dam, Belgrade Dam, Howell Mine Dam, Cadet #2 Dam, National Lead Industries Dam, Blackwell Mine Dam, Sun Mine Dam, Eshbaugh-Martin Dam, Cadet Mine Tailings Dam, Indian Creek Lower Dam, Little Indian Creek Dam, Ditch Creek Dam, Minnetonka Dam, Kinston No. 1 Dam, Big Four Mines Dam, Dorlac Dam, Bottom Diggins Dam, Dresser Old #1 Dam, Casey Dam, Old Wolf Dam, Flying S Ranch Dam, Black Tailings Dam, Pinson Grave Dam, Richwoods Mine B Dam, King Arthur's Dam, Cadet No. 3 Dam, and Heimos Dam. These emergency action plans are available from the department upon request.

Figure 3.4. NID High Hazard Dam Locations in Washington County



Source: MSDIS, MRPC

Figure 3.5. Ashley Branch Dam Inundation Zone

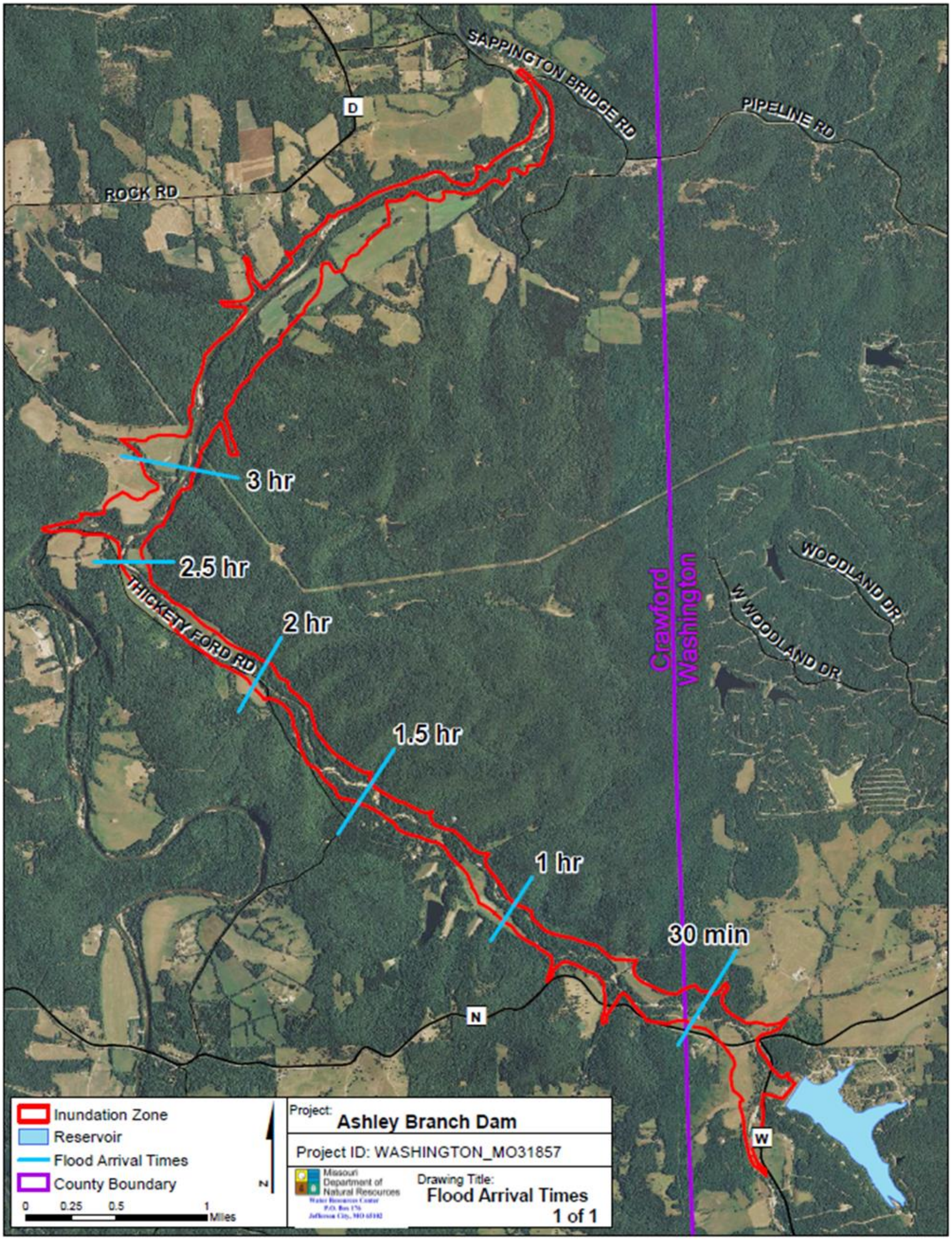


Figure 3.6. Crystal Lake Dam Inundation Zone

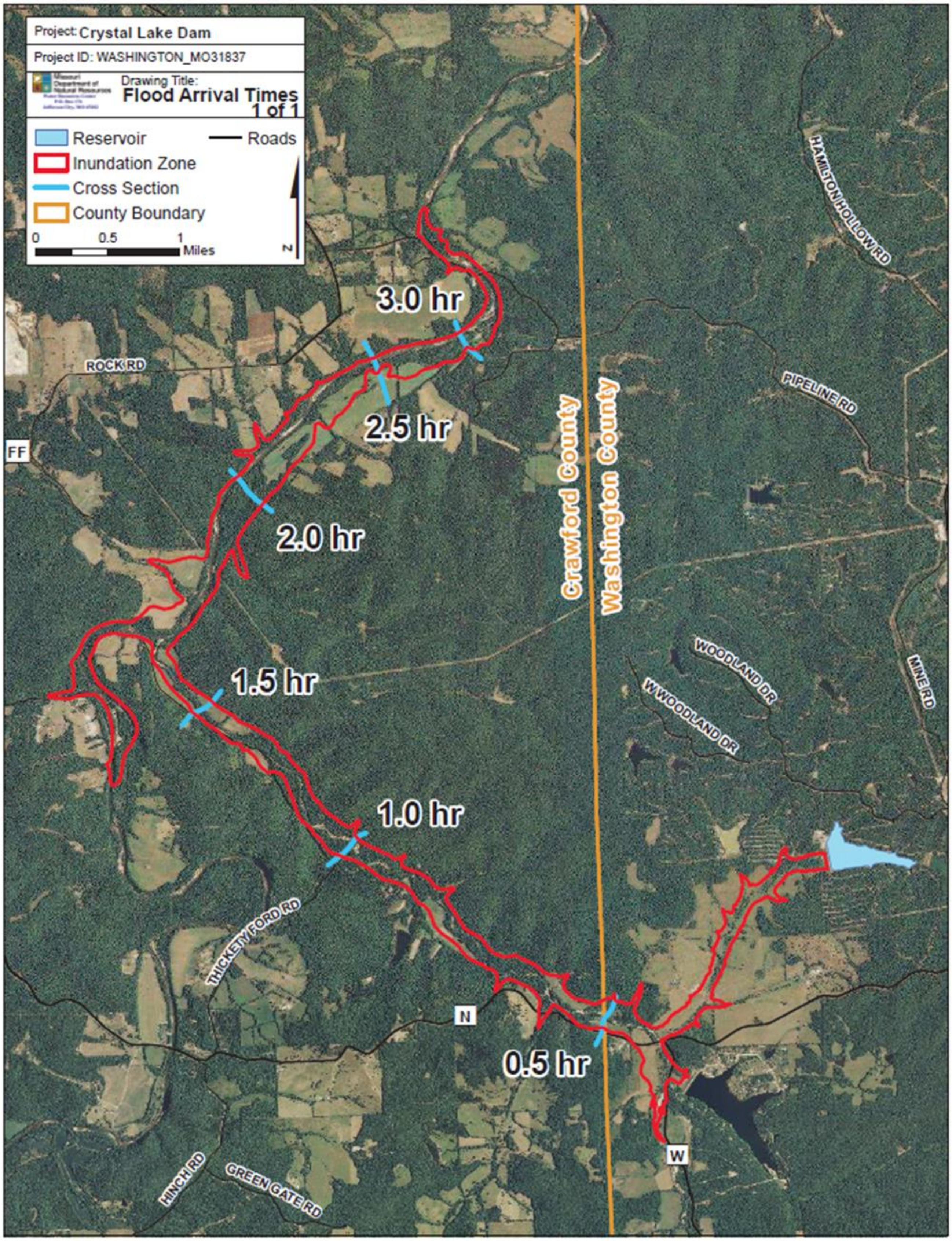


Figure 3.7. Emerald Lake Dam Inundation Zone

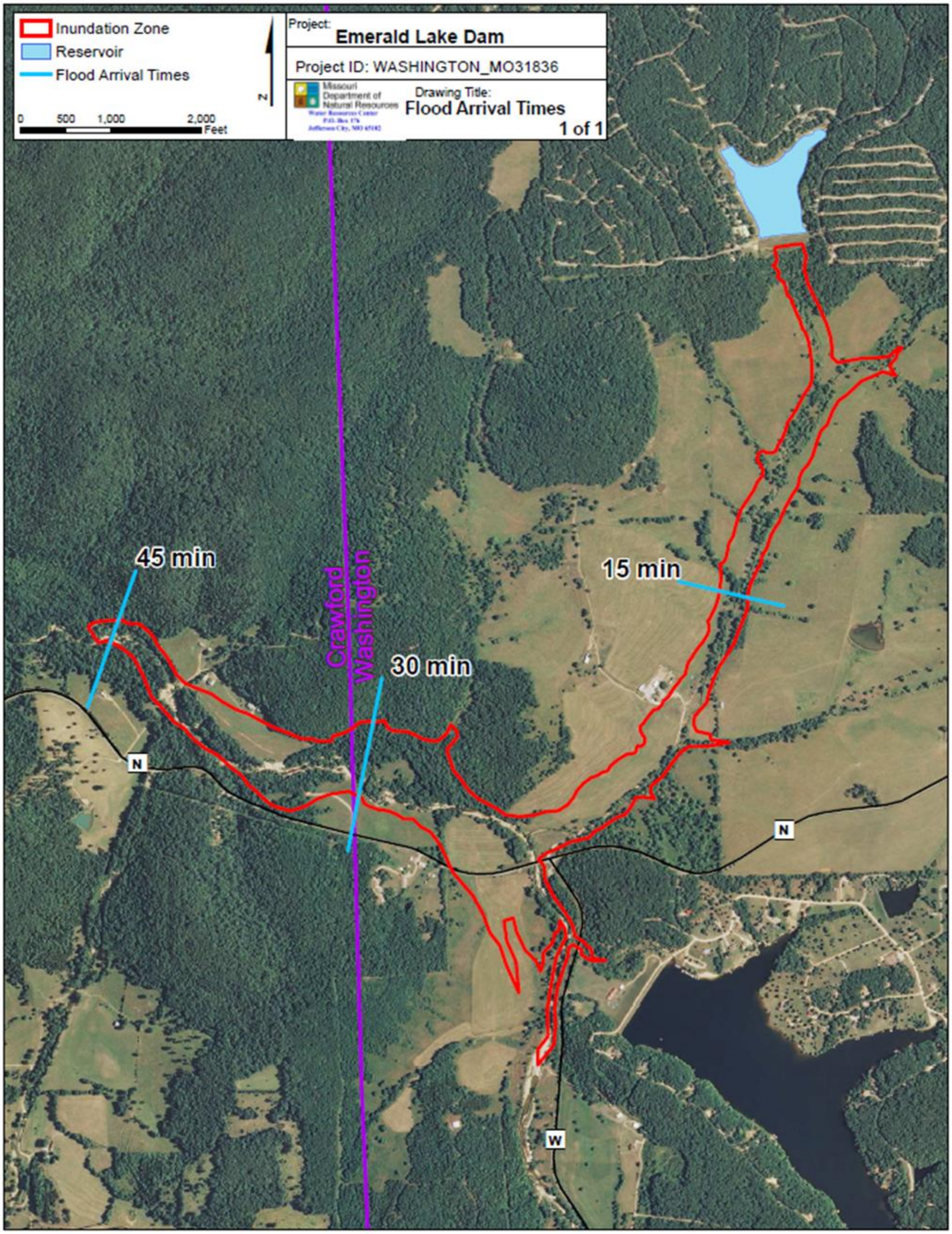


Figure 3.8. Forest Lake Dam Inundation Zone Continued

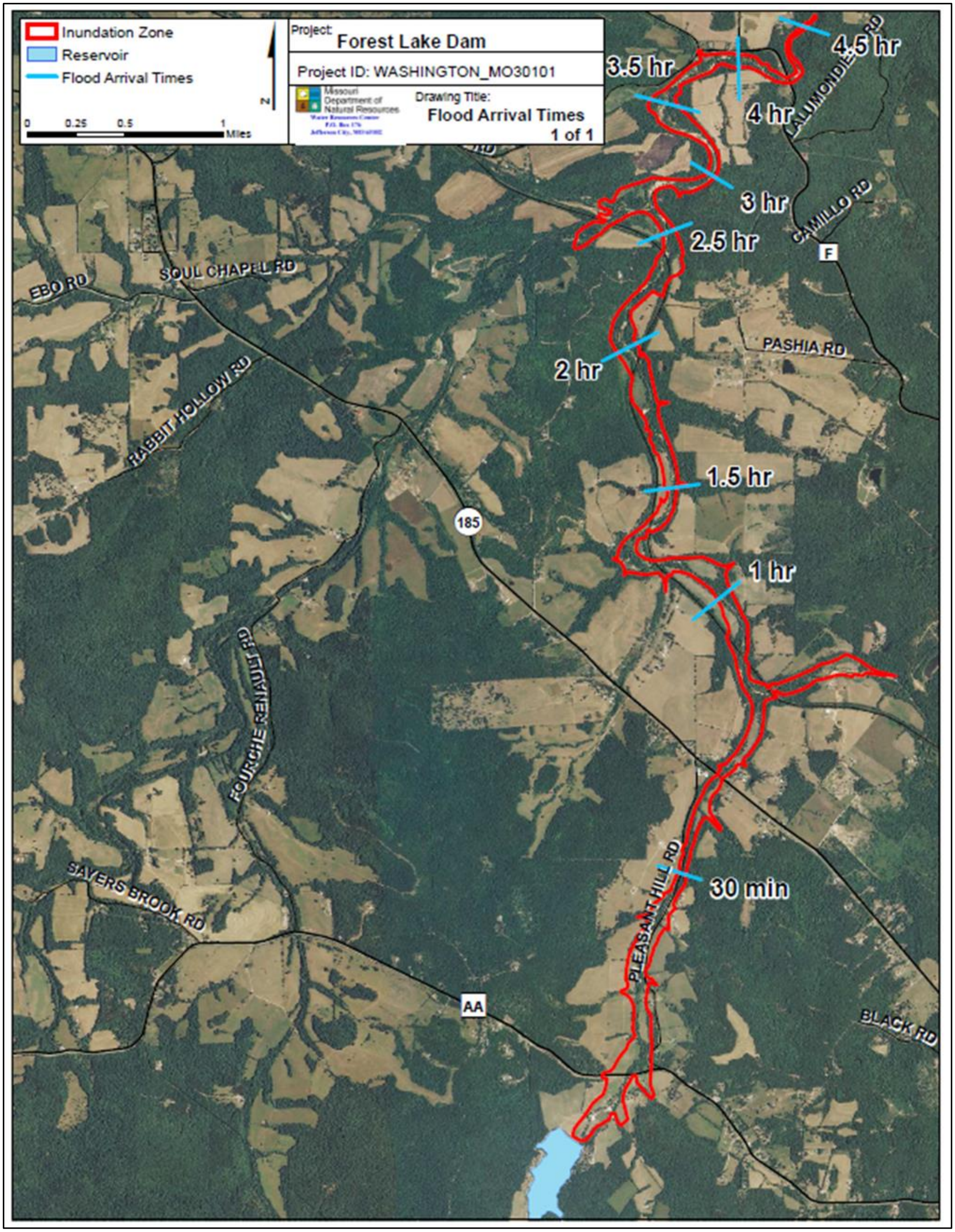


Figure 3.9. Gibson Memorial Dam Inundation Zone

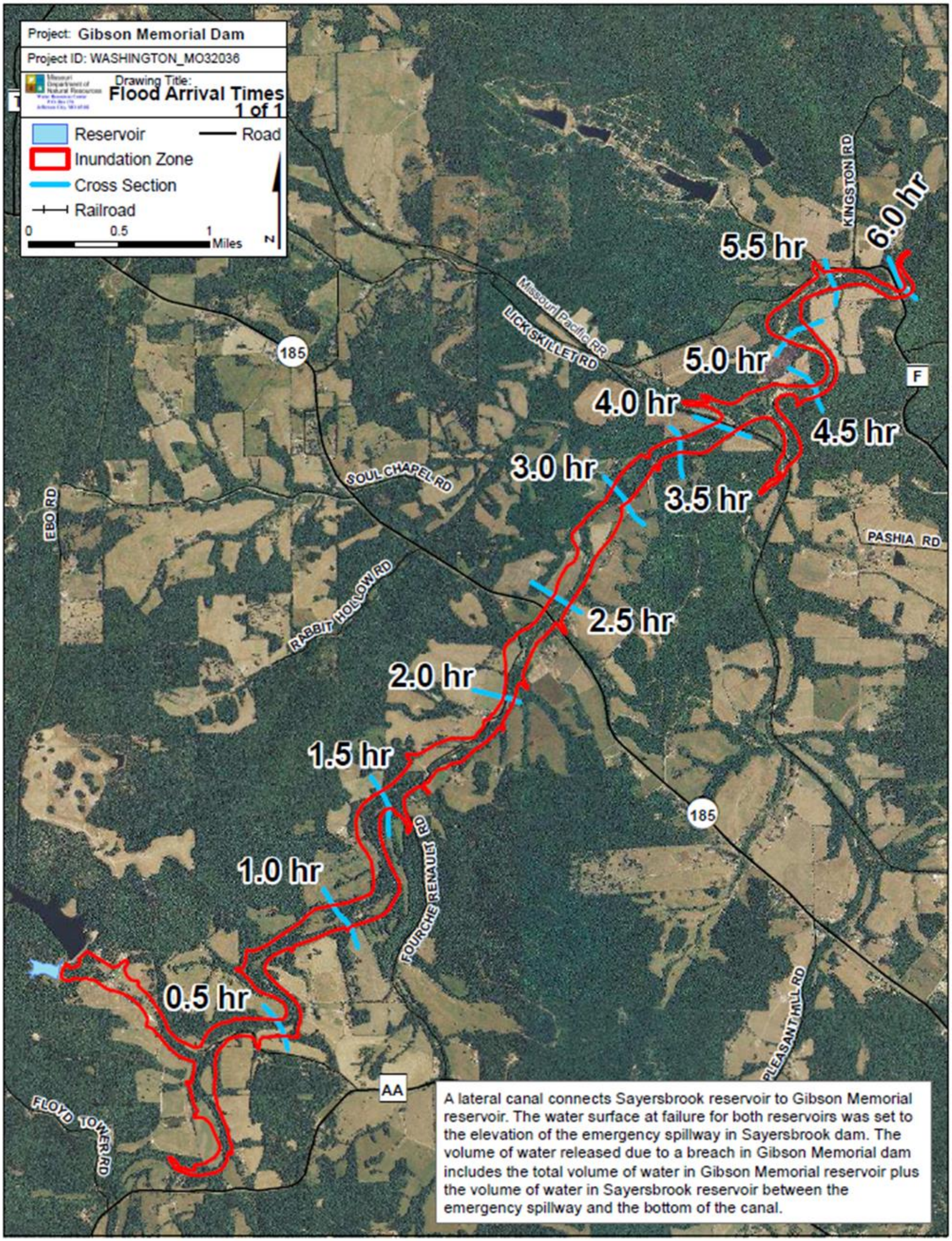


Figure 3.10. Keuss Dam Inundation Zone

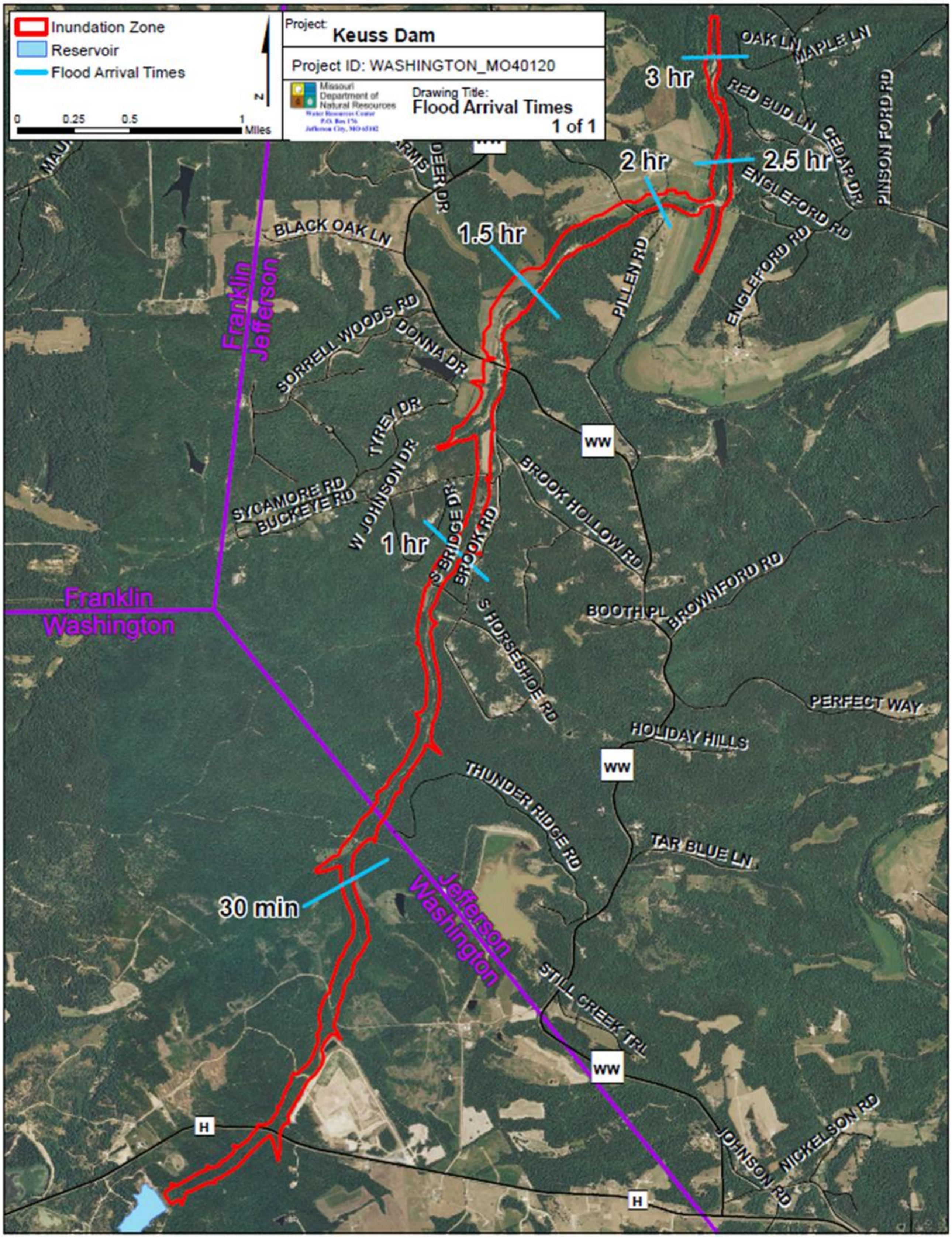


Figure 3.11. Lac Shayne Dam Inundation Zones

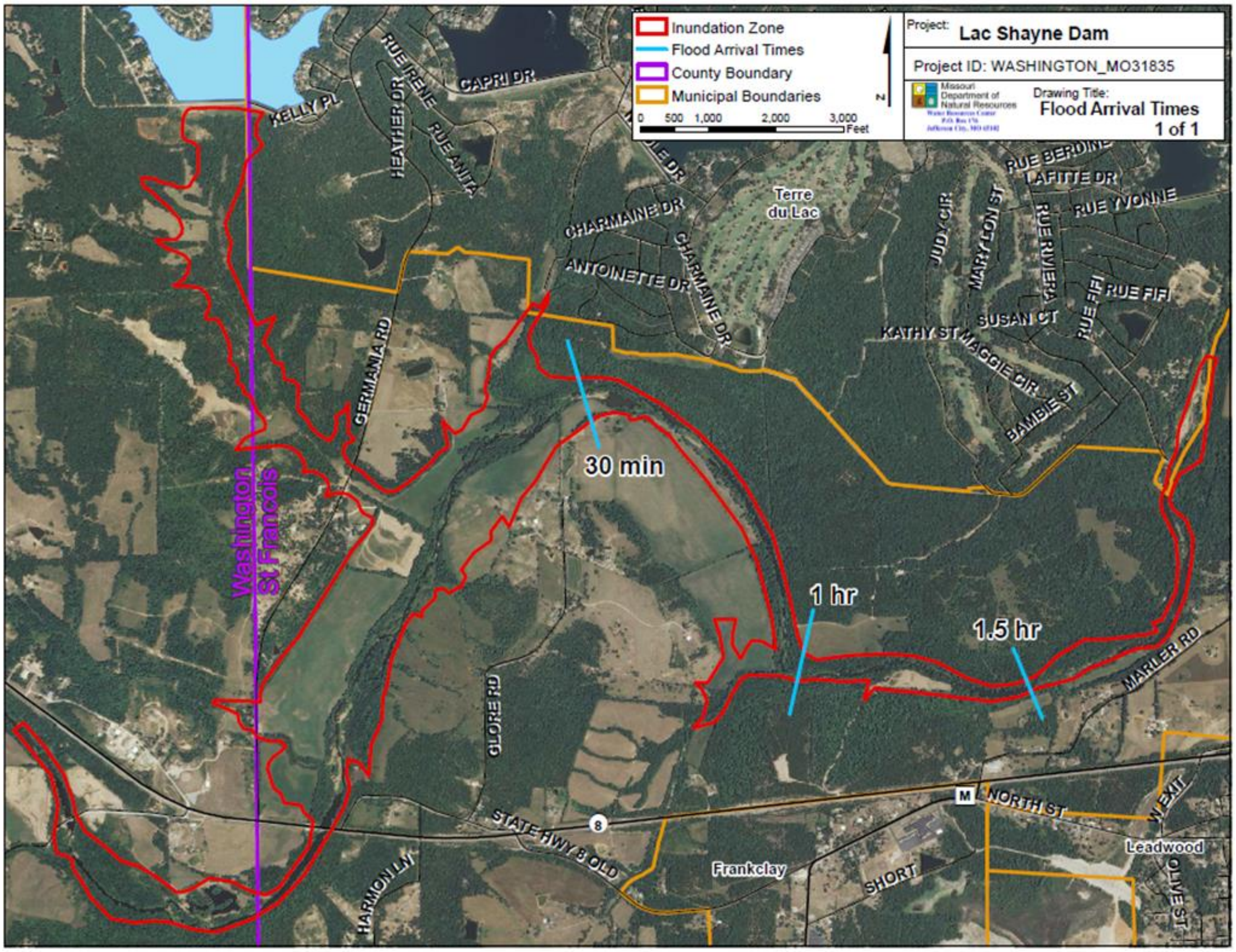


Figure 3.12. Lake Apache Dam Inundation Zones

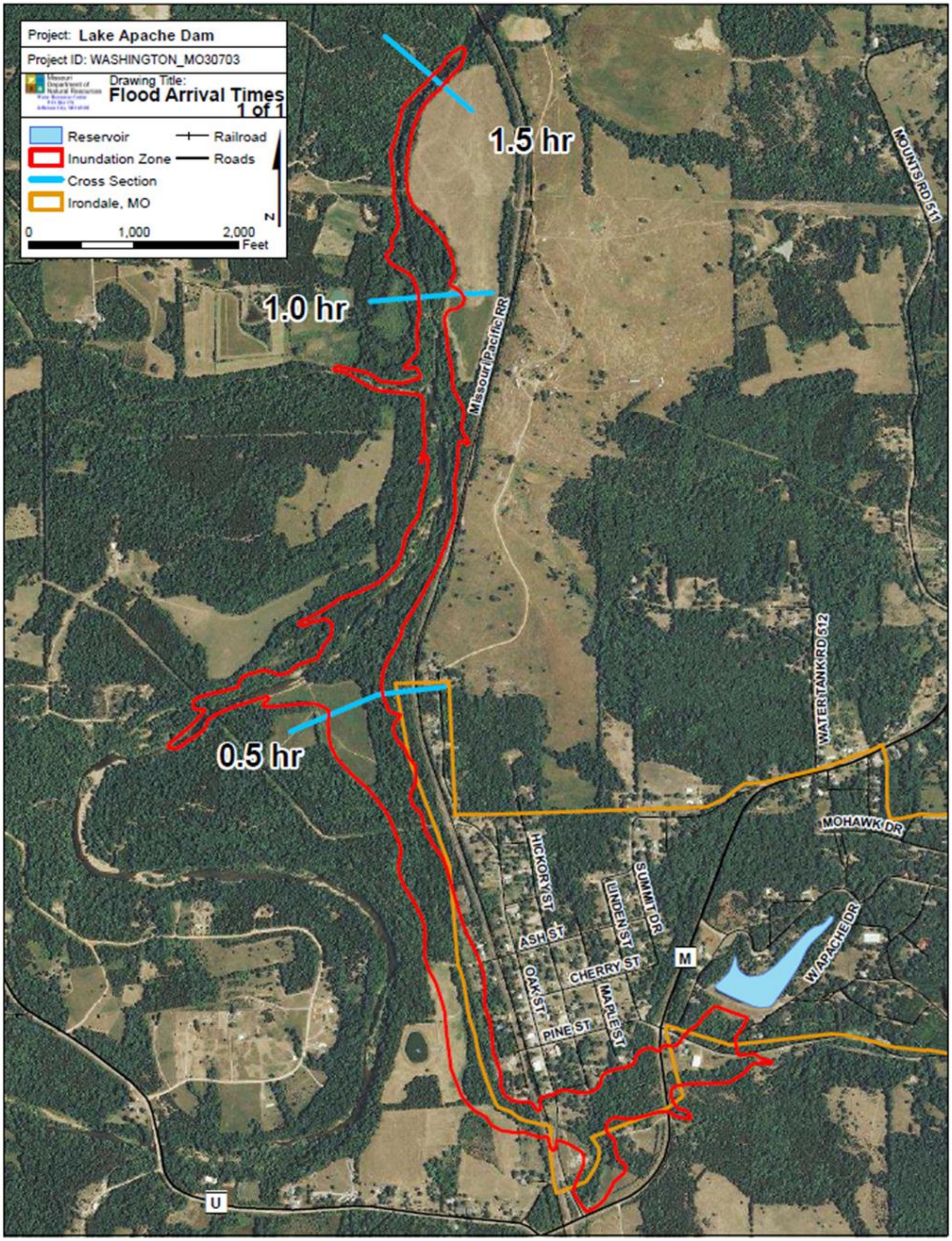


Figure 3.13. Sayersbrook Dam Inundation Zone

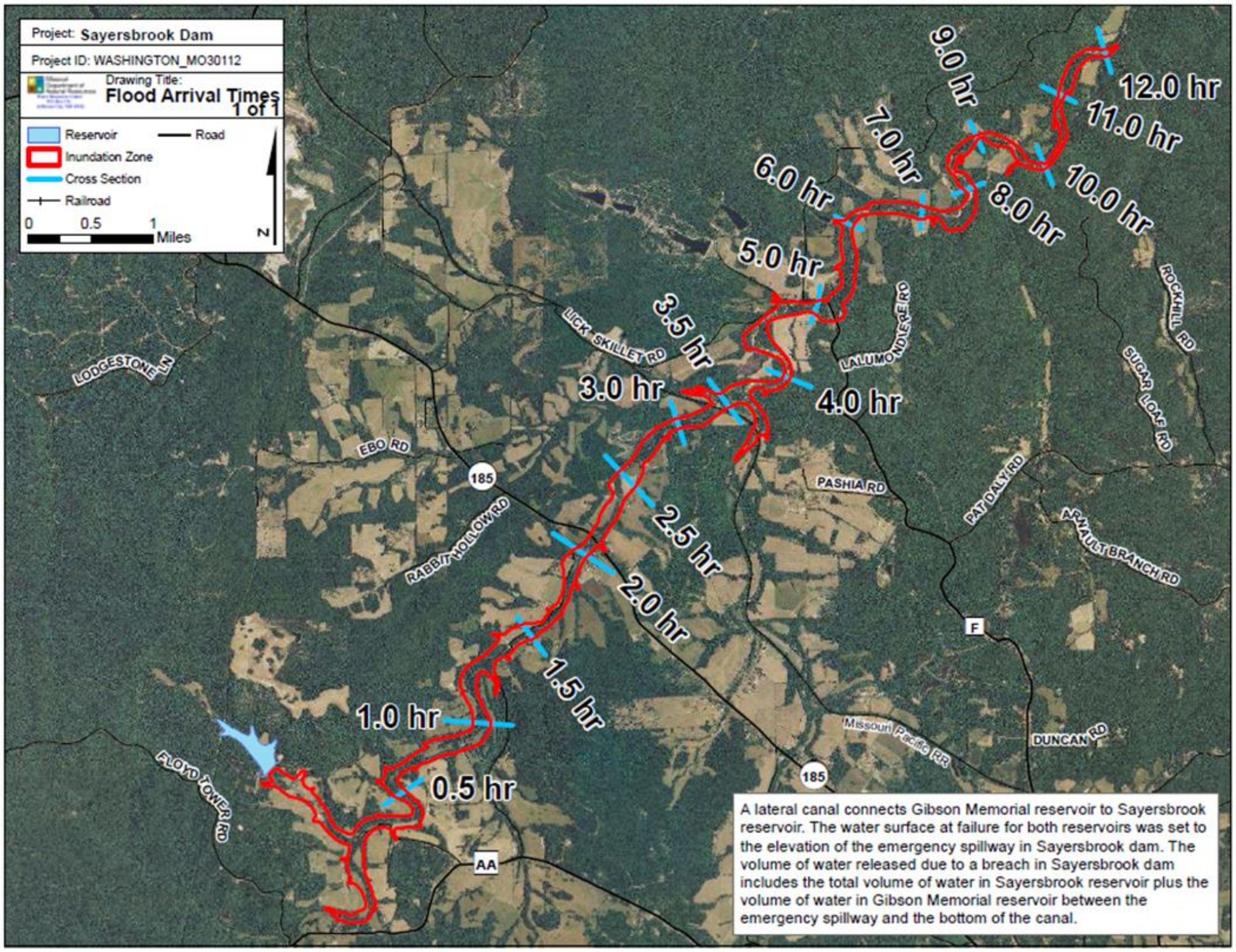
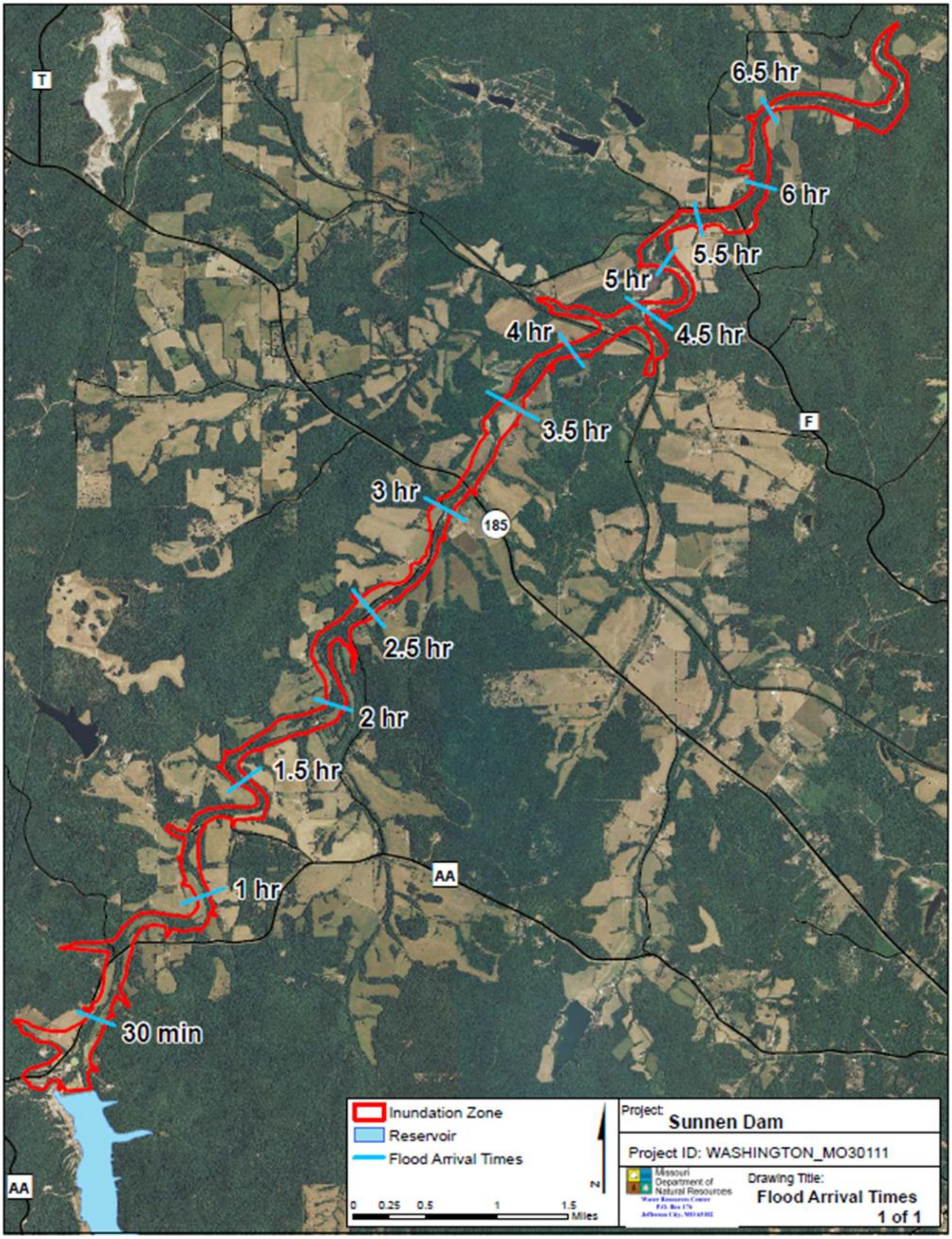


Figure 3.14. Sunnen Dam Inundation Zone

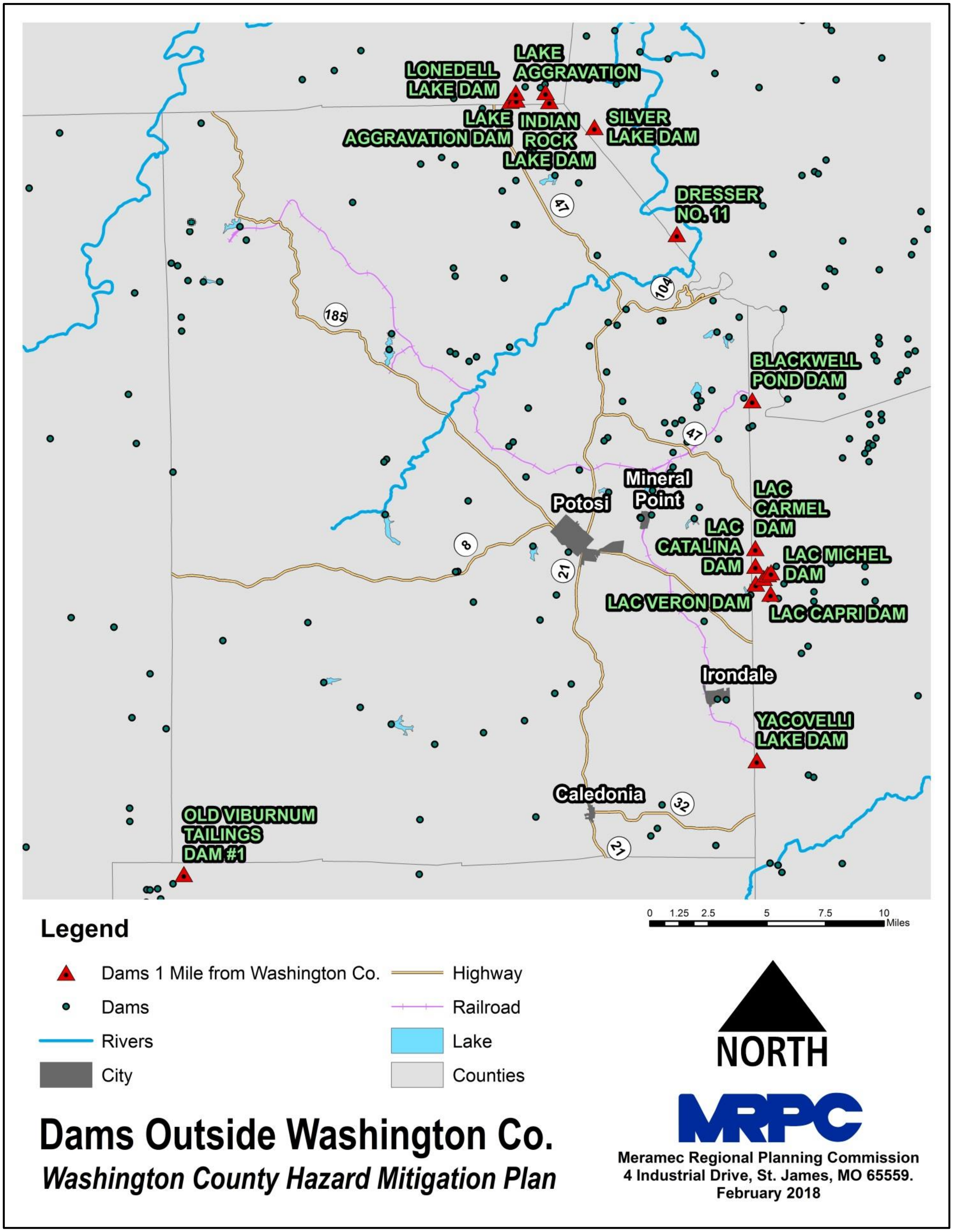


Upstream Dams Outside the Planning Area

Figure 3.15 depicts dams outside of Washington County. Seventeen High Hazard dams (11 regulated) are located within a 1 mile buffer of the county. According to the Missouri Department of Natural Resources, Missouri Geological Survey, Water Resources Center, there are eight regulated high hazard dams that could flow into Washington County from surrounding counties during a failure event; Blackwell Pond Dam in St. Francois County (Regulated, High Hazard, Class 1) resides approximately 293 yards from the county (**Figure 3.16**); Lac Bourbon Dam (Regulated, High Hazard, Class 2), Lac Capri Dam (Regulated, High Hazard, Class 1), Lac Carmel Dam (Regulated, High Hazard, Class 2), Lac Darcie Dam (Regulated, High Hazard, Class 2), Lac Michel Dam (Regulated, High Hazard, Class 2), and Lac Veron Dam (Regulated, High Hazard, Class 2) in St. Francois County reside 300+ yards from the county line (**Figure 3.17**). Additionally, Old Viburnum Tailings Dam #1 in Iron County (Regulated, High Hazard, Class 1) resides 900 yards from the county (**Figure 3.18**). Two unregulated dams Lac Catalina Dam (Unregulated, High Hazard, Class 1) and Yacovelli Lake Dam (Unregulated, High Hazard, Class 2) in St. Francois County reside 200 to 300+ yards from the county (**Figure 3.17** and **Figure 3.19**).

DRAFT

Figure 3.15. Upstream Dams Outside Washington County



Source: MSDIS, MRPC

Figure 3.16. Blackwell Pond Dam

Figure 3.17. Lac Dams (7)

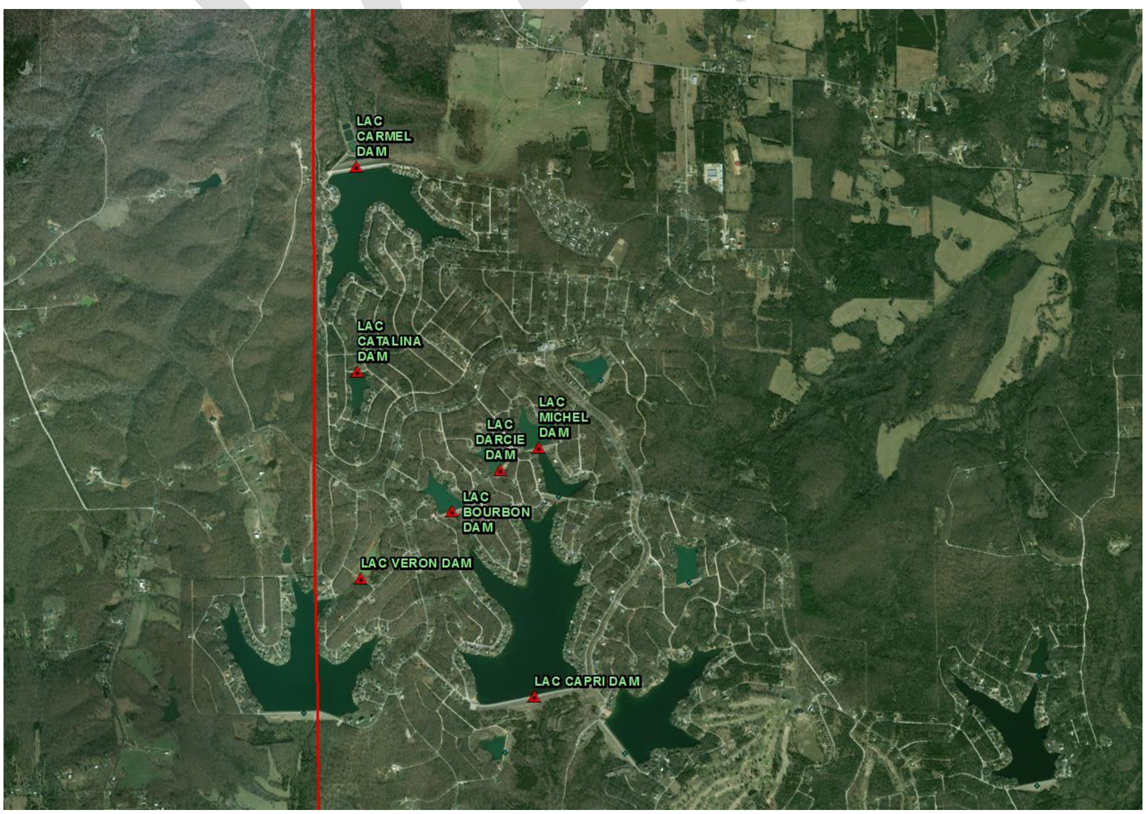


Figure 3.18. Old Viburnum Tailings Dam #1

Figure 3.19. Yacovelli Lake Dam

Severity/Magnitude/Extent

The severity/magnitude of dam failure would be similar in some cases to the impacts associated with flood events (see the flood hazard vulnerability analysis and discussion). Based on the hazard class definitions, failure of any of the High Hazard/Class I dams could result in a serious threat of loss of human life, serious damage to residential, industrial or commercial areas, public utilities, public buildings, or major transportation facilities. Catastrophic failure of any high hazard dams has the potential to result in greater destruction due to the potential speed of onset and greater depth, extent, and velocity of flooding.

Previous Occurrences

According to Stanford University's National Performance of Dams Program and the Missouri State Emergency Management Agency, there were 86 recorded dam incidents in Missouri between 1917 and 2008. For the 42-year period from 1975 to 2016 for which dam failure statistics are available, 19 dam failures and 68 incidents are recorded. Fortunately, only one drowning has been associated with a dam failure in the state. The problem of unsafe dams in Missouri was underscored by dam failures at Lawrenceton in 1968, Washington County in 1975, Fredricktown in 1977, and a near failure in Franklin County in 1979. A severe rainstorm and flash flooding in October 1998 compromised about a dozen small, unregulated dams in the Kansas City area. But perhaps the most spectacular and widely publicized dam failure in recent years was the failure of the Taum Sauk Hydroelectric Power Plant Reservoir atop Profitt Mountain in Reynolds County, MO.

In the early morning hours of December 14, 2005, a combination of human and mechanical error in the pump station resulted in the reservoir being overfilled. The manmade dam around the reservoir failed and dumped over a billion gallons of water down the side of Profitt Mountain, into and through Johnson's Shut-Ins State Park and into the East Fork of the Black River. The massive wall of water scoured a channel down the side of the mountain that was over 6000 feet wide and 7,000 feet long that carried a mix of trees, rebar, concrete, boulders and sand downhill and into the park[10]. The deluge destroyed Johnson's Shut-Ins State Park facilities, including the campground, and deposited sediment, boulders and debris into the park. The flood of debris diverted the East Fork of the Black River into an older channel and turned the river chocolate brown. Fortunately, the breach occurred in mid-winter. Five people were injured when the park superintendent's home was swept away by the flood, but all were rescued and eventually recovered. Had it been summer, and the campground filled with park visitors, the death toll could have been very high[11]. This catastrophe has focused the public's attention on the dangers of dam failures and the need to adequately monitor dams to protect the vulnerable.

Despite the significance of the immediate damage done by the Taum Sauk Reservoir dam failure, the incident also highlights the long-term environmental and economic impacts of an event of this magnitude. Four years later, the toll of the flooding and sediment on aquatic life in the park and Black River is still being investigated. Even after the removal of thousands of dump truck loads of debris and mud, the river is still being affected by several feet of sediment left in the park. The local economy, heavily reliant upon the tourism from the park and Black River, has also been hit hard[12].

Event Description

According to Stanford University's National Performance of Dams Program, 3 dam incidents have been

DRAFT

[10] United States Geological Survey. Damage Evaluation of the Taum Sauk Reservoir Failure using LiDAR. https://www.researchgate.net/publication/268325451_Damage_Evaluation_of_the_Taum_Sauk_Reservoir_Failure_using_LiDAR

[11] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.

[12] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.

recorded for Washington County since 1990[13]. Rogue Creek Upper Dam experienced an inflow flood on May 25, 1990. An embankment slide occurred at Lac Shayne Dam on October 7, 1993. Furthermore, concrete deterioration was observed at Four Winds Way Dam on March 1, 1994. Additionally, both Bust Lake Dam and Hematite Lake Dam were breached according to MoDNR; specific data was not given. Lastly, on October 15, 1975 piping failed at the Dresser No. 4 Dam in Washington Co., resulting in failure[14].

Probability of Future Occurrence

Since it is unknown which dams, if any might fail at any given time, determining the probability of future occurrence is not possible[15]. In addition, dam failure within the county has not occurred according to available data.

Vulnerability

Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for the vulnerability analysis of dam failure for Washington County. There are however data limitations regarding dams unregulated by the State of Missouri due to height requirements. These limitations hinder vulnerability analysis; nonetheless, failure potential still exists. **Table 3.21** provides vulnerability analysis data for the failure of State-regulated dams in Missouri.

Table 3.21. Vulnerability Analysis for Failure of State-regulated Dams in Missouri

County	Class 1	Class 2	Class 3	Total	Estimated # of Buildings Vulnerable	Average Exposure Value per Structure ($)	Estimated Total Potential Building Exposure ($)	Estimated Total Population Exposure	Estimated Building Losses ($)
Washington	22	31	4	57	48	$27,382	$1,314,354	16	0

Source: 2018 Missouri State Hazard Mitigation Plan (DNR, MSDIS, Hazus)

For the vulnerability analysis of State regulated dams, the State developed the following assumptions for overview.

- Class 1 dams: the number of structures in the inundation area was estimated to be 10 or more permanent dwellings or any public building. Inspection of these dams must occur every two years.

[13] http://www.npdp.standord.edu/dam_incidents
[14] 2013 Missouri State Hazard Mitigation Plan
[15] 2018 Missouri State Hazard Mitigation Plan

- Class 2 dams: the area downstream from the dam that would be affected by inundation contains one to nine permanent dwellings, or one or more campgrounds with permanent water, sewer and electrical services or one or more industrial buildings. Inspection of these dams must occur once every three years.
- Class 3 dams: the area downstream from the dam that would be affected by inundation does not contain any of the structures identified for Class 1 or Class 2 dams. Inspection of these dams must occur once every five years.

The 2018 Missouri State Hazard Mitigation Plan used many sources of information for dam data which is why some figures and tables have different data values. According to Table 3.19 which used DNR, MSDIS, and Hazus sources there is an estimated 48 buildings vulnerable to failure of State-regulated dams. However, the sources of DNR and MSDIS shown in **Figure 3.20** show zero buildings vulnerable to failure in Washington County. Furthermore, the state quantified potential loss estimates in terms of property damages. To execute the analysis, the following assumptions were utilized.

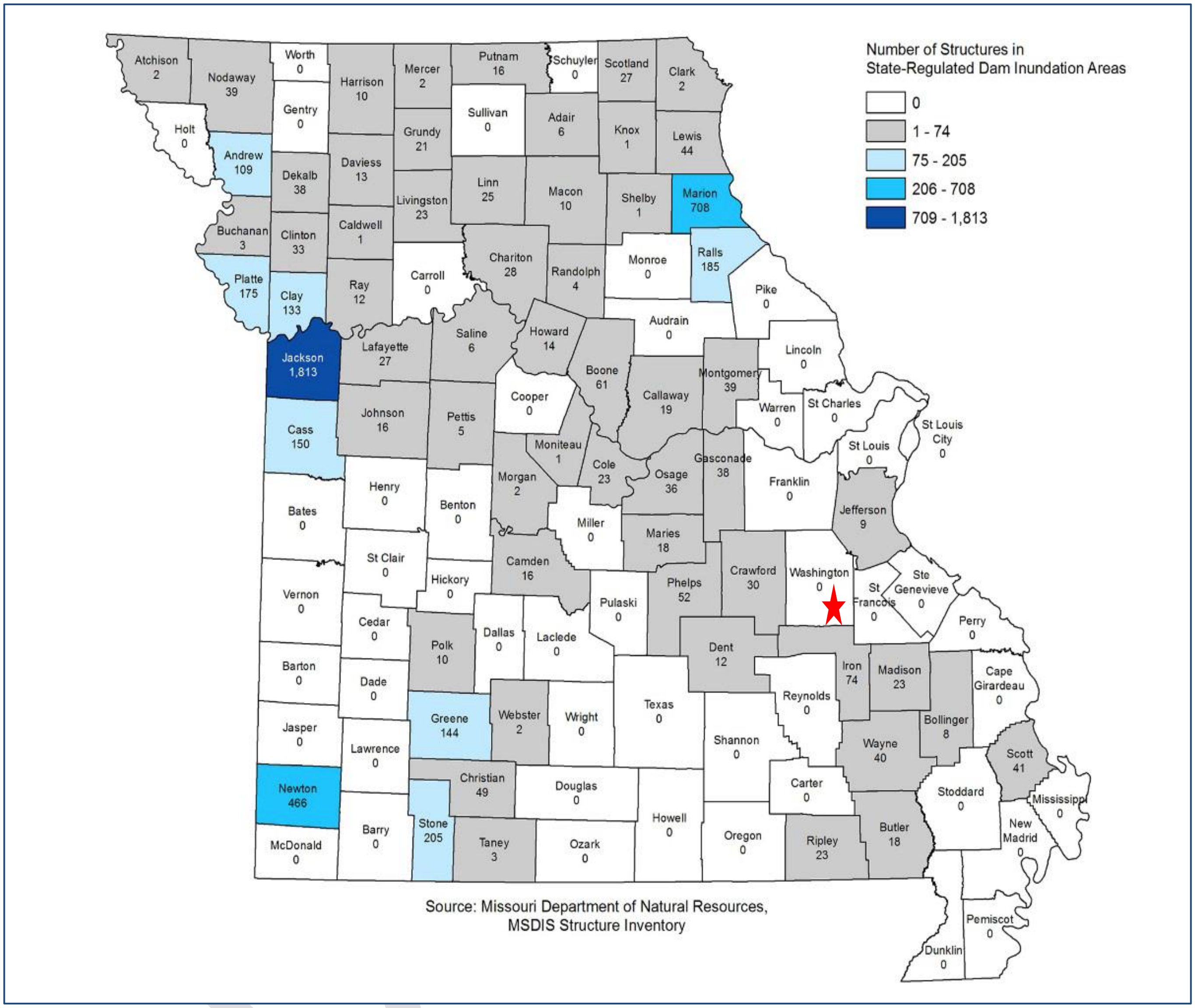
- For State-regulated Class 1 and Class 2 dams that have available inundation maps as well as USACE dams for which inundation maps were made available, GIS comparative analysis was accomplished against the building exposure data to determine the types, numbers and estimated values of buildings at risk to dam failure.
- The building exposure data was based on the structure inventory data layer available from the Missouri Spatial Data Inventory Service (MSDIS). The available dam inundation areas were compared against the structure inventory to determine the numbers and types of structures at risk to dam failure.
- To calculate estimated values of buildings at risk, buildings values available in the HAZUS census block data were used to determine an average value for each property type. This average value per property type was then applied to the number of structures in dam inundation areas by type to calculate an overall estimated value of buildings at risk by type.[16]

Figure 3.21 and **Figure 3.22** depict the total estimated building losses and population exposure by county, respectively. The estimated building losses from failure of State-regulated dams is $0. The estimated population exposure to failure of State-regulated dams ranges between 0.

[16] 2018 Missouri State Hazard Mitigation Plan

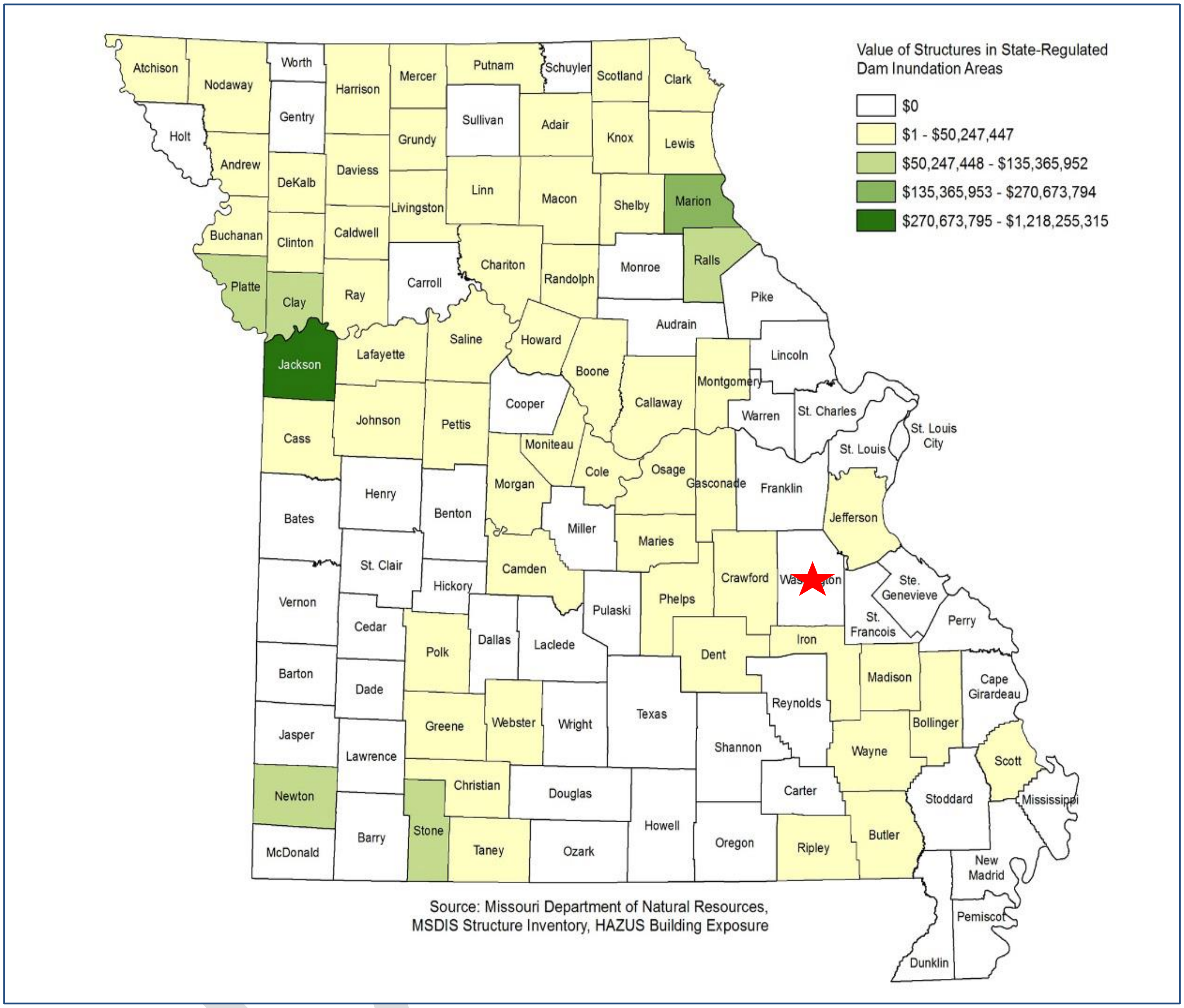
DRAFT

Figure 3.20. Estimated Number of Buildings Vulnerable to Failure of State-regulated Dams



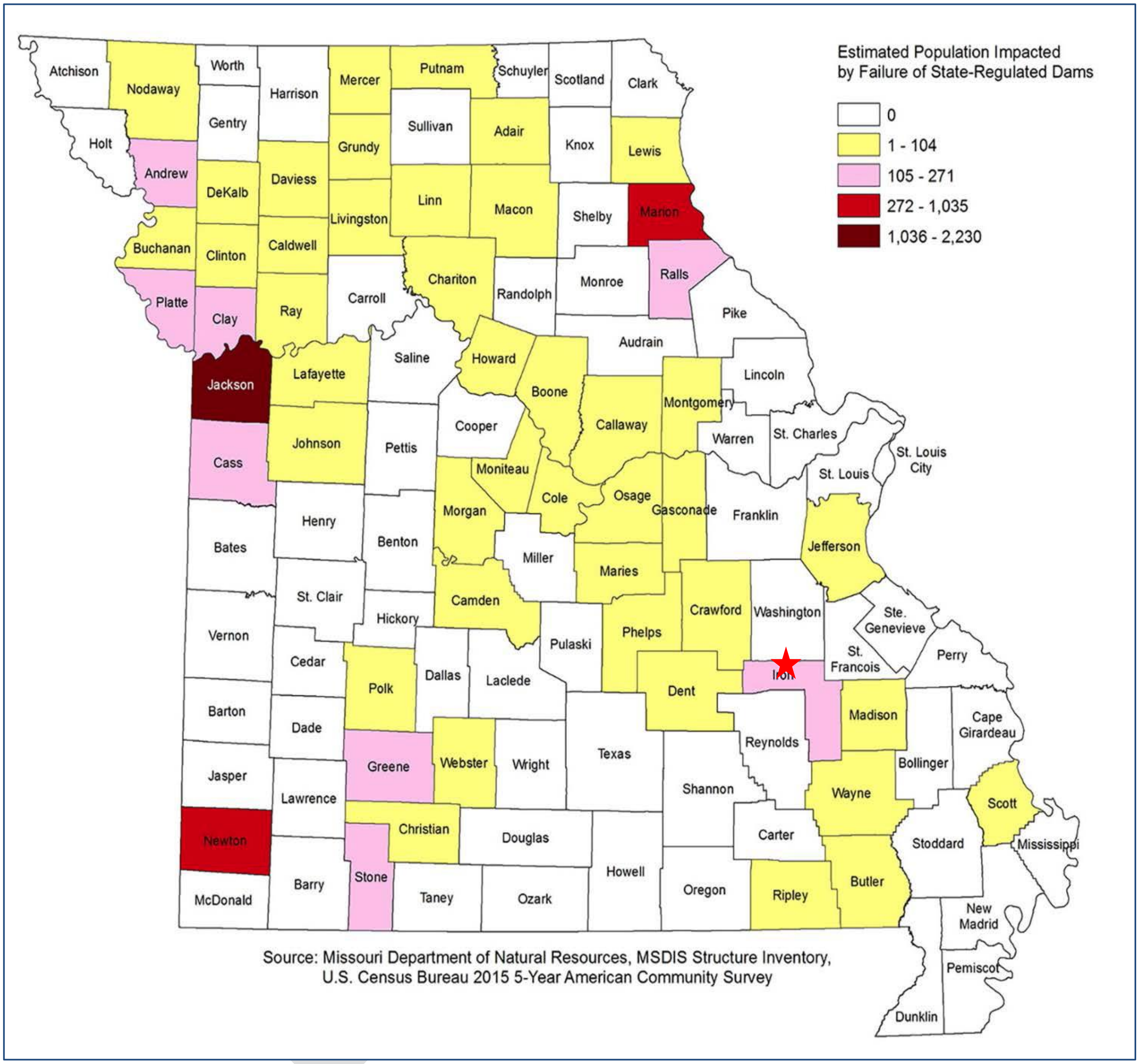
Source: 2018 Missouri State Hazard Mitigation Plan – DNR and MSDIS
*Red star indicates Washington County

Figure 3.21. Estimated Building Losses from Failure of State-regulated Dams



Source: 2018 Missouri State Hazard Mitigation Plan – DNR, MSDIS, Hazus
*Red star indicates Washington County

Figure 3.22. Estimated Population Exposure to Failure of State-regulated Dams



Source: 2018 Missouri State Hazard Mitigation Plan – DNR, MSDIS, Census Bureau
*Red star indicates Washington County

Potential Losses to Existing Development: (including types and numbers, of buildings, critical facilities, etc.)

The most obvious worst case dam failure scenario would occur at any High Hazard/Class 1 dam. During a failure event, serious loss to road infrastructure, commercial and residential structures, and human life is likely. However, the majority of dams in Washington County are rural in nature.

Ashley Branch Dam Downstream Crossings

- Ashley Rd

- Anthonies Mill Rd.
- Rte. N
- Rte. W
- Brazil Rd.
- Thickety Ford Rd.
- Carter Creek Rd.
- Sappington Bridge Rd.

Crystal Lake Dam Downstream Crossings
- Ashley Rd
- Anthonies Mill Rd.
- Rte. N
- Rte. W
- Brazil Rd.
- Thickety Ford Rd.
- Carter Creek Rd.
- Sappington Bridge Rd

Emerald Lake Dam Downstream Crossings
- Leisure Dr.
- Rte. N
- Rte. W

Forest Lake Dam Downstream Crossing
- Rte. AA
- Pleasant Hill Rd.
- State Hwy 185
- Rte. F

Gibson Memorial Dam Downstream Crossing
- Sayersbrook Dam Rd.
- Sayersbrook Rd.
- Fourche Renault Rd.
- Kline Farm Rd.
- State Hwy 185
- Missouri Pacific Railroad
- Lick Skillet Rd.
- Rte. F

Keuss Dam Downstream Crossing
- Rte. H
- Still Creek Pass
- Thunder Ridge Rd
- Floras Pl
- South Bridge Rd
- Buckeye Rd
- Brook Hollow Rd
- Rte. WW
- Pillen Rd

DRAFT

Lac Shayne Dam Downstream Crossing

- Shayne Dr
- St Francois Rd
- State Hwy 8
- Benny Meyer Rd
- Glore Rd

Lake Apache Dam Downstream Crossing

- Apache Rd
- Scout Camp Rd
- State Hwy M
- Elm St
- SGM Patrick R Hurley Dr

Sayersbrook Dam Downstream Crossing

- Sayersbrook Dam Rd.
- Sayersbrook Rd.
- Fourche Renault Rd.
- Kline Farm Rd.
- State Hwy 185
- Missouri Pacific Railroad
- Lick Skillet Rd.
- Rte. F

Sunnen Dam Downstream Crossing

- Rte. AA
- Floyd Tower Rd
- Sayersbrook Rd.
- Fourche Renault Rd.
- Kline Farm Rd.
- State Hwy 185
- Missouri Pacific Railroad
- Lick Skillet Rd.
- Rte. F

Impact of Future Development

Future development within the County that has potential to be influenced by dam failure includes any areas downstream of a dam within the 100 Year Floodplain. No development is planned in any floodplain or areas downstream of dams in the county or cities.

Hazard Summary by Jurisdiction

Variations in vulnerability across the planning area depend upon multiple variables. For example, with 57 state-regulated dams and 86 NID high hazard dams, conclusions can be drawn that many of the high hazard dams in the county are un-regulated and may not be inspected/maintained appropriately. Kingston K-14 School District has assets located in two tailings dam inundation areas. Other jurisdictions have road and utility infrastructure assets located in dam breach inundation areas. Most dams within the county are rural in nature.

DRAFT

Problem Statement

In summary, the hazard risk for dam failure in Washington County ranges between high and low, dependent upon the dam. If a dam does fail, the expected impacts could vary from negligible to critical, and could potentially affect road infrastructure, residential structures, commercial buildings, public structures, and human life. It is recommended to encourage land use management practices to decrease the potential for damage from a dam collapse, including the discouragement of development in areas with the potential for sustaining damage from a dam failure. Installation of education programs to inform the public of dam safety measures and preparedness activities would be beneficial. In addition, the availability of training programs to encourage landowners how to properly inspect their dams and develop emergency action plans would be advantageous.

DRAFT

3.4.2 Drought

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.6, Page 3.235
- Maps of effects of drought, National Drought Mitigation Center (NDMC) located at the University of Nebraska in Lincoln; http://www.drought.unl.edu/.
- Historical drought impacts, National Drought Mitigation Center (NDMC) located at the University of Nebraska in Lincoln; at http://droughtreporter.unl.edu/ .
- Recorded low precipitation, NOAA Regional Climate Center, (http://www.hprcc.unl.edu).
- Water shortages, Missouri's Drought Response Plan, Missouri Department of Natural Resources, https://dnr.mo.gov/water/hows-water/state-water/drought
- Populations served by groundwater by county, USGS-NWIS, http://maps.waterdata.usgs.gov/mapper/index.html
- Census of Agriculture, https://agcensus.library.cornell.edu/census_parts/2012-missouri/
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/en/Information-Tools/Summary-of-Business/Cause-of-Loss
- Natural Resources Defense Council, http://www.nrdc.org/globalWarming/watersustainability/
- Missouri Department of natural Resources (MDNR), Drought News, Conditions and Resources
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Vulnerability to drought by County
  - Crop insurance claims due to drought by County

Hazard Profile

Hazard Description

Drought is generally defined as a condition of moisture levels significantly below normal for an extended period of time over a large area that adversely affects plants, animal life, and humans. A drought period can last for months, years, or even decades. There are four types of drought conditions relevant to Missouri, according to the 2018 Missouri State Hazard Mitigation Plan, which are as follows.

- Meteorological drought is defined in terms of the basis of the degree of dryness (in comparison to some "normal" or average amount) and the duration of the dry period. A meteorological drought must be considered as region-specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region.

- Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on surface or subsurface water supply (e.g., streamflow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts. It takes longer for precipitation deficiencies to show up in components of the hydrological system such as soil moisture, streamflow, and ground water and reservoir levels. As a result, these impacts also are out of phase with impacts in other economic sectors.

- Agricultural drought focus is on soil moisture deficiencies, differences between actual and potential evaporation, reduced ground water or reservoir levels, etc. Plant demand for water depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil.
- Socioeconomic drought refers to when physical water shortage begins to affect people[17] - which impacts supply and demand of some economic commodity.

Geographic Location

All areas and jurisdictions in Washington County are susceptible to drought, but particularly cities where thousands of residents are served by the same source of water. These cities use deep hard rock wells that are 1,100 to 1,800 feet deep and can experience drought when recharge of these wells is low. The majority of individuals living in Washington County rely on groundwater resources, often private wells, for drinking water. Approximately 21% of the land in the county is utilized for agricultural purposes. Furthermore, livestock sales comprise 84% of the market of agricultural products sold in Washington County. A drought would directly impact livestock production and the agriculture economy in Washington County[18].

Severity/Magnitude/Extent

The National Drought Monitor Center at the University of Nebraska at Lincoln summarized the potential severity of drought as follows. Drought can create economic impacts on agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to losses in yields in crop and livestock production, drought is associated with increases in insect infestations, plant disease, and wind erosion. Droughts also bring increased problems with insects and disease to forests and reduce growth. The incidence of forest and range fires increases substantially during extended droughts, which in turn place both human and wildlife populations at higher levels of risk. Income loss is another indicator used in assessing the impacts of drought because so many sectors are affected. Finally, while drought is rarely a direct cause of death, the associated heat, dust and stress can all contribute to increased mortality.

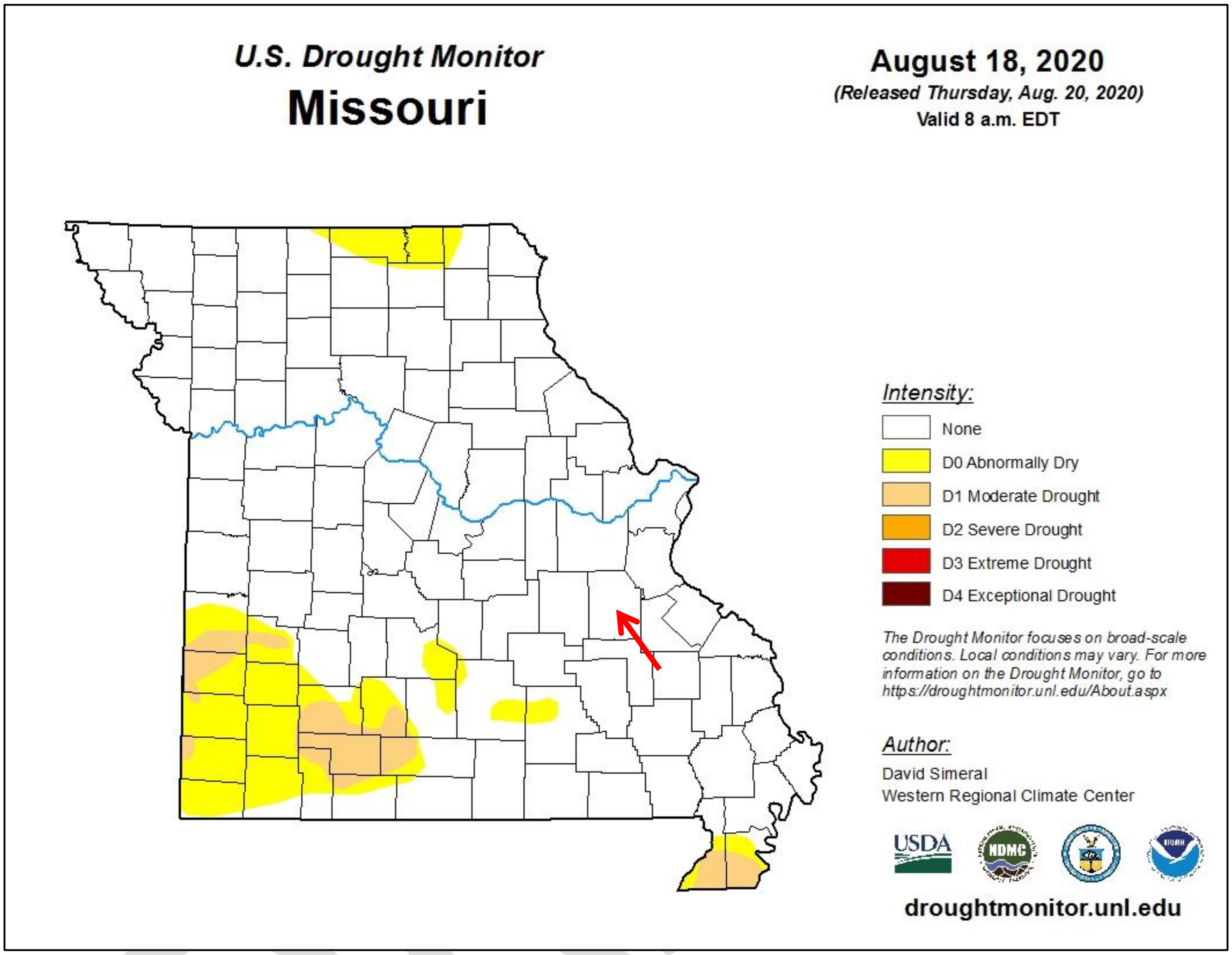
Figure 3.23 depicts a U.S. Drought Monitor map of Missouri on August 18, 2020. This map illustrates the planning area, which could be in drought at any given moment in time. A red arrow indicates the location of the planning area (Washington County).

[17] http://www.drought.unl.edu/ http://droughtreporter.unl.edu/

[18] http://www.agcensus.usda.gov/Publications/2012/Online_Resources/County_Profiles/Missouri/cp29161.pdf

DRAFT

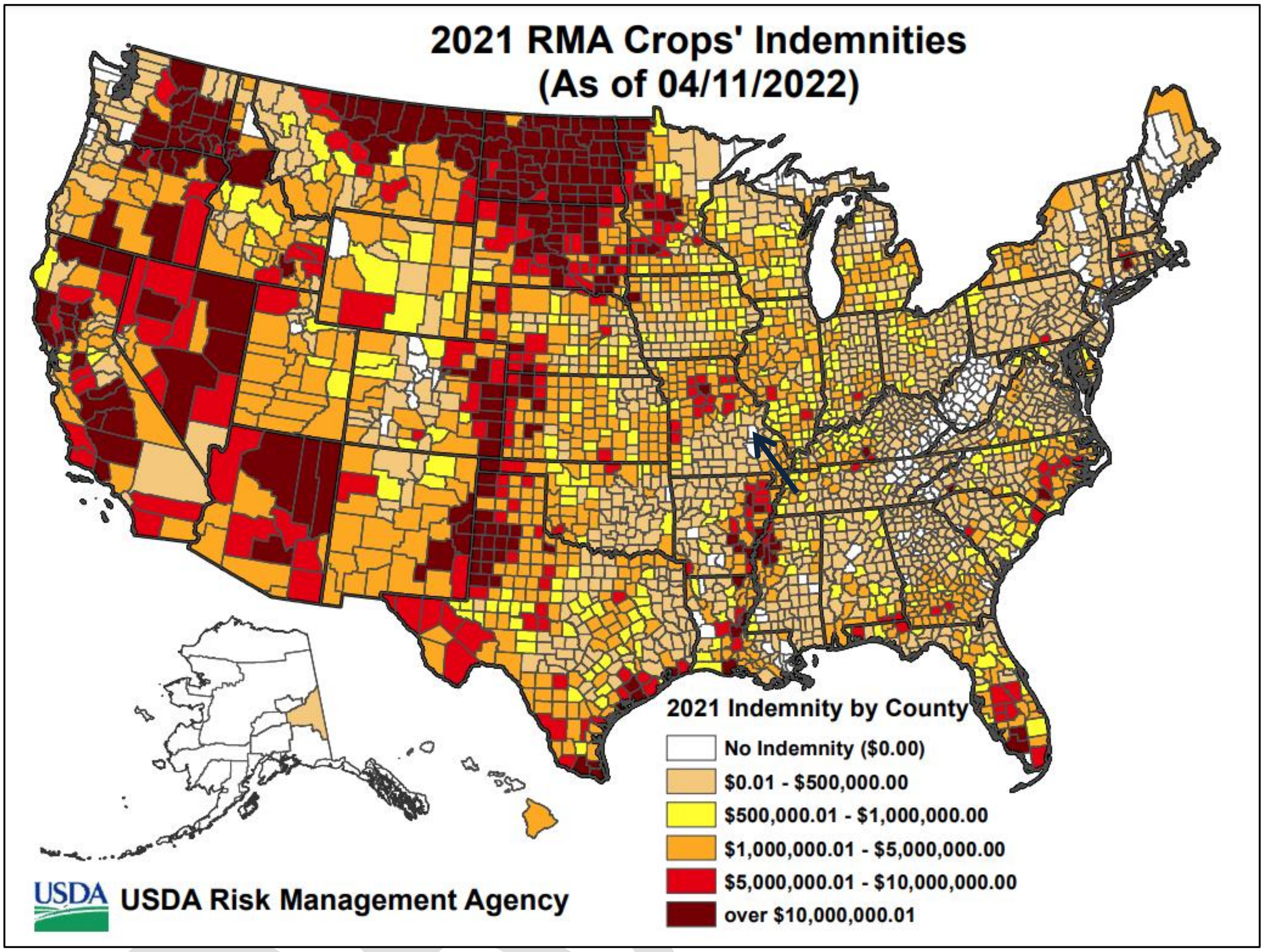
Figure 3.23. U.S. Drought Monitor Map of Missouri on August 18, 2020



Source: U.S. Drought Monitor, http://droughtmonitor.unl.edu/CurrentMap/StateDroughtMonitor.aspx?MO

Figure 3.24 illustrates RMA crop indemnities for 2021 across the United States. Washington County fell in the $0 category for crop indemnities.

Figure 3.24. 2021 RMA Crop Indemnities for the United States



Source: https://www.rma.usda.gov/-/media/RMA/Maps/Total-Crop-Indemnity-Maps/Crop-Year-2021/041122map.ashx
*Black arrow indicates Washington County

According to the USDA's Risk Management Agency, there has been 1 crop insurance payments due to drought in Washington County since 2001, totaling $4,590.00. **Table 3.22** illustrates the year, number of payments, and total amount of crop insurance payments.

Table 3.22. Washington County Crop Indemnity Payments (1999-2019)

Year	Number of Payments	Total
2018	1	$4590.00
TOTAL	**1**	**$4,590.00**

Source: http://www.rma.usda.gov/en/Information -Tools/Summary-of-Business/Cause-of-Loss

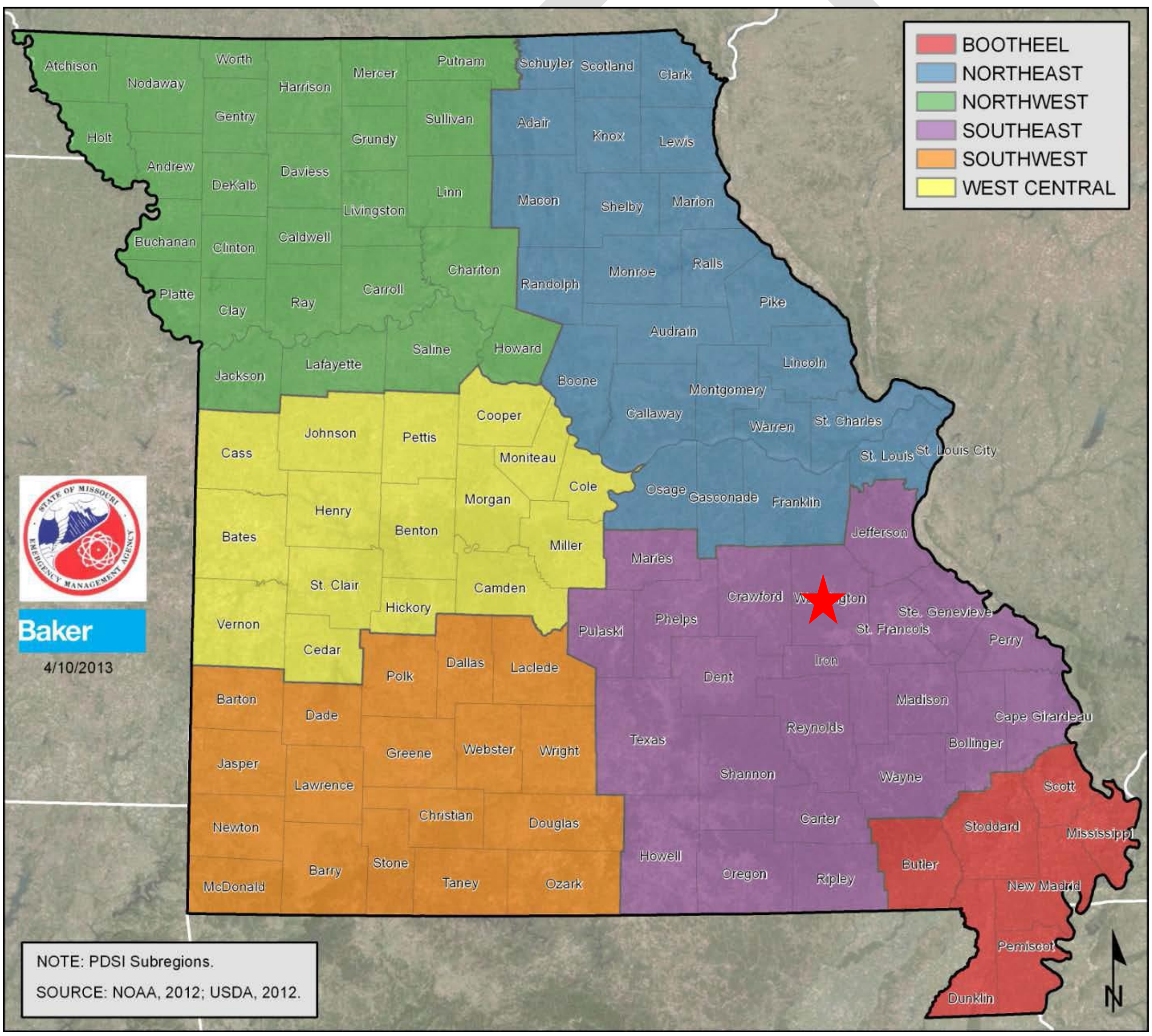
The Palmer Drought Indices measure dryness based on recent precipitation and temperature. The indices are based on a "supply-and-demand model" of soil moisture. Calculation of supply is relatively straightforward, using temperature and the amount of moisture in the soil. However, demand is more complicated as it depends on a variety of factors, such as evapotranspiration and recharge rates. These rates are harder to calculate. Palmer tried to overcome these difficulties by developing an algorithm that approximated these rates and based the algorithm on the most readily available data — precipitation and temperature.

The Palmer Index has proven most effective in identifying long-term drought of more than several months. However, the Palmer Index has been less effective in determining conditions over a matter of weeks. It uses a “0” as normal, and drought is shown in terms of negative numbers; for example, negative 2 is moderate drought, negative 3 is severe drought, and negative 4 is extreme drought. Palmer's algorithm also is used to describe wet spells, using corresponding positive numbers.

Palmer also developed a formula for standardizing drought calculations for each individual location based on the variability of precipitation and temperature at that location. The Palmer index can therefore be applied to any site for which sufficient precipitation and temperature data is available.

Figure 3.25 illustrates the Palmer Drought Severity Index sub-regions of Missouri. Washington County is categorized under the Southeast sub-region.

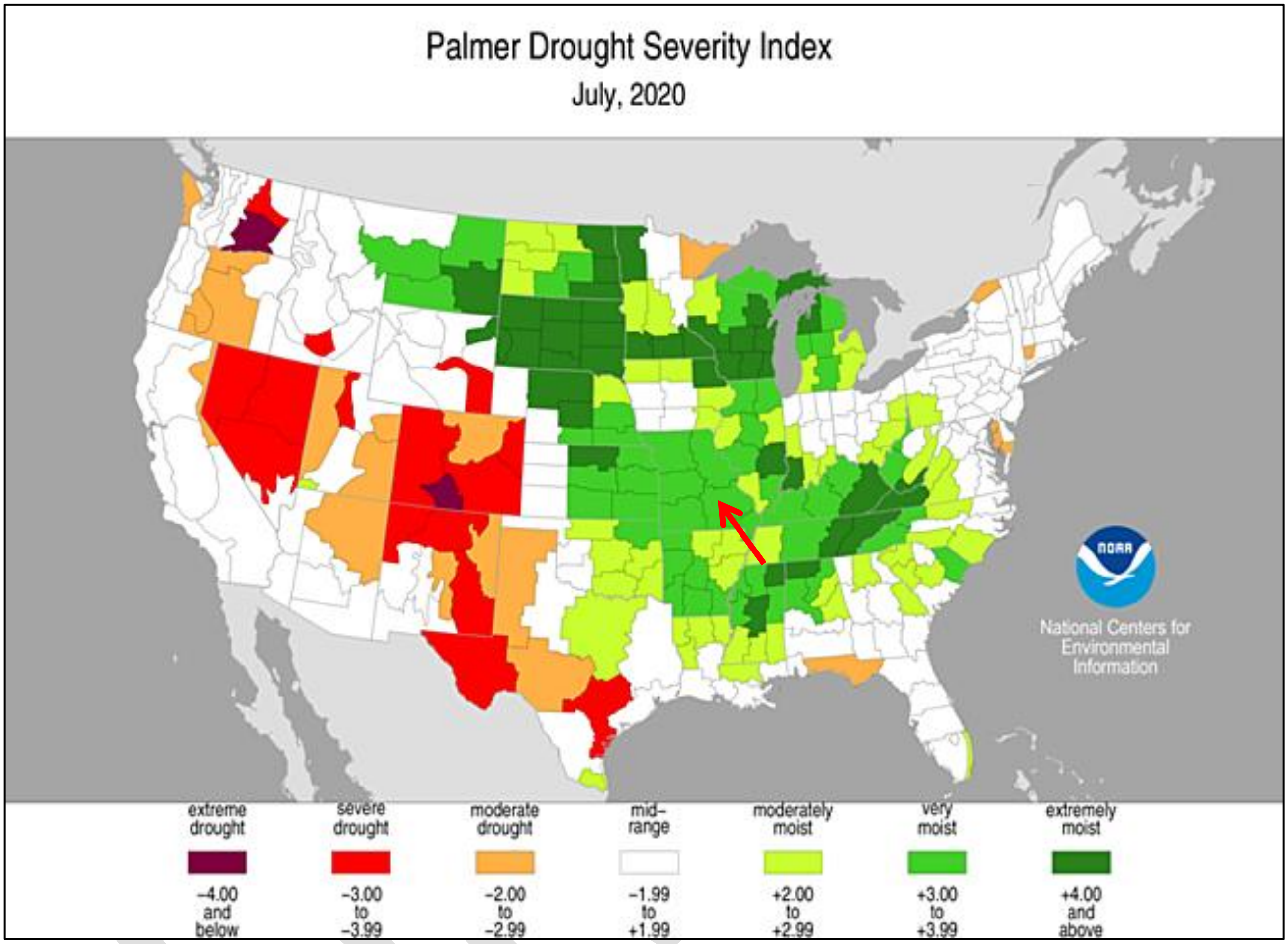
Figure 3.25. Palmer Drought Severity Index: Missouri Sub-regions



Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County

Figure 3.26 is an example of the Palmer Modified Drought Index for the United States on July, 2020.

Figure 3.26. Palmer Modified Drought Index National Map July, 2020



*Source: http://www.ncdc.noaa.gov/temp-and-precip/drought/historical-palmers/; *Red arrow indicates Washington County*

Data was collected from the Missouri Department of Natural Resources (2021 Census of Missouri Public Water Systems) to determine water source by jurisdiction. Washington County and the cities of Caledonia, Irondale, Mineral Point, and Potosi utilize well water as their sole source of water (**Table 3.23**). Communities that exclusively depend upon ground water could experience hardship in the event of a long term drought.

Table 3.23. 2021 Water Source by Jurisdiction

Jurisdiction	% of source that is groundwater
Washington County	100
Caledonia	100
Irondale	100
Mineral Point	100
Potosi	100

Source: Missouri Dept. of Natural Resources, 2021 Census of Missouri Public Water Systems

Previous Occurrences

Table 3.24 offers Palmer Drought Severity Index data for Washington County between 2011 and 2020. This information exemplifies drought conditions on a monthly basis for Missouri's Southeast sub-region within the United States.

Table 3.24. Palmer Drought Severity Index for Washington County, MO (2011 – 2020)

	Year									
Year	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Jan.	Extremely moist	Mid-range	Mid-range	Moderate Drought	Moderately moist	Extremely moist	Mid-range	Moderate drought	Mid-range	Extremely moist
Feb.	Extremely moist	Mid-range	Mid-range	Moderate Drought	Moderately moist	Very moist	Mid-range	Mid-range	Moderately moist	Very moist
March	Extremely moist	Mid-range	Mid-range	Moderate Drought	Mid-range	Very moist	Mid-range	Mid-range	Moderately moist	Very moist
April	Very moist	Mid-range	Moderately moist	Mid-range	Mid-range	Moderately moist	Mid-range	Mid-range	Moderately moist	Very moist
May	Very moist	Mid-range	Very moist	Mid-range	Mid-range	Moderately moist	Mid-range	Mid-range	Very moist	Very moist
June	Very moist	Moderate drought	Very moist	Mid-range	Very moist	Mid-range	Mid-range	Mid-range	Very moist	Very moist
July	Mid-range	Severe drought	Mid-range	Mid-range	Extremely moist	Mid-range	Mid-range	Moderate drought	Very moist	Very moist
Aug.	Mid-range	Extreme drought	Mid-range	Mid-range	Extremely moist	Very moist	Mid-range	Mid-range	Extremely moist	Very moist
Sept.	Mid-range	Severe drought	Mid-range	Moderately moist	Very moist	Very moist	Mid-range	Mid-range	Very moist	Very moist
Oct.	Moderate drought	Severe drought	Mid-range	Very moist	Moderately moist	Moderately moist	Mid-range	Mid-range	Very moist	Moderately moist
Nov.	Mid-range	Severe drought	Mid-range	Very moist	Very moist	Mid-range	Mid-range	Mid-range	Very moist	Moderately moist
Dec.	Mid-range	Severe drought	Moderate drought	Moderately moist	Extremely moist	Mid-range	Moderate drought	Mid-range	Very moist	Mid-range

Source: https://www.ncei.noaa.gov/access/monitoring/historical-palmers/maps/psi/201101-202012

DRAFT

Probability of Future Occurrence

To calculate the probability of future occurrence of drought in Washington County, historical climate data was analyzed. There were 32 months of recorded drought (**Table 3.25**) over a 20-year span (January, 2001 to December, 2020). The number of months in drought (32) was divided by the total number of months (240) and multiplied by 100 for the annual average percentage probability of drought (**Table 3.26**). Although drought is not predictable, long-range outlooks and predicted impacts of climate change could indicate an increase change of drought.

Table 3.25. Palmer Drought Severity Index for Washington County, MO (2001 – 2020)

	Year											
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
2001												
2002												
2003	x	x	x									
2004												
2005							x				x	x
2006	x	x	x	x	x	x	x	x	x			
2007										x	x	
2008												
2009												
2010												
2011										x		
2012						x	x	x	x	x	x	x
2013												x
2014	x	x	x									
2015												
2016												
2017												x
2018	x						x					
2019												
2020												

Source: https://www.ncei.noaa.gov/access/monitoring/historical-palmers/maps/psi/200101-202012
*x indicates drought

DRAFT

Table 3.26. Annual Average Percentage Probability of Drought in Washington County, MO

Location	Annual Avg. % P of Drought
Washington County	13.3%

Source: NOAA National Centers for Environmental Information, Historical Palmer Drought Indices
*P = probability; see page 3.44 for definition.

Vulnerability

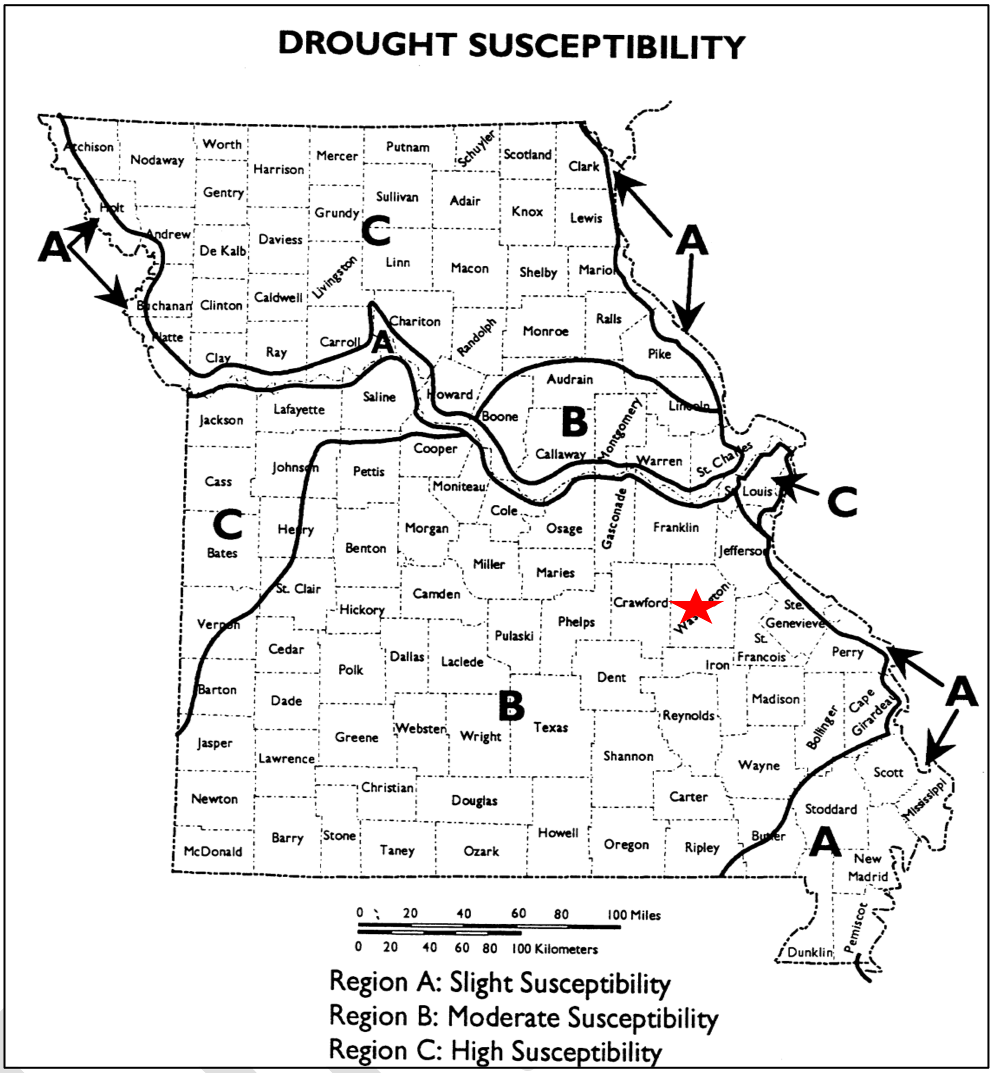
Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for the drought vulnerability analysis. **Table 3.27** depicts the ranges for drought vulnerability factor ratings created by SEMA. The array ranges between 1 (low) and 5 (high). The factors considered include social vulnerability, crop exposure ratio, annualized crop claims paid and likelihood of occurrence. Once the ranges were determined and applied to all factors considered in the analysis, the ratings were combined to determine an overall vulnerability rating for drought. Washington County is determined as having a low vulnerability to crop loss (**Table 3.28**) as a result of a drought. Additionally, SEMA has divided the State into 3 regions in regards to drought susceptibility (**Figure 3.27**). Washington County is included in Region B (Moderate Susceptibility). Region B is described as having groundwater sources that are suitable in meeting domestic and municipal water needs, but due to required well depths, irrigation wells are very expensive. Also, the topography is commonly unsuitable for row-crop irrigation[19].

[19] 2018 Missouri State Hazard Mitigation Plan

DRAFT

Figure 3.27. Drought Susceptibility in Missouri



Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County

Table 3.27. Ranges for Drought Vulnerability Factor Ratings

Factors Considered	Low (1)	Medium-low (2)	Medium (3)	Medium-high (4)	High (5)
Social Vulnerability Index	1	2	3	4	5
Crop Exposure Ratio Rating	\$866,000 - \$10,669,000	\$10,669,001 - \$33,252,000	\$33,252,001 - \$73,277,000	\$73,277.001 - \$155,369,000	\$155,369,001 - \$256,080,000
Annualized USDA Crop Claims Paid	<\$340,000	\$340,000 - \$669,999	\$670,000 – \$999,999	\$1M - \$1,299,999	>\$1,300,000
Likelihood of Occurrence of Severe or Extreme Drought	1-1.9%	2-3.9%	4-5.9%	6-8.9%	9-10.72%
Total Drought Vulnerability Rating	7-8	9-10	11-12	13-14	15-17

Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.28. Vulnerability of Washington County to Drought

SOVI index rating	USDA RMA Total Drought Crop Claims	Avg Annualized Crop Claims	USDA Claims Rating	2012 Crop Exposure	Crop Exposure Rating	Likelihood of severe drought %	Drought occurrence rating	Total Rating	Total rating (text) drought
3	$0	$0	1	$2,301,000	1	6.42	4	9	Low-medium

Source: 2018 Missouri State Hazard Mitigation Plan

Potential Losses to Existing Development

Drought is not limited to a hazard that affects just agriculture but can extend to encompass the nation's whole economy. Its impact can adversely affect a small town's water supply, the corner grocery store, commodity markets, or tourism. Additionally, extreme droughts have the ability to damage roads, water mains, and building foundations. On average, drought costs the U.S. economy about $7 billion to $9 billion a year, according to the National Drought Mitigation Center. Moreover, drought prone regions are also prone to increased fire hazards[20].

Impact of Future Development

Impacts of drought on future development within Washington County would be negligible. Population projections as provided by the Missouri Office of Administration suggest that Washington County will increase by approximately 2,500 individuals by 2030[21]. Moreover, with an increasing population, water use and demand would be expected to increase as well; potentially straining the water supply systems. Long term drought could expose vulnerabilities during construction/upgrades of water distribution and sewer infrastructures. Furthermore, any agriculture related development in terms of crop or livestock production would also be at risk.

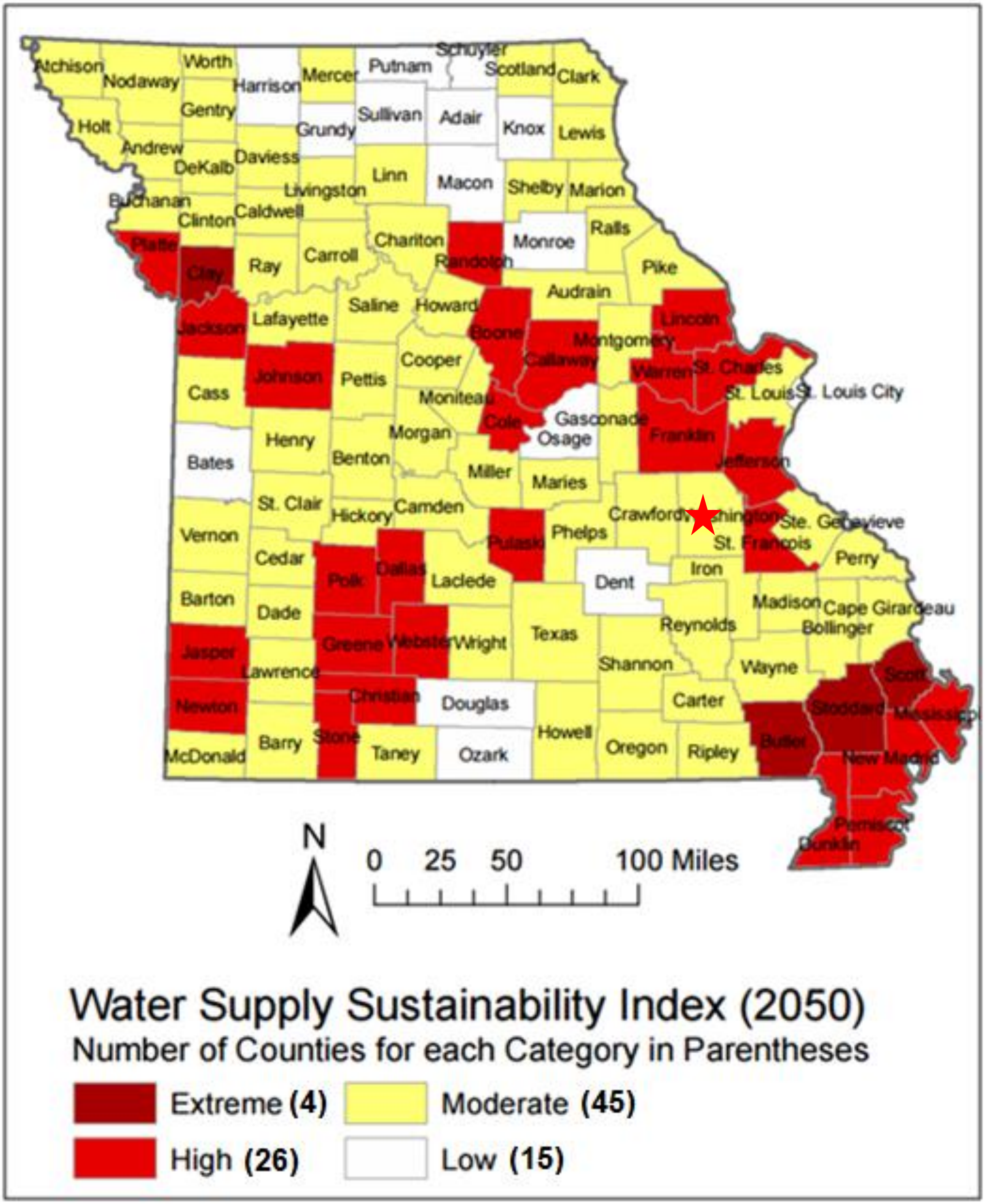
Impact of Climate Change

A new analysis, performed for the Natural Resources Defense Council, examined the effects of climate change on water supply and demand in the contiguous United States. The study found that more than 1,100 counties will face higher risks of water shortages by mid-century as a result of climate change. Two of the principal reasons for the projected water constraints are shifts in precipitation and potential evapotranspiration (PET). Climate models project decreases in precipitation in many regions of the U.S., including areas that may currently be described as experiencing water shortages of some degree. Washington County is predicted to experience moderate water shortages as a result of global warming (**Figure 3.28**) by the year 2050.

[20] https://drought.unl.edu/
[21] Missouri Office of Administration https://mcdc.missouri.edu/applications/MO-county-factsheets/?c=29221

DRAFT

Figure 3.28. Water Supply Sustainability Index (2050) with Climate Change Impacts



Source: Natural Resources Defense Council (NRDC), Climate Change, Water, and Risk
*Red star indicates Washington County

Hazard Summary by Jurisdiction

The variations between jurisdictions are non-existent to minimal. All communities in Washington County utilize ground/well water as their water source. In all cities, drought conditions would be the same as those experienced in rural areas, but the magnitude would be different with only lawns and local gardens impacted. Long term drought, spanning months at a time, could negatively impact the amount of potable drinking water available.

Problem Statement

In summary, drought within Washington County is considered low-moderate risk. Climate change predictions also suggest low-moderate risks by the year 2050. Washington County has some agricultural economy. Drought would impact commodities, specifically livestock and crops. Potential impacts to local economies and infrastructures are foreseeable in the event of a long-term drought.

The county and all cities should develop water monitoring plans as an early warning system. Each sector should inventory and review their groundwater operation plans. A water conservation awareness program should be presented to the public either through pamphlets, workshops or a drought information center. Voluntary water conservation should be encouraged to the public. The county and both cities should continually look for and fund water system improvements, new systems, and new wells.

DRAFT

3.4.3 Earthquakes

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.4, Page 3.192
- U.S. Seismic Hazard Map, United States Geological Survey, https://www.usgs.gov/programs/earthquake-hazards/maps;
- Impact of Earthquakes on the Central USA http://www.cusec.org/documents/aar/NMSZ_CAT_PLANNING_SCENARIO.pdf
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Total population impacted by earthquakes by County
  - Total number of structures impacted by earthquakes by County
  - Total value of structures impacted by earthquakes by County
  - Property loss ratio to earthquakes by County
- 6.5 Richter Magnitude Earthquake Scenario, New Madrid Fault Zone map, https://iowageologicalsurvey.org/;
- Facts about the New Madrid Seismic Zone, https://dnr.mo.gov/land-geology/hazards/earthquakes/science/facts-new-madrid-seismic-zone

Hazard Profile

Hazard Description

An earthquake is a sudden motion or trembling that is caused by a release of energy accumulated within or along the edge of the earth's tectonic plates. Earthquakes occur primarily along fault zones and tears in the earth's crust. Along these faults and tears in the crust, stresses can build until one side of the fault slips, generating compressive and shear energy that produces the shaking and damage to the built environment. Heaviest damage generally occurs nearest the earthquake epicenter, which is that point on the earth's surface directly above the point of fault movement. The composition of geologic materials between these points is a major factor in transmitting the energy to buildings and other structures on the earth's surface.

The closest fault to Washington County is the New Madrid Seismic Zone (NMSZ). The NMSZ is the most active seismic area in the United States east of the Rocky Mountains. Unfortunately, the faults in the NMSZ are poorly understood due to concealment by alluvium deposits. Moreover, the NMSZ is estimated to be 30 years overdue for a 6.3 magnitude earthquake[22].

Geographic Location

There are eight earthquake source zones in the Central United States, one of which is located within the state of Missouri—the New Madrid Fault. Other seismic zones, because of their close proximity, also affect Missourians. These are the Wabash Valley Fault, Illinois Basin, and the Nemaha Uplift. The most active zone is the New Madrid Fault, which runs from Northern Arkansas through Southeast Missouri and Western Tennessee and Kentucky to the Illinois side of the Ohio River Valley.

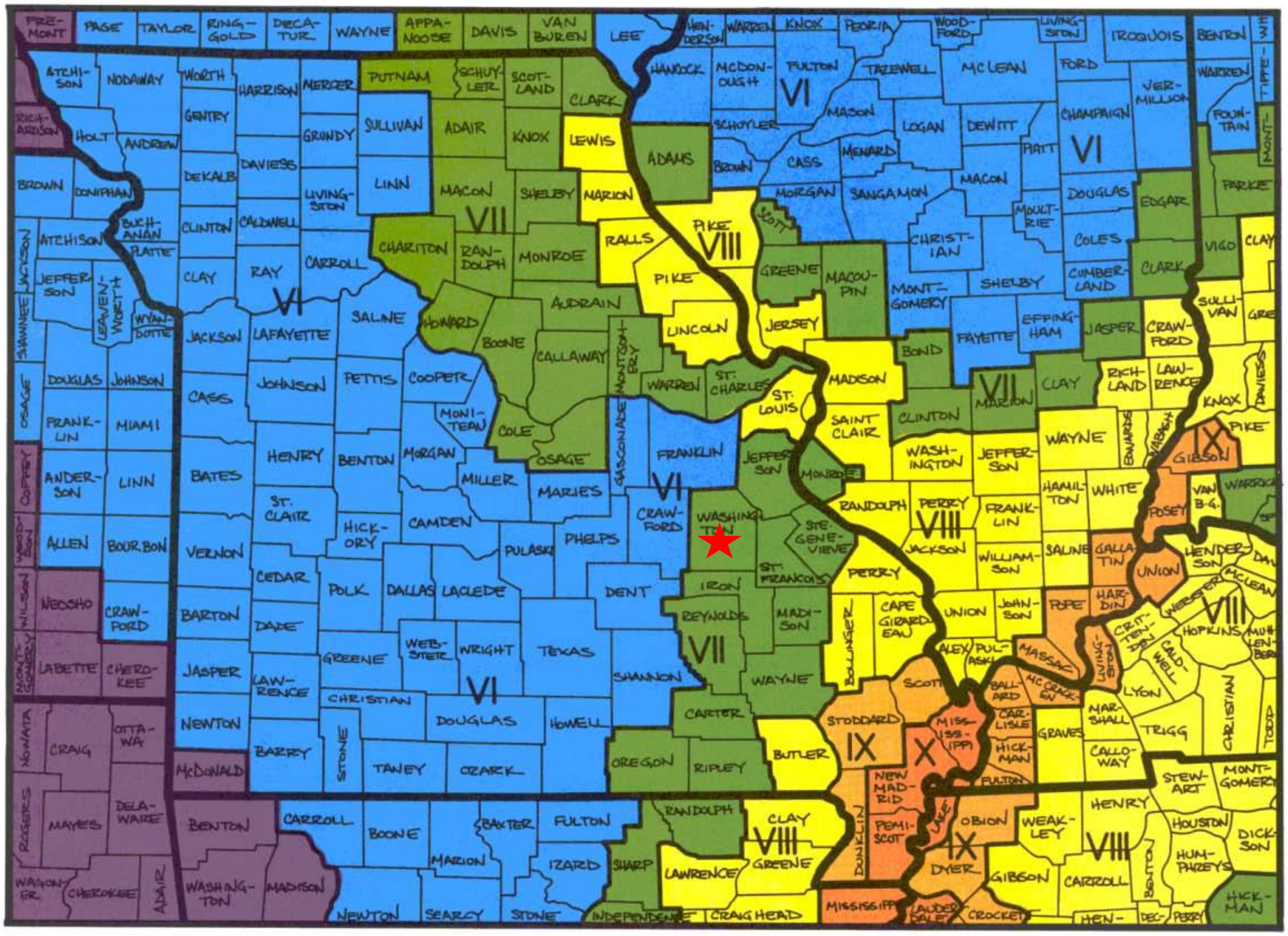
Figure 3.29 depicts impact zones for a magnitude 7.6 earthquake along the New Madrid Fault along with associated Modified Mercalli Intensities. Washington County is indicated by a red star.

[22] Missouri Department of Natural Resources, Facts about the New Madrid Seismic Zone

Furthermore, the Modified Mercalli Intensities for potential 6.7 and 8.6 magnitude earthquakes are illustrated. In the event of a 6.7 magnitude earthquake, Washington County would experience a Modified Mercalli Intensity of VI (**Figure 3.30**). This intensity is categorized as being felt by everyone. Poorly built buildings are damaged slightly. Considerable quantities of dishes and glassware, and some windows are broken. People have trouble walking. Pictures fall off walls. Objects fall from shelves. Plaster in walls might crack. Some furniture is overturned. Small bells in churches, chapels, and schools ring. Additionally, in the occurrence of 7.6 and 8.6 magnitude earthquakes; the county would experience Modified Mercalli Intensities of VII and VIII respectively. There will actually be a range in intensities within any small area such as a town or county, with the highest intensity generally occurring at only a few sites. **Figure 3.30** and **Table 3.29** further define Richter Scale intensities.

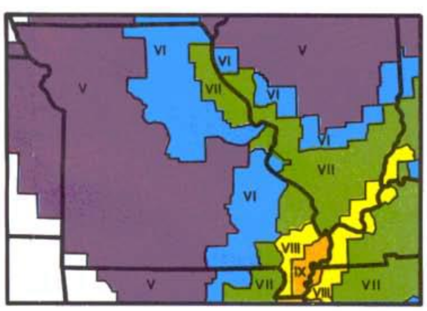
DRAFT

Figure 3.29. Impact Zones for Earthquake Along the New Madrid Fault



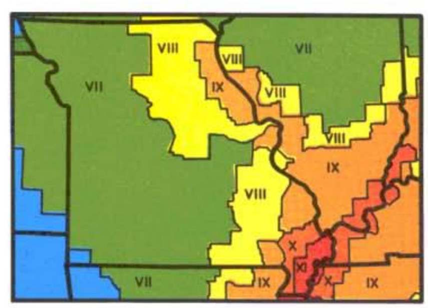
This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

6.7 7.6 8.6



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

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



Source: sema.dps.mo.gov; *Red star indicates Washington County

Figure 3.30.   Projected Earthquake Intensities

MODIFIED MERCALLI INTENSITY SCALE

I People do not feel any Earth movement.

II A few people might notice movement.

III Many people indoors feel movement. Hanging objects swing.

IV Most people indoors feel movement. Dishes, windows, and doors rattle. Walls and frames of structures creak. Liquids in open vessels are slightly disturbed. Parked cars rock.

V Almost everyone feels movement. Most people are awakened. Doors swing open or closed. Dishes are broken. Pictures on the wall move. Windows crack in some cases. Small objects move or are turned over. Liquids might spill out of open containers.

VI Everyone feels movement. Poorly built buildings are damaged slightly. Considerable quantities of dishes and glassware, and some windows are broken. People have trouble walking. Pictures fall off walls. Objects fall from shelves. Plaster in walls might crack. Some furniture is overturned. Small bells in churches, chapels and schools ring.

VII People have difficulty standing. Considerable damage in poorly built or badly designed buildings, adobe houses, old walls, spires and others. Damage is slight to moderate in well-built buildings. Numerous windows are broken. Weak chimneys break at roof lines. Cornices from towers and high buildings fall. Loose bricks fall from buildings. Heavy furniture is overturned and damaged. Some sand and gravel stream banks cave in.

VIII Drivers have trouble steering. Poorly built structures suffer severe damage. Ordinary substantial buildings partially collapse. Damage slight in structures especially built to withstand earthquakes. Tree branches break. Houses not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Temporary or permanent changes in springs and wells. Sand and mud is ejected in small amounts.

IX Most buildings suffer damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks conspicuously. Reservoirs suffer severe damage.

X Well-built wooden structures are severely damaged and some destroyed. Most masonry and frame structures are destroyed, including their foundations. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, and lakes. Railroad tracks are bent slightly. Cracks are opened in cement pavements and asphalt road surfaces.

XI Few if any masonry structures remain standing. Large, well-built bridges are destroyed. Wood frame structures are severely damaged, especially near epicenters. Buried pipelines are rendered completely useless. Railroad tracks are badly bent. Water mixed with sand, and mud is ejected in large amounts.

XII Damage is total, and nearly all works of construction are damaged greatly or destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move. Lakes are dammed, waterfalls formed and rivers are deflected.

Intensity is a numerical index describing the effects of an earthquake on the surface of the Earth, on man, and on structures built by man. The intensities shown in these maps are the highest likely under the most adverse geologic conditions. There will actually be a range in intensities within any small area such as a town or county, with the highest intensity generally occurring at only a few sites. Earthquakes of all three magnitudes represented in these maps occurred during the 1811 - 1812 "New Madrid earthquakes." The isoseismal patterns shown here, however, were simulated based on actual patterns of somewhat smaller but damaging earthquakes that occurred in the New Madrid seismic zone in 1843 and 1895.

Prepared and distributed by
THE MISSOURI STATE
EMERGENCY MANAGEMENT AGENCY
P.O. BOX 116
JEFFERSON CITY, MO 65102
Telephone: 573-526-9100

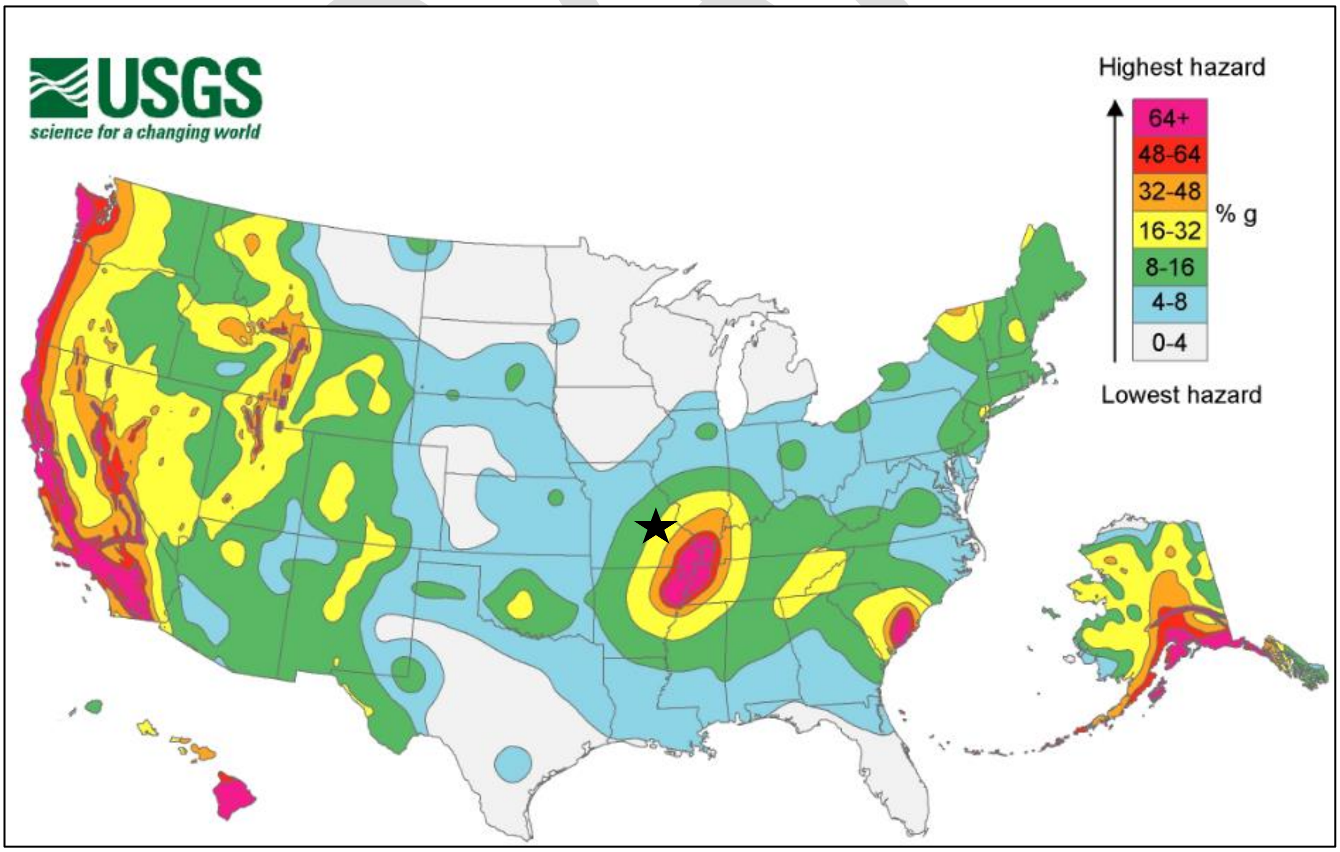
Source: sema.dps.mo.gov

Table 3.29. Richter Scale of Earthquake Magnitude

Magnitude Level	Category	Effects	Earthquake per Year
Less than 1.0 to 2.9	Micro	Generally not felt by people, though recorded on local instruments	More than 100,000
3.0-3.9	Minor	Felt by many people; no damage	12,000-100,000
4.0-4.9	Light	Felt by all; minor breakage of objects	2,000-12,000
5.0-5.9	Moderate	Some damage to weak structures	200-2,000
6.0-6.9	Strong	Moderate damage in populated areas	20-200
7.0-7.9	Major	Serious damage over large areas; loss of life	3-20
8.0 and higher	Great	Severe destruction and loss of life over large areas	Fewer than 3

Figure 3.31 illustrates the seismicity in the United States. A black star indicates the location of Washington County. The seismic hazard map displays earthquake peak ground acceleration (PGA) that has a 2% chance of being exceeded in 50 years, which has a value between 16-32% g.

Figure 3.31. United States Seismic Hazard Map



Source: USGS, http://earthquake.usgs.gov; *Black star indicates Washington County

Severity/Magnitude/Extent

The extent or severity of earthquakes is generally measured in two ways: 1) the Richter Magnitude Scale is a measure of earthquake magnitude; and 2) the Modified Mercalli Intensity Scale is a measure of earthquake severity. The two scales are defined a follows:

Richter Magnitude Scale

The Richter Magnitude Scale was developed in 1935 as a device to compare the size of earthquakes. The magnitude of an earthquake is measured using a logarithm of the maximum extent of waves recorded by seismographs. Adjustments are made to reflect the variation in the distance between the various seismographs and the epicenter of the earthquakes. On the Richter Scale, magnitude is expressed in whole numbers and decimal fractions. Each whole number increase in magnitude represents a tenfold increase in measured amplitude, an estimate of energy. For example, comparing a 5.3 and a 6.3 earthquake shows that a 6.3 earthquake is ten times bigger than a magnitude 5.3 earthquake on a seismogram, but is 31.622 times stronger (energy release)[23].

Modified Mercalli Intensity Scale

The intensity of an earthquake is measured by the effect of the earthquake on the earth's surface. The intensity scale is based on the responses to the quake, such as people awakening, movement of furniture, damage to chimneys, etc. The intensity scale currently used in the United States is the Modified Mercalli (MM) Intensity Scale. It was developed in 1931 and is composed of 12 increasing levels of intensity. They range from imperceptible shaking to catastrophic destruction, and each of the twelve levels is denoted by a Roman numeral. The scale does not have a mathematical basis but is based on observed effects. Its use gives the laymen a more meaningful idea of the severity.

Previous Occurrences

Most of Missouri's earthquake activity has been concentrated in the southeast corner of the state, which lies within the New Madrid seismic zone. The written record of earthquakes in Missouri prior to the nineteenth century is virtually nonexistent; however, there is geologic evidence that the New Madrid seismic zone has had a long history of activity. The first written account of an earthquake in the region was by a French missionary on a voyage down the Mississippi River. He reported feeling a distinct tremor on Christmas Day 1699 while camped in the area of what is now Memphis, TN.

Whatever the seismic history of the region may have been before the first Europeans arrived, after Dec. 16, 1811, there could be no doubt about the area's potential to generate severe earthquakes. On that date, shortly after 2 a.m., the first tremor of the most violent series of earthquakes in the United States history struck southeast Missouri. In the small town of New Madrid, about 290 kilometers south of St. Louis, residents were aroused from their sleep by the rocking of their cabins, the cracking of timbers, the clatter of breaking dishes and tumbling furniture, the rattling of falling chimneys, and the crashing of falling trees. A terrifying roaring noise was created as the earthquake waves swept across the ground. Large fissures suddenly opened and swallowed large quantities of river and marsh water. As the fissures closed again, great volumes of mud and sand were ejected along with the water.

The earthquake generated great waves on the Mississippi River that overwhelmed many boats and washed others high upon the shore. The waves broke off thousands of trees and carried them into the river. High riverbanks caved in, sand bars gave way, and entire islands disappeared. The violence of

[23] Measuring the Size of an Earthquake, http://earthquake.usgs.gov/learn/topics/measure.php

the earthquake was manifested by great topographic changes that affected an area of 78,000 to 130,000 square kilometers.

On Jan. 23, 1812, a second major shock, seemingly more violent than the first, occurred. A third great earthquake, perhaps the most severe of the series, struck on Feb. 7, 1812.

The three main shocks probably reached intensity XII, the maximum on the Modified Mercalli scale, although it is difficult to assign intensities, due to the scarcity of settlements at the time. Aftershocks continued to be felt for several years after the initial tremor. Later evidence indicates that the epicenter of the first earthquake (Dec. 16, 1811) was probably in northeast Arkansas. Based on historical accounts, the epicenter of the Feb. 7, 1812, shocks were probably close to the town of New Madrid.

Although the death toll from the 1811-12 series of earthquakes has never been tabulated, the loss of life was very slight. It is likely that if at the time of the earthquakes the New Madrid area had been as heavily populated as at present, thousands of persons would have perished. The main shocks were felt over an area covering at least 5,180,000 square kilometers. Chimneys were knocked down in Cincinnati, Ohio, and bricks were reported to have fallen from chimneys in Georgia and South Carolina. The first shock was felt distinctly in Washington, D.C., 700 miles away, and people there were frightened badly. Other points that reported feeling this earthquake included New Orleans, 804 kilometers away; Detroit, 965 kilometers away; and Boston, 1,769 kilometers away.

The New Madrid seismic zone has experienced numerous earthquakes since the 1811-12 series, and at least 35 shocks of intensity V or greater have been recorded in Missouri since 1811. Numerous earthquakes originating outside of the state's boundaries have also affected Missouri. Five of the strongest earthquakes that have affected Missouri since the 1811-12 series are described below.

On Jan. 4, 1843, a severe earthquake in the New Madrid area cracked chimneys and walls at Memphis, Tennessee. One building reportedly collapsed. The earth sank at some places near New Madrid; there was an unverified report that two hunters were drowned during the formation of a lake. The total felt area included at least 1,036,000 square kilometers.

The Oct. 31, 1895, earthquake near Charleston, MO probably ranks second in intensity to the 1811-12 series. Every building in the commercial area of Charleston was damaged. Cairo, Illinois, and Memphis, Tennessee, also suffered significant damage. Four acres of ground sank near Charleston and a lake was formed. The shock was felt over all or portions of 23 states and at some places in Canada.

A moderate earthquake on April 9, 1917, in the Ste. Genevieve/St. Mary’s area was reportedly felt over a 518,000 square kilometer area from Kansas to Ohio and Wisconsin to Mississippi. In the epicentral area people ran into the street, windows were broken, and plaster cracked. A second shock of lesser intensity was felt in the southern part of the area.

The small railroad town of Rodney, MO experienced a strong earthquake on Aug. 19, 1934. At nearby Charleston, windows were broken, chimneys were overthrown or damaged, and articles were knocked from shelves. Similar effects were observed at Cairo Mounds and Mound City, IL, and at Wickliff, KY. The area of destructive intensity included more than 596 square kilometers.

The Nov. 9, 1968, earthquake centered in southern Illinois was the strongest in the central United States since 1895. The magnitude 5.5 shock caused moderate damage to chimneys and walls at Hermann, St. Charles, St. Louis, and Sikeston, Missouri. The felt areas include all or portions of 23 states[i].

DRAFT

Small earthquakes continue to occur frequently in Missouri. Averages of 200 earthquakes are detected every year in the New Madrid Seismic Zone alone. Most are detectable only with sensitive instruments, but on an average of every 18 months, southeast Missouri experiences an earthquake strong enough to crack plaster in buildings[24].

Vulnerability

Vulnerability Overview

As stated in the 2018 Missouri Hazard Mitigation Plan, the impacts and severity of earthquakes on Missouri can be significant. The New Madrid earthquakes of 1811-1812 are among the largest that have happened on the North American continent. Losses at the time were limited due to low population and little development. However, a similar quake at this time would result in devastating damage.

The most important direct earthquake hazard is ground shaking, which affects structures close to the earthquake epicenter. However, ground shaking can also affect structures located great distances from epicenters, particularly where thick clay-rich soils can amplify ground motions. Certain types of buildings are more vulnerable to ground shaking than others. Unreinforced masonry structures, tall structures without adequate lateral resistance and poorly maintained structures are specifically susceptible to large earthquakes.

According to MDNR's Missouri Geological Survey, damage from earthquakes in the New Madrid Seismic Zone will vary depending on the earthquake magnitude, the character of the land and the degree of urbanization. Washington County is rural with few clusters of population. Infrastructure in the region such as highways, bridges, pipelines, communication lines and railroads might suffer damage, which would adversely affect Washington County, even if the county itself did not suffer heavy damage. Infrastructure could take a significant time to repair.

An important tool for homeowners to address the risk of earthquake damage to property is the purchase of earthquake insurance coverage. The Missouri Department of Insurance, Financial Institutions and Professional Registration (DIFP) prepared a report in 2020 on the state of earthquake insurance coverage in Missouri. The report notes that earthquake coverage has become less available and less affordable over the last 15 years. The cost of earthquake insurance has increased from an average of $50 per year to $209 per year. In high-risk counties the increases have been more substantial – from $57 per year in 2000 to $490 per year in 2020. The number of residences covered by earthquake insurance has dropped over the last 15 years – likely due to the increased cost of premiums. In 2020 the percentage of residential policies with earthquake coverage in Washington County was 27.2 percent with the average cost of coverage at $90 per year.[25]

Probability of Future Occurrence

Three earthquakes have been reported in Washington County since 2001. **Table 3.30** provides details about earthquakes in Washington County 2001 – 2020.

[24] Missouri State Hazard Mitigation Plan 2018

[25] The State of Earthquake Coverage Report, https://insurance.mo.gov/earthquake/documents/OverviewofResidentialEarthquakeInsurancein2020.pdf

Table 3.30. Earthquakes detected originating in Washington County 2001-2020

Date	Origin	Magnitude	Felt Report	Damages
03/07/2009	38.174°N 91.076°W	2.6	23	-
06/07/2011	38.077°N 90.902°W	3.9	5707	-
02/03/2014	38.064°N 90.932°W	2.6	11	-

Source: Untied State Geological Survey, https://earthquake.usgs.gov/earthquakes/eventpage/nm610279/executive

The county, located in south central Missouri, is a good distance from the southeast corner of the state where the New Madrid Fault resides. Should a significant earthquake occur, it would have the potential to cause moderate damage within the county.

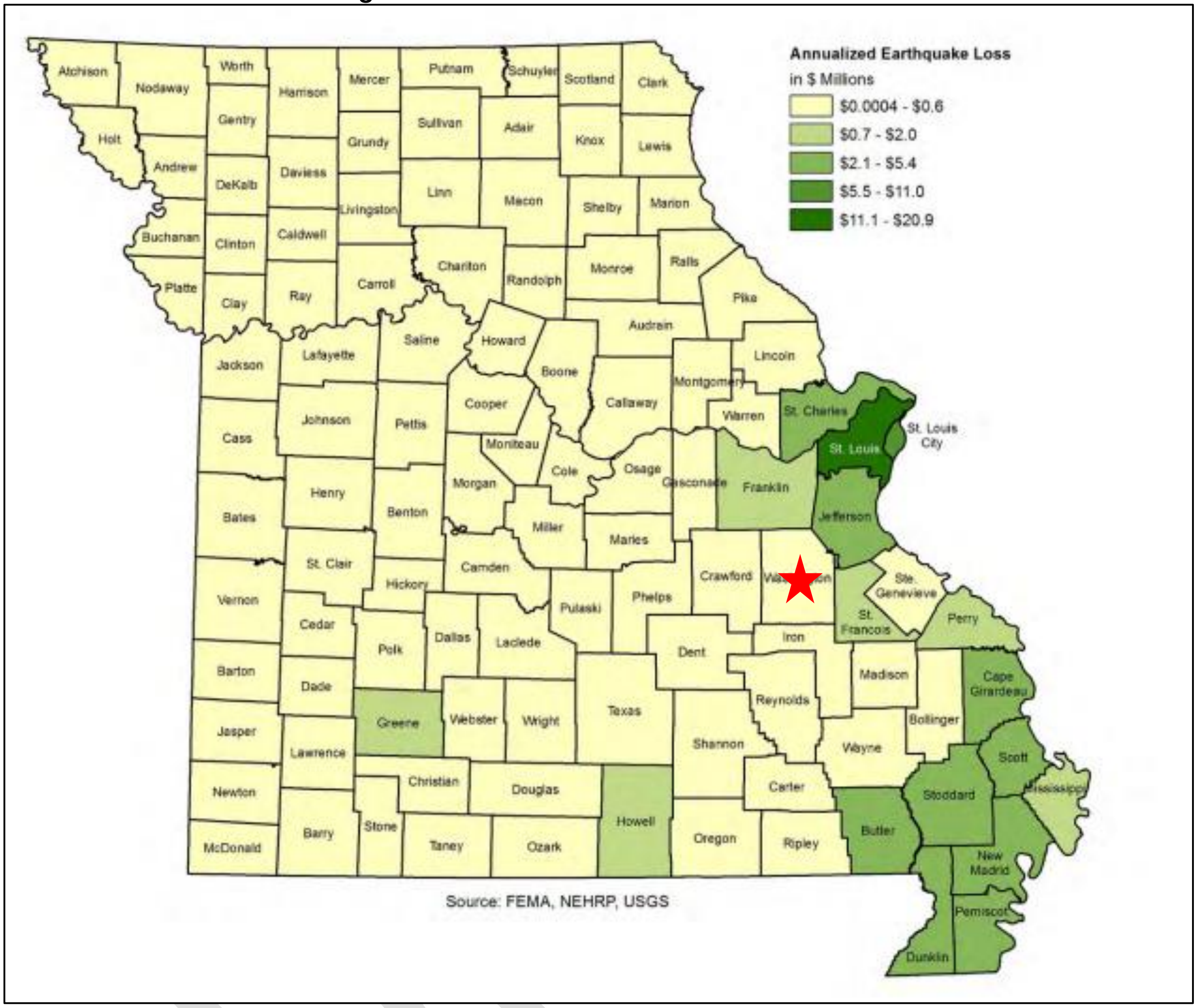
The 2018 Missouri Hazard Mitigation Plan states that there have been 31 recorded earthquake events greater than or equal to M 4.0 in the 43-year period from 1973 to 2018. According to this data, annual probability calculates to 72 percent. Additionally, the USGS estimated in 2006 that the probability of a repeat of the 1811-1812 earthquakes (magnitude 7.5 – 8.0) was seven to ten percent in a 50-year time period (Source: http://pubs.usgs.gov/fs/2006/3125). Given the historical frequency of earthquake events, this hazard is determined to have a high probability of occurrence within the State.

SEMA utilized Hazus V 3.2 to analyze vulnerability and estimate losses to earthquakes. Hazus is a program developed by FEMA which is a nationally applicable standardized methodology that encompasses models for assessing potential losses from earthquakes, floods, and hurricanes. All Hazus analyses were run using Level 1 building inventory database comprised of updated demographic and aggregated data based on the 2010 census. An annualized loss scenario that enabled an "apples to apples" comparison of earthquake risk for each county was synthesized from a FEMA nationwide annualized loss study (FEMA 366 Hazus Estimated Annualized Earthquake Losses for the United States, April 2017). A second scenario, based on an event with a two percent probability of exceedance in 50 years, was done to model a worst-case earthquake using a level of ground shaking recognized in earthquake-resistant design.

Annualized loss is the maximum potential annual dollar loss resulting from eight return periods (100, 200, 500, 750, 1,000, 1,500, 2,000, and 2,500 years) averaged on a 'per year' basis[26]. This is the scenario that FEMA uses to compare relative risk from earthquakes and other hazards at the county level nationwide. The Hazus earthquake loss estimation is depicted in **Figure 3.32** which shows annualized loss scenario direct economic losses to buildings. In this scenario, the annualized earthquake loss for buildings in Washington County in any one year is estimated to be $4,000 to $600,000. **Table 3.31** provides information on total estimated losses, estimated losses per capita and loss ratio. This results in the county being ranked 28th in the state for expected loss with low vulnerability for this hazard. This loss ratio indicates impacts on local economies in the event of an earthquake, and the difficulty for jurisdictions to recover from said event.

[26] 2018 Missouri State Hazard Mitigation Plan

Figure 3.32. HAZUS-MH Earthquake Loss Estimation: Annualized Loss Scenario –Direct Economic Losses to Buildings.



*Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County*

Table 3.31. HAZUS-MH Earthquake Loss Estimation-Washington County: Annualized Loss Scenario

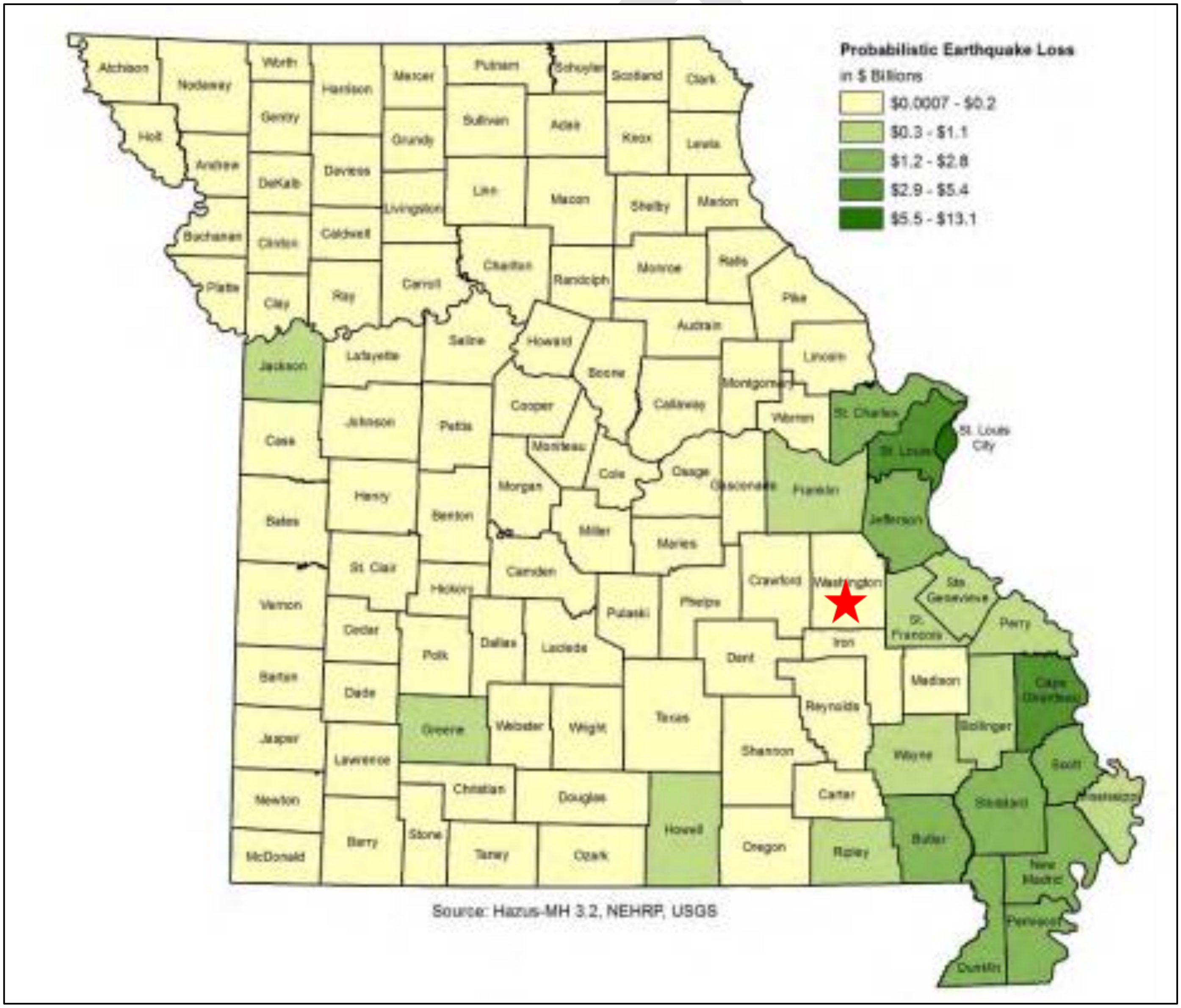
Total Losses in $ Thousands	Loss Per Capita, In $ Thousands	Loss Ratio in $ Per Million	Statewide Ranking for Expected Losses
$265	$0.0105	$153	28th

Source: 2018 Missouri State Hazard Mitigation Plan
**All $values are in thousands*
***Loss ratio is the sum of structural and nonstructural damage divided by the entire building inventory value within a county*

Likewise, SEMA developed a second scenario which incorporated a 2% probability of exceedance in 50 years. This model was to demonstrate a worst-case scenario. This scenario is equivalent to the 2,500-year earthquake scenario in HAZUS-MH. The methodology is based on probabilistic seismic hazard shaking grids developed by the U.S. Geological Survey (USGS) for the National Seismic Hazard

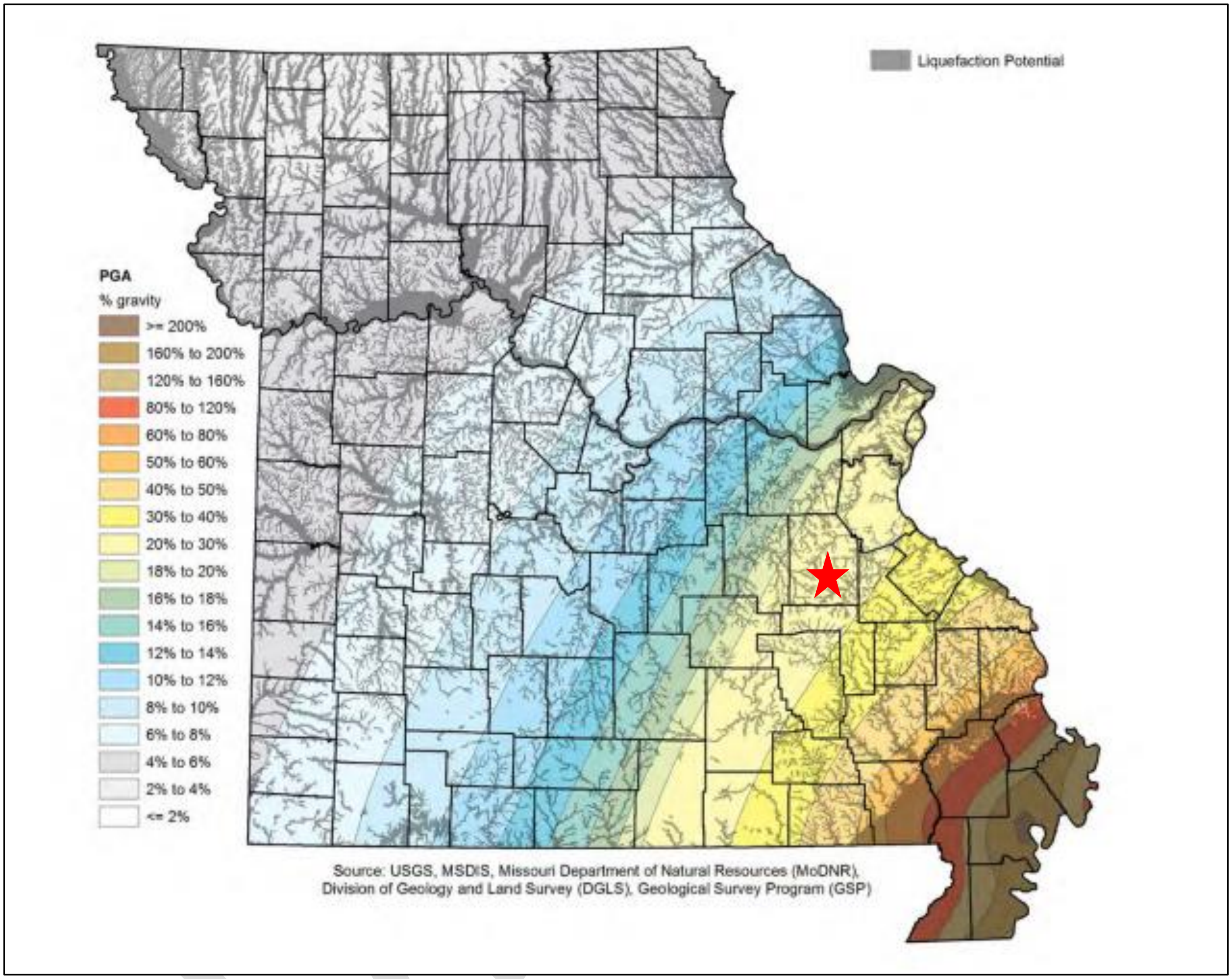
Maps that are included with HAZUS-MH. The USGS updated this mapping in 2014. **Figure 3.33** illustrates direct economic loss to buildings. Washington County is anticipated to lose between $700,000 and $200,000,000 in a 50-year scenario. **Figure 3.34** provides estimates of peak ground acceleration and spectral acceleration (ground shaking potential) at intervals of 0.3 and 1.0 seconds, respectively which have a two percent probability of exceedance in the next 50 years. These acceleration events have a 2% probability of exceedance in the next 50 years. A 7.7 magnitude earthquake was utilized in this scenario, which is typically utilized for New Madrid fault planning scenarios in Missouri. Furthermore, this pattern of shaking can be seen in with corresponding potential for damage and areas with soils potentially susceptible to liquefaction. Washington County is estimated to have peak ground acceleration between 20 percent and 30 percent.

Figure 3.33. HAZUS-MH Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Total Building Loss



*Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County*

Figure 3.34. Hazus Earthquake 2% Probability of Exceedance in 50 Years – Ground Shaking and Liquefaction Potential



*Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County*

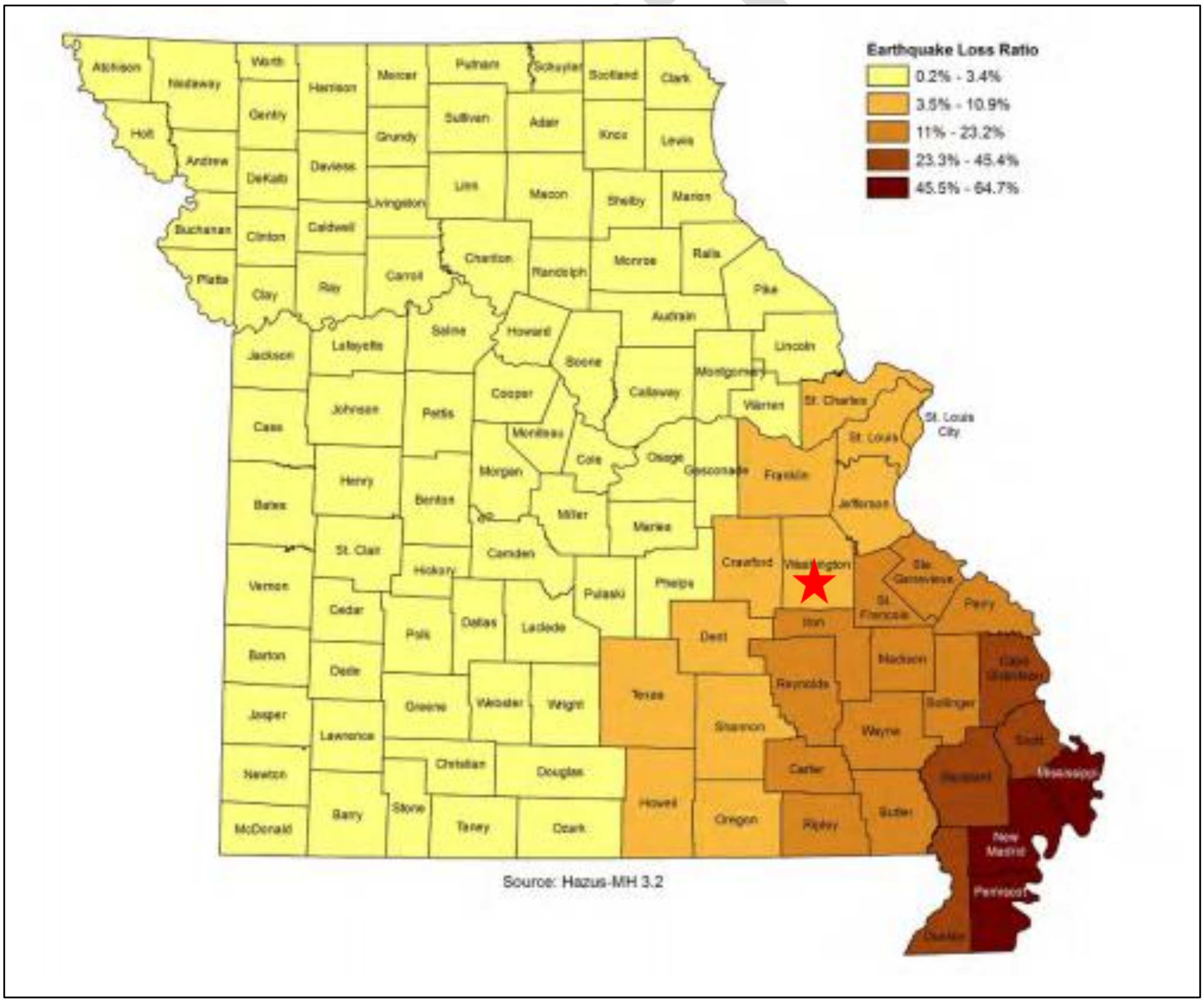
Figure 3.35 depicts a map of the modeled earthquake impacts by county based on building losses, including structural and nonstructural damage, content and inventory loss, and wage and income loss. Washington County shows a loss ratio of 3.5 percent to 10.9 percent. **Figure 3.35** depicts loss ratio by county, which is the ratio of the building structure and nonstructural damage to the value of the entire building inventory. The loss ratio is a measure of the disaster impact to community sustainability, which is generally considered at risk when losses exceed 10 percent of the built environment (FEMA). **Table 3.32** provides information on estimated direct economic losses for Washington County, including structural, nonstructural, inventory, contents, relocation costs, capital related loss, wages, and rental income loss. According to the 2018 Missouri Hazard Mitigation Plan, Washington County's loss ratio is 7.57 percent. Washington County ranks 28th in the state for direct economic losses in this scenario.

Table 3.32. HAZUS-MH Earthquake Loss Estimation 2% Probability of Exceedance in 50 Years Scenario Direct Economic Losses Results Summary for Washington County*

Cost Structural Damage	Cost Non-Structural Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related Loss	Wages Losses	Rental Income Loss	Total Loss
$32,398	$98,709	$32,139	$436	7.57	$22,252	$3,321	$5,511	$7,078	$201,844

Source: 2018 Missouri Hazard Mitigation Plan
All values in thousands

Figure 3.35. Hazus Earthquake Loss Estimation with a 2% Probability of Exceedance in 50 Years Scenario – Loss Ratio



*Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County*

Changing Future Conditions Considerations

Scientists are beginning to believe that there may be a correlation between changing climate conditions and earthquakes. Changing ice caps and sea-level redistribute weight over fault lines, which could potentially have an influence on earthquake occurrences. However, currently no studies quantify the relationship to a high level of detail, so recent earthquakes should not be linked with climate change. While not conclusive, early research suggests that more intense earthquakes and tsunamis may eventually be added to the adverse consequences that are caused by changing future conditions.[27]

Impact of Previous and Future Development

Future development is not expected to increase the risk other than contributing to the overall exposure of what could be damaged as a result of an earthquake. As new development arises, minimum standards of building codes should be established in all jurisdictions to decrease the potential damage/loss should an earthquake occur.

The Revised Statutes of MO, Section 160.451 require that: The governing body of each school district which can be expected to experience an intensity of ground shaking equivalent to a Modified Mercalli Intensity of VII or above from an earthquake occurring along the New Madrid Fault with a potential magnitude of 7.6 on the Richter Scale shall establish an earthquake emergency procedure system in every school building under its jurisdiction[28].

Hazard Summary by Jurisdiction

There will be a range in intensities within any small areas such as a town or county, with the highest intensity generally occurring at only a few sites. Washington County is not near the New Madrid Seismic Zone, but it will most likely endure mild secondary effects from the earthquake, such as fire, structure damage, utility disruption, environmental impacts, and economic disruptions/losses. However, damages could differ if there are structural variations in the planning area's built environment. For example, if one community has a higher percentage of residences built prior to 1939 than the other participants, that community is likely to experience higher damages. **Table 3.33** depicts the percent of residences built prior to 1939 in Washington County. In addition, if school districts have buildings built prior to 1939, those facilities may be at higher risk of damage should an earthquake occur. If a major earthquake should occur, Washington County would likely be impacted by the number of refugees traveling through the area seeking safety and assistance.

Table 3.33. Washington County Residences Built Prior to 1939

Jurisdiction	Number of Residences Built Prior to 1939	% of Residences Built Prior to 1939
Unincorporated Washington County	588	7.5%
Caledonia	41	45.1%
Irondale	35	16.0%
Mineral Point	20	16.4%
Potosi	147	13.9%

Source: US Census Bureau 2016-2020 ACS Data

[27] Missouri State Hazard Mitigation Plan 2018
[28] https://revisor.mo.gov/main/OneSection.aspx?section=160.451

DRAFT

Problem Statement

In a worst-case scenario, the county is expected to encounter $201,844,000 in total economic losses to buildings. Caledonia and Irondale both have a higher risk of damage to buildings due to over 30 percent of the homes having been built prior to 1939.

Jurisdictions should encourage purchase of earthquake hazard insurance. As well as establishing structurally sound emergency shelters in several parts of the county. In addition, stringent minimum standards of building codes should be established. Lastly, outreach and education should be utilized more frequently to prepare citizens for the next occurrence.

DRAFT

3.4.4 Extreme Temperatures

Hazard Profile

Some specific sources for this hazard are:

- 2018 Missouri State hazard Mitigation Plan, Chapter 3, Section 3.3.7, Page 3.253 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- Heat Index Chart & typical health impacts from heat, National Weather Service; National Weather Service Heat Index Program, https://www.weather.gov/safety/heat-index;
- Wind Chill chart, National Weather Service, http://www.nws.noaa.gov/om/cold/wind_chill.shtml ;
- Daily temperatures averages and extremes, High Plains Regional Climate Summary, https://hprcc.unl.edu/climate_extremes.php, http://climod.unl.edu/;
- Hyperthermia mortality, Missouri; Missouri Department of Health and Senior Service, http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper1.pdf;
- Hyperthermia mortality by Geographic area, Missouri Department of Health and Senior Services,
- http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper2.pdf;
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide

    - Average annual occurrence for extreme heat by County
    - Vulnerability to extreme heat by County
    - Average annual occurrence for extreme cold by County
    - Vulnerability to extreme cold by County

Hazard Profile

Hazard Description

Extreme temperature events, both hot and cold, can impact human health and mortality, natural ecosystems, agriculture and other economic sectors. According to information provided by FEMA, extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several days. Ambient air temperature is one component of heat conditions, with relative humidity being the other. The relationship of these factors creates what is known as the apparent temperature. The Heat Index chart shown in **Figure 3.36** uses both of these factors to produce a guide for the apparent temperature or relative intensity of heat conditions. Other factors that should be taken into account include duration of exposure to high temperatures, wind and activity.

The NWS has increased its efforts to more effectively alert the general public and local authorities on the hazards of heat waves. The Heat Index (HI) is an effective tool in helping people understand the dangers of high temperatures and how temperature and relative humidity together provide a more accurate gauge of heat intensity. The HI, provided in degrees Fahrenheit, is an accurate measure of how hot it actually feels when the relative humidity is added to the air temperature. For example – using the Heat Index Chart in **Figure 3.36** - if the air temperature is 96 degrees Fahrenheit, (found in the top of the table), and the relative humidity is 55 percent (found on the left of the table), the Heat Index is 112 degrees Fahrenheit (the intersection of the 96-degree row and the 55 percent column). Because

DRAFT

HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15 degrees Fahrenheit. Also, strong winds, particularly with very hot, dry air, can be extremely dangerous.

High humidity, a common factor in Missouri, can magnify the effects of extreme heat. While heat-related illness and death can occur from exposure to intense heat in just one afternoon, heat stress on the body has a cumulative effect. The persistence of a heat wave increases the threat to public health.

Extreme cold often accompanies severe winter storms and can lead to hypothermia and frostbite in people without adequate clothing protection. Cold can cause fuel to congeal in storage tanks and supply lines, stopping electric generators and furnaces. Cold temperatures can also overpower a building's heating system and cause water and sewer lines to freeze and rupture. Extreme cold also increases the likelihood for ice jams on flat rivers and streams. When combined with high winds from winter storms, extreme cold becomes extreme wind chill, which is hazardous to health and safety.

The National Institute on Aging estimates that more than 2.5 million Americans are elderly and especially vulnerable to hypothermia, with those who are isolated being most at risk. About 10 percent of people over the age of 65 have some kind of bodily temperature-regulating defect, and three to four percent of all hospital patients over 65 are hypothermic.

Figure 3.36. Heat Index (HI) Chart

NWS Heat Index

Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

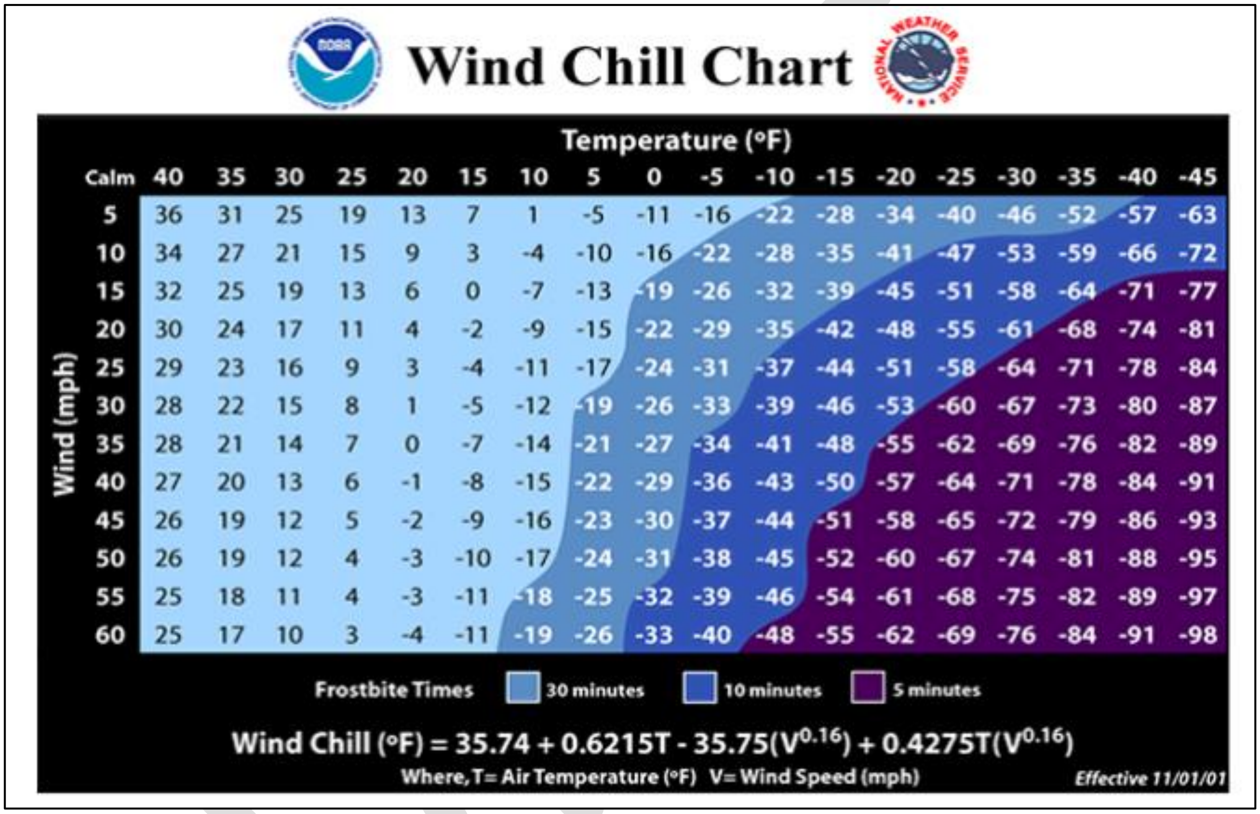
Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service (NWS); https://www.weather.gov/safety/heat-index
Note: Exposure to direct sun can increase Heat Index values by as much as 15°F. The shaded zone above 105°F corresponds to a HI that may cause increasingly severe heat disorders with continued exposure and/or physical activity.

Also at risk, are those without shelter, those who are stranded, or who live in a home that is poorly insulated or without heat. Other impacts of extreme cold include asphyxiation (unconsciousness or death from a lack of oxygen) from toxic fumes from emergency heaters; household fire, which can be caused by fireplaces and emergency heaters; and frozen/burst pipes.

The NWS Wind Chill Temperature (WCT) index, shown in **Figure 3.37,** uses advances in science, technology, and computer modeling to provide an accurate understandable and useful formula for calculating the dangers from winter winds and freezing temperatures. The figure below presents wind chill temperatures which are based on the rate of heat loss from exposed skin caused by wind and cold. As the wind increases, it draws heat from the body, driving down skin temperature and eventually the internal body temperature.

Figure 3.37. Wind Chill Chart



Wind Chill 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

Source: *https://www.weather.gov/safety/cold-wind-chill-chart*

Geographic Location

Extreme temperature is considered to be an area-wide hazard event. In such a case, the chance of variation in temperatures across Washington County is minimal to nonexistent.

Strength/Magnitude/Extent

The National Weather Service (NWS) has an alert system in place (advisories or warnings) when the Heat Index is expected to have a significant impact on public safety. The expected severity of the heat determines whether advisories or warnings are issued. A common guideline for issuing excessive heat alerts is when for two or more consecutive days: (1) when the maximum daytime Heat Index is expected to equal or exceed 105 degrees Fahrenheit (°F); and the nighttime minimum Heat Index is 80°F or above. A heat advisory is issued when temperatures reach 105 degrees, and a warning is issued at 115 degrees.

Extreme heat can cause stress to crops and animals. However, according to the NOAA Storm Events Data Base and USDA Risk Management website, there were no reported agricultural losses for Washington County during that 20-year time period. Extreme heat can also strain electricity delivery infrastructure overloaded during peak use of air conditioning during extreme heat events. Another type of infrastructure damage from extreme heat is road damage. When asphalt is exposed to prolonged extreme heat, it can cause buckling of asphalt-paved roads, driveways, and parking lots.

From 1988 through 2011, there were 3,496 fatalities in the U.S. attributed to summer heat. This translates to an annual average of 146 deaths. During the same time period, zero deaths were recorded in Washington County, according to NOAA Storm Events Data Base. The national Weather Service stated that among natural hazards, no other natural disaster – not lightning, hurricanes, tornadoes, floods or earthquakes – causes more deaths.

Those at greatest risk for heat-related illness include infants and children up to five years of age, people 65 years of age and older, people who are overweight, and people who are ill or on certain medications. However, even young and healthy individuals are susceptible if they participate in strenuous physical activities during hot weather. In agricultural areas, the exposure of farm workers, as well as livestock, to extreme temperatures is a major concern.

Table 3.34 lists typical symptoms and health impacts due to exposure to extreme heat.

Table 3.34. Typical Health Impacts of Extreme Heat

Heat Index (HI)	Disorder
80-90° F (HI)	Fatigue possible with prolonged exposure and/or physical activity
90-105° F (HI)	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity
105-130° F (HI)	Heatstroke/sunstroke highly likely with continued exposure

Source: National Weather Service Heat Index Program, https://www.weather.gov/safety/heat-index

Previous Occurrences

0 provides data in relation to record heat events between 2001 and 2020 in Washington County. Maximum heat index values and temperatures are shown for each extreme temperature event. Fortunately, there were zero recorded injuries and fatalities during this time. In addition, **Figure 3.38** illustrates heat related deaths by county in Missouri between 1980 and 2016.

Table 3.35. Washington County Recorded Heat Events 2001 – 2020

Month, Year	# of Event Days	Fatalities	Injuries	Temperature (F°)	Heat Index Values (F°)
7/7/2001	3	0	0	95-100	105-110
7/17/2001	1	0	0	95-100	110-115
7/21/2001	3	0	0	95-100	105-115
7/29/2001	2	0	0	90-95	105-110
8/1/2001	1	0	0	95-100	105
8/7/2001	2	0	0	95-100	102-110
8/21/2001	1	0	0	95-100	105-110
6/1/2002	3	0	1	85-95	-
7/8/2002	1	1	0	95-100	105-110
7/20/2002	2	0	0	95-100	105-115
7/26/2002	5	0	3	95-100	105-115
8/1/2002	5	0	1	95-100	-
8/15/2003	6	0	9	95-105	-
8/24/2003	4	0	0	95-100	105-110
7/20/2004	2	0	0	90-95	105-110
7/20/2005	6	0	0	100+	105-120
7/17/2006	3	0	0	95-100	105-110
7/30/2006	1	0	0	95-100	105-110
8/1/2006	1	0	0	100+	-
7/1/2011	2	0	0	95-100	105
7/10/2011	2	0	0	95-100	-
8/6/2011	1	0	0	95-100	105-110
8/31/2011	1	0	0	100+	105-110
9/1/2011	2	0	0	100	105

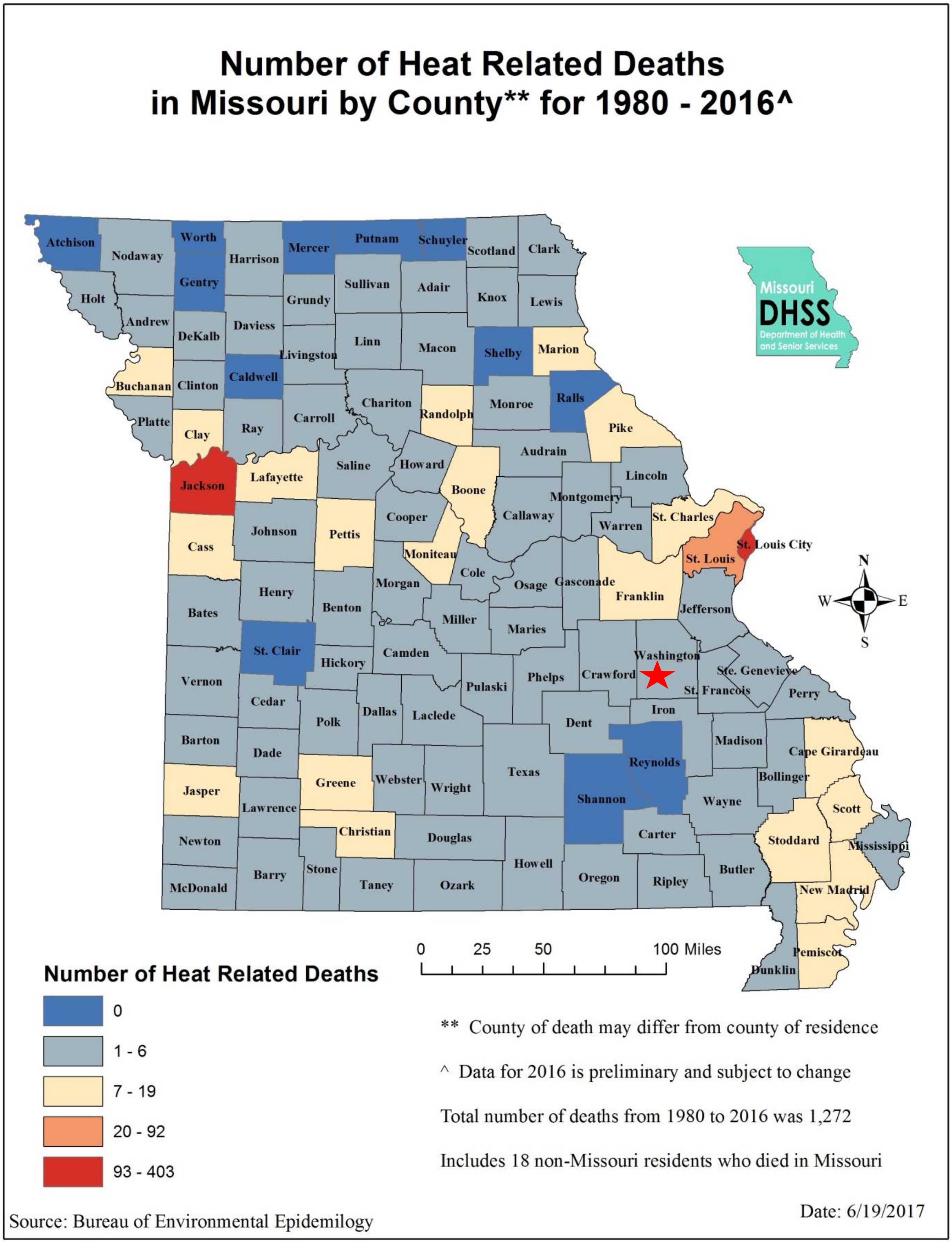
DRAFT

Month, Year	# of Event Days	Fatalities	Injuries	Temperature (F°)	Heat Index Values (F°)
8/31/2013	1	0	0	100	105-110
9/1/2013	1	0	0	100	105-110
6/15/2016	1	0	0	95-100	105
Total	**63**	**1**	**14**	**-**	**-**

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

DRAFT

Figure 3.38. Heat Related Deaths in Missouri 2000 - 2016

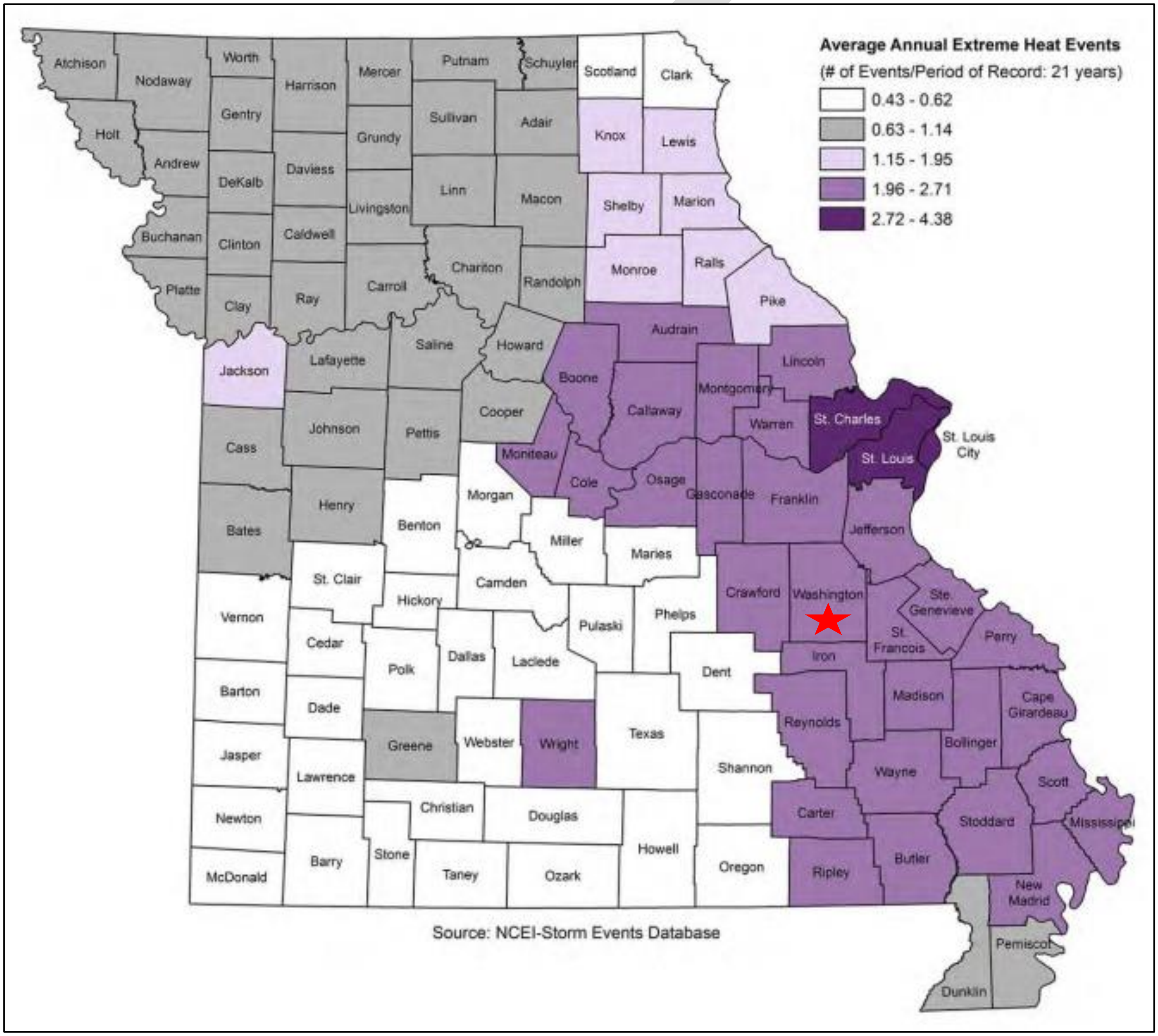


Source: https://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/stat-report.pdf
*Red star indicates Washington County

Probability of Future Occurrence

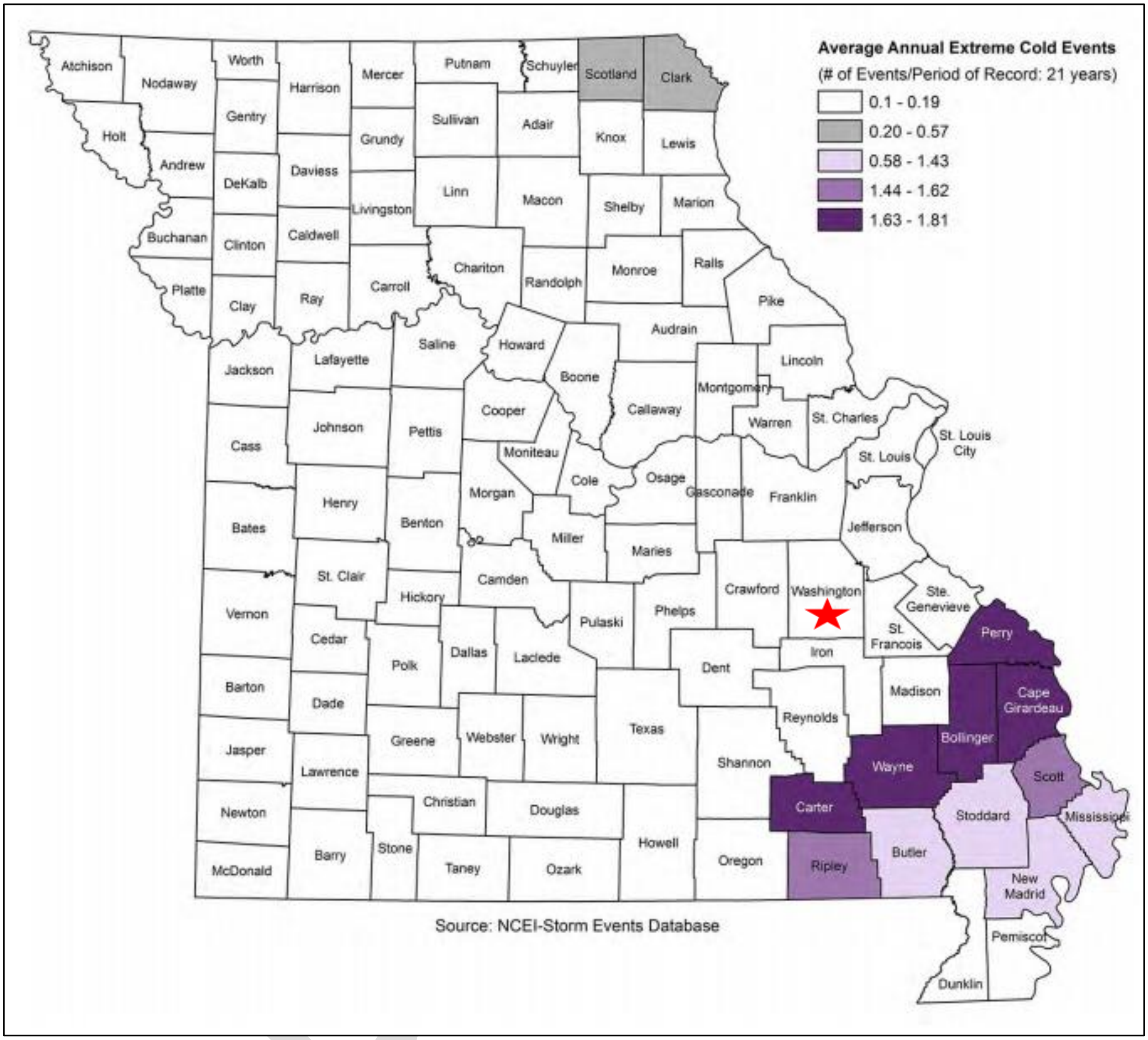
Figure 3.39 illustrates the average annual occurrence for extreme heat statewide. Based on information provided in the 2018 Missouri State Hazard Mitigation Plan, Washington County has an average of 1.96 to 2.71 events per year based on data from 21 years. **Figure 3.40** illustrates the average annual occurrence for extreme cold statewide. Washington County has an average of 0.1 to 0.19 events per year based on data from 21 years. It should be noted that there are data limitations due to underreporting of extreme heat and cold events.

Figure 3.39. Average Annual Occurrence for Extreme Heat



*Source: 2018 Missouri State Hazard Mitigation Plan; *Red star indicates Washington County*

Figure 3.40. Average Annual Occurrence for Extreme Cold



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Changing Future Conditions Considerations

According to the 2018 Missouri Hazard Mitigation Plan, under a higher emissions pathway, historically unprecedented warming is projected by the end of the century. Even under a pathway of lower greenhouse gas emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. For example, in southern Missouri, the annual maximum number of consecutive days with temperatures exceeding 95 degrees F is projected to increase by up to 20 days. Temperature increases will cause future heat waves to be more intense, a concern for this region which already experiences hot and humid conditions. If the warming trend continues, future heat waves are likely to be more intense and cold spells are projected to decrease.

Furthermore, higher temperatures are experienced more acutely by vulnerable populations such as the elderly, the very young, the homeless, the ill and disabled, and those living in poverty. Higher demands and costs for electricity to run air conditioners can stress power systems. Higher temperatures can also cause harmful algal blooms in warmer water – resulting in poor water quality.

Mitigation against the impacts of future temperature increases may include increasing education on heat stress prevention, organizing cooling centers, allocating additional funding to repair and maintain roads damaged by buckling and potholes and reducing nutrient runoff that contributes to algal blooms. Local governments should also prepare for increased demand on utility systems. Improving energy efficiency in public buildings will also present an increasingly valuable savings potential.

Vulnerability

Vulnerability Overview

Washington County, along with the rest of the state of Missouri is vulnerable to extreme heat and cold events. **Table 3.36** shows the typical health impacts of extreme heat. Jurisdictions with higher percentages of individuals below the age of 5, and above the age of 65 tend to be more at risk for extreme heat (**Table 3.39**). People who are overweight, ill or on certain medication can also be more vulnerable to high temperatures. Unincorporated Washington County has an estimated 16.0 percent of individuals are 65 or older. The city of Mineral Point had the lowest number of older residents with 8.5 percent aged 65 and over. Caledonia had the highest rate overall with 24.0 percent of residents falling into the 65 and older category. However, even young and healthy individuals are susceptible if they participate in strenuous physical activities during hot weather. The exposure to extreme temperatures of farm workers and livestock is also a major concern.

Table 3.36. Typical Health Impacts of Extreme Heat

Heat Index (HI)	Disorder
80°- 90° F (HI)	Fatigue possible with prolonged exposure and/or physical activity.
90° - 105° F (HI)	Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity.
105° - 130° F (HI)	Heatstroke/sunstroke highly likely with continued exposure.

Source: National Weather Service Heat Index Program, https://www.weather.gov/safety/heat-index

The method used by state planners to determine vulnerability to extreme temperatures across Missouri was statistical analysis of data from several sources: National Centers for Environmental Information (NCEI) storm events data (1996- December 31, 2016), percentage of population over 65 data from the U.S. Census (2015 ACS) and the calculated Social Vulnerability Index for Missouri counties from the hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina. Four factors were considered in determining overall vulnerability to extreme temperatures – total population, percentage of population over 65, likelihood of occurrence and social vulnerability. Based on natural breaks in the data, a rating value of one through five was assigned with one being low, two being low-medium, three being medium, four being medium-high and five being high.

Table 3.37 shows the population, percent of population over 65 and social vulnerability index data for

Washington County overall.

Table 3.37. Population, Percent of Population Over 65 and SOVI Data for Washington County

County	Total Population Rating	Percentage of Population Over 65	Percent of Population Over 65 Rating	SOVI Ranking	SOVI Rating
Washington	3	14.7	2	Medium	3

Source: 2018 Missouri Hazard Mitigation Plan

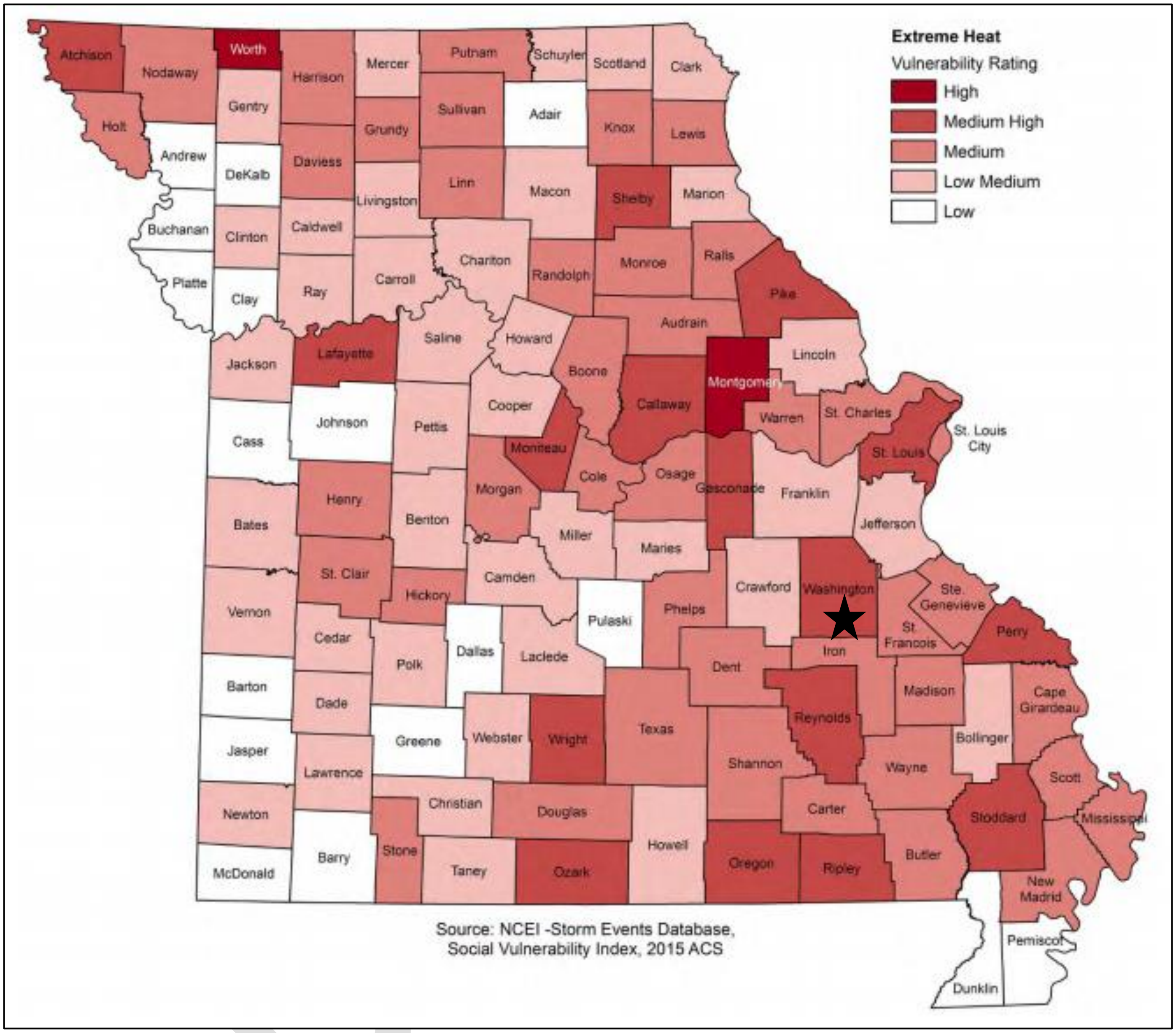
Table 3.38 illustrates the likelihood of occurrence and overall vulnerability rating for extreme temperatures for Washington County. **Figure 3.41** and **Figure 3.42** provide a vulnerability summary for extreme heat and extreme cold, respectively. Washington County has medium vulnerability for extreme heat and Medium-High vulnerability for extreme cold.

Table 3.38. Washington County Likelihood of Occurrence and Overall Vulnerability Rating for Extreme Temperatures

Heat					Cold				
Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description	Total Events	Likelihood of Occurrence	Likelihood Rating	Total Vulnerability	Total Vulnerability Description
50	2.38	4	12	Medium-High	2	0.10	1	9	Medium

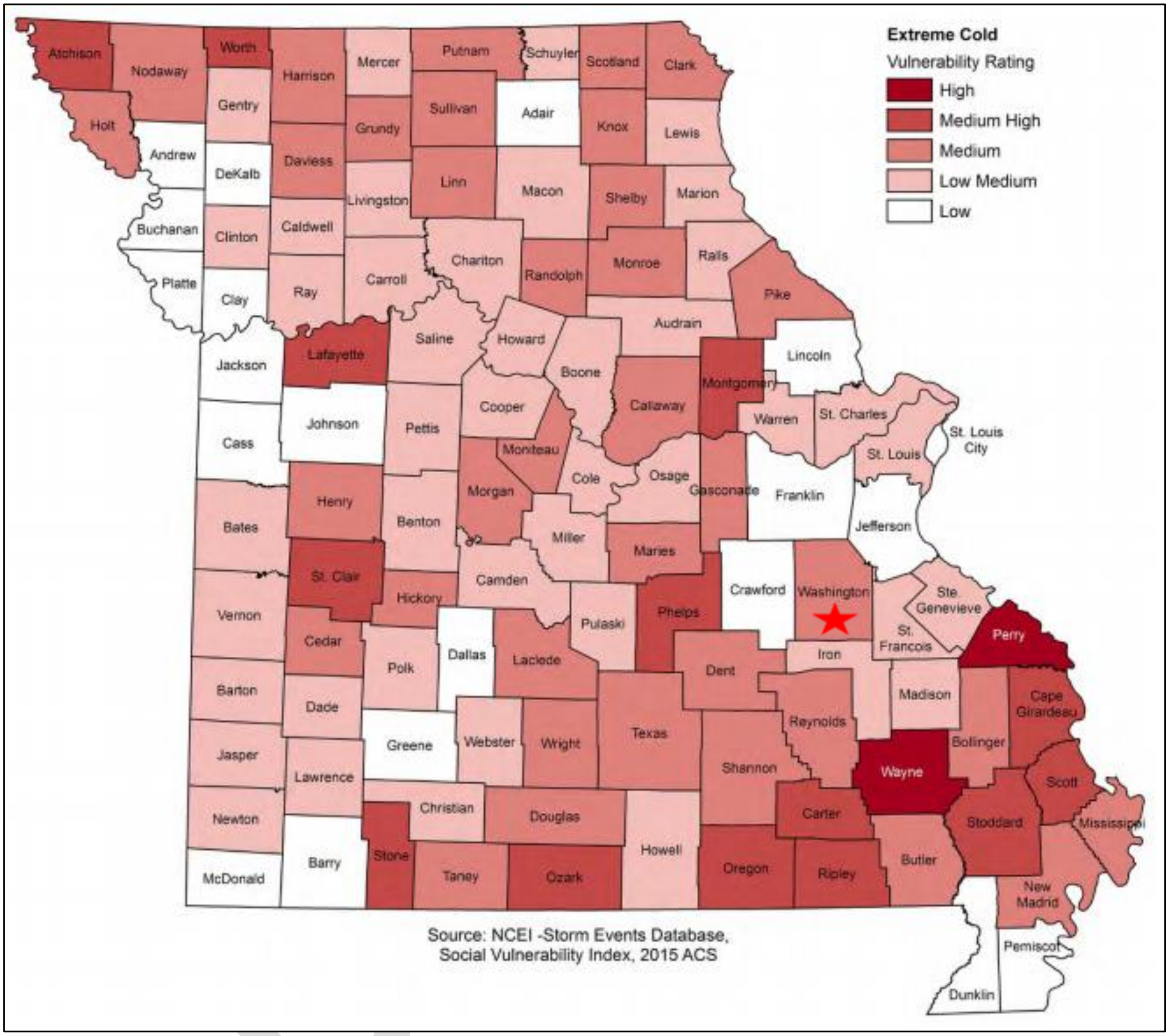
Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.41. Vulnerability Summary for Extreme Heat



*Source: 2018 Missouri Hazard Mitigation Plan, *Black star indicates Washington County*

Figure 3.42. Vulnerability Summary for Extreme Cold



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

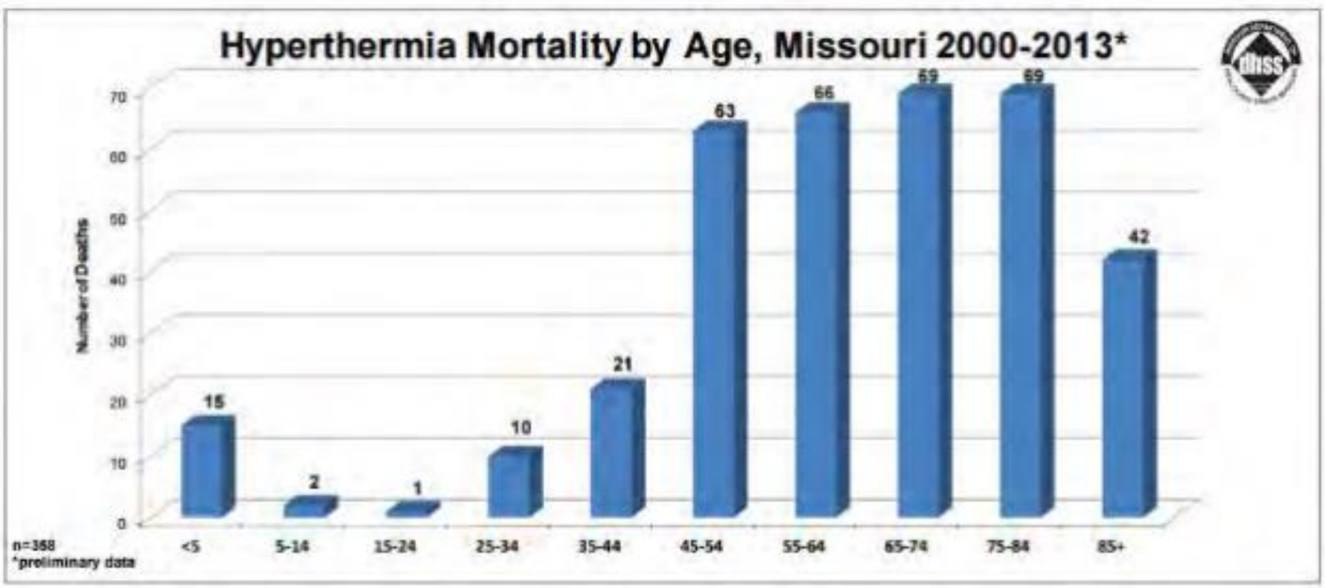
Potential Losses to Existing Development

Extreme Heat/Heat Wave

Of greatest concern during extreme heat events are hyperthermia injuries and deaths. The 2018 Missouri Hazard Mitigation plan states that there were 358 heat-related deaths reported in Missouri from 2000 through 2013. There were 217 (61%) deaths in the metropolitan areas of Kansas City and St. Louis and 141 (39%) deaths in rural parts of the state. Half of the deaths were age 65 or older. People in this demographic group are more vulnerable to this hazard for a number of reasons. Many live alone and have medical conditions that put them at higher risk. The lack of air conditioning or the refusal to use it for fear of higher utility bills further increases their risk. Deaths among children under the age of five are often linked to being left in vehicles during hot weather. Between 2000 and 2013 there were 15 (4%) heat-related deaths of children less than five years old. In the age group between

5 years and 65 years deaths are generally due to over exertion at work or in sports activities, complicating medical conditions or substance abuse. **Figure 3.43** shows the hyperthermia mortality rate by age for the 2000-2013 timeframe.

Figure 3.43. Hyperthermia Mortality of Age, Missouri 2000-2013



Source: Missouri DHSS, http://health.mo.gov/living/healthcondiseases/hyperthermia/pdf/hyper4.pdf

During extreme heat events structural, road, and electrical infrastructure are vulnerable to damages. Depending upon temperatures and duration of extreme heat, losses will vary.

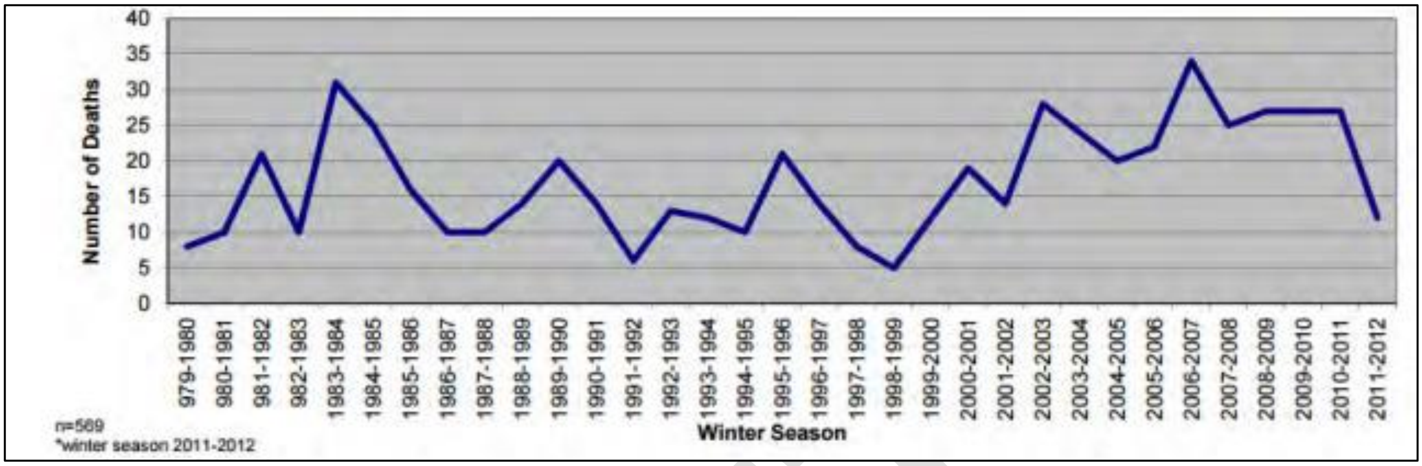
Extreme Cold

According to the Missouri Department of Health and Senior Services, 569 people died in Missouri due to extreme cold conditions between 1979 and 2012, see **Figure 3.44**. As with extreme heat, the elderly are more vulnerable to cold-related deaths. Elderly or disabled individuals fall outside their homes and are not able to call for help or reach the safety of shelter during periods of extreme cold. According to the 2018 Missouri State Hazard Mitigation plan, during the winters of 1989-2012, a total of 414 hypothermia deaths occurred, with 186 (44.9%) being 65 years of age or older. As with extreme heat, substance abuse can be a contributing factor for people between the ages of 25 and 64. Between 1989 and 2012, substance abuse factored into the hypothermia deaths of 107 of the 208 (51.4%) deaths in this age group. Fortunately, hypothermia deaths in people under the age of 25 are rare in Missouri, accounting for only 19 (4.6%) of the total extreme cold related deaths during this timeframe. There were two (0.5%) deaths of children under the age of five. Over 72 percent of hypothermia deaths are among males – 299 of the total 414. The remaining 115 (27.8%) were female.

In regards to urban versus rural, hypothermia deaths tend to be higher in rural areas than in urban communities. There were 183 (44.2%) cold related deaths in the Kansas City and St. Louis metropolitan areas, while 231 (55.8%) occurred in other parts of the state.

DRAFT

Figure 3.44. Hypothermia Deaths, Missouri: Winter Seasons 1979-2012



Source: Missouri DHSS, http://health.mo.gov/living/healthcondiseases/hypothermia/pdf/hypo1.pdf

Impact of Future Development

Population trends from 2010 to 2020 for Washington County indicate that the population in unincorporated areas has fallen by an estimated 2.17 percent. The city of Potosi's population has increased by a 2.26 percent. The city of Mineral Point has fallen by 34.19 percent. Overall, the county's population has shrunk 6.7 percent. Population growth can result in increased age groups that are more susceptible to extreme heat and cold. Additionally, as populations increase, so does the strain on each jurisdiction's electricity and road infrastructure. Local government and local emergency management should take extreme heat and cold in consideration when upgrades occur to the local power grid.

Hazard Summary by Jurisdiction

Those at greatest risk for heat-related illness and deaths include children up to five years of age, people 65 years of age and older, people who are overweight, and people who are ill or on certain medications or have medical conditions that make them more vulnerable. To determine jurisdictions within the planning area with populations more vulnerable to extreme heat, demographic data was obtained from the 2016-2020 census on population percentages in each jurisdiction comprised of those under age 5 and over age 65. Data was not available for overweight individuals and those on medications vulnerable to extreme heat or with medical conditions that made them more vulnerable. **Table 3.39** below summarizes vulnerable populations in the participating jurisdictions. Note that school and special districts are not included in the table because students and those working for the special districts are not customarily in these age groups.

Table 3.39. County Population Under Age 5 and Over Age 65 (2016-2020)

Jurisdiction	Population Under 5 Years	Population 65 Years and over
Unincorporated Washington County	5.4%	16.6%
Caledonia	3.7%	21.6%
Irondale	8.7%	6.4%
Mineral Point	6.8%	21.1%
Potosi	8.5%	18.1%

Source: U.S. Census Bureau, 2016-2020 American Community Survey 5-Year Estimates

Due to lack of data, strategic buildings that lack air-conditioning could not be analyzed for this report. Additionally, school policy data in regard to extreme heat or cold were not available.

In summary, the risks of extreme heat or cold can impact the health/lives of citizens within the county, specifically the young and elderly. The city of Caledonia has a high percentage of individuals 65 and over, with 21.6 percent.

Many people do not realize how deadly a heat wave can be. Extreme heat is a natural disaster that is not as dramatic as floods or tornadoes. Working with the Washington County Health Department and EMD, local governments should encourage residents to:

- Stay indoors as much as possible and limit exposure to the sun;
- Stay on the lowest floor out of the sunshine if air conditioning is not available;
- Consider spending the warmest part of the day in public buildings such as libraries or other public or community buildings. Circulating air can cool the body by increasing the evaporation rate of perspiration;
- Eat light, well-balanced meals at regular intervals and avoid using salt tablets unless directed by a physician;
- Hydrate by drinking plenty of water. Individuals with epilepsy or heart, kidney or liver disease who are on fluid restricted diets or have problems with fluid retention should consult their physicians on liquid intake;
- Limit consumption of alcoholic beverages;
- Dress in loose-fitting, lightweight and light colored clothes that dover as much skin as possible;
- Protect your face and head by wearing a wide-brimmed hat. Wear sunscreen;
- Check on family, friends and neighbors who do not have air conditioning and are generally alone;
- Never leave children or pets in closed vehicles;
- Avoid strenuous work during the warmest part of the day and use the buddy system when working in extreme heat and take frequent breaks.

People who work outdoors should be educated about the dangers and warning signs of heat disorders. Buildings, ranging from homes (particularly those of the elderly) to factories, should be equipped with properly installed, working air conditioning units, or have fans that can be used to generate adequate ventilation. However, although fans are less expensive to operate than air conditioning, they may not be effective, and may even be harmful when temperatures are very high. As the air temperature rises, air flow is increasingly ineffective in cooling the body. At temperatures above 100° F, the fan may be delivering overheated air to the skin at a rate that exceeds the capacity of the body to get rid of this heat – even with perspiring – and the net effect is to add heat rather than to cool the body. An air conditioner is a much better option. Charitable organizations and the health department should work together to provide fans, when appropriate, to at-risk residents during times of critical heat. When temperatures are too high, however, these groups should work to get at-risk populations into cooling shelters.

Extreme Cold

Extreme cold can also be life-threatening and the following precautions should be taken when someone is suffering from hypothermia:

- Call 9-1-1 for immediate medical assistance;
- Move the victim to a warm place;
- Monitor the victim's blood pressure and breathing;

DRAFT

- If necessary, provide rescue breathing and CPR;
- Remove wet clothing;
- Dry off the victim;
- Take the victim's temperature;
- Warm the body core first, NOT the extremities. Warming the extremities first can cause the victim to go into shock and can also drive cold blood toward the heart and lead to heart failure;
- Do not warm the victim too fast – rapid warming may cause heart arrhythmias

Problem Statement

In summary, the risks of extreme heat and cold can impact the health/lives of citizens within the county, specifically the young and elderly. Based on the vulnerability analysis, the city of Caledonia and the city of Potosi have the highest risk because both have large populations of people aged 65 and over (**Table 3.39**).

All jurisdictions should make sure they have plans in place to provide both cooling and warming shelters during times of extreme temperatures. School districts should have policies in place to minimize strenuous exercise outdoors during heat waves and to consider policies for delaying or cancelling school during times of extreme cold to reduce risk to students waiting for buses.

3.4.5 Flooding (Riverine and Flash)

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.1, Page 3.80 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Watershed map, Environmental Protection Agency, http://cfpub.epa.gov/surf/county.cfm?fips_code=19169
- FEMA Map Service Center, Digital Flood Insurance Rate Maps (DFIRM) for all jurisdictions, if available, https://msc.fema.gov/portal/home
- NFIP Community Status Book, http://www.fema.gov/national-flood-insurance-program/national-flood-insurance-program-community-status-book
- NFIP claims status, BureauNet, http://bsa.nfipstat.fema.gov/reports/reports.html
- Flood Insurance Administration—Repetitive Loss List (this must be requested from the State Floodplain Management agency or FEMA)
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/en/Information-Tools/Summary-of-Business/Cause-of-Loss
- FEMA Data Visualization Tool, https://www.fema.gov/data-visualization-floods-data-visualization
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Risk MAP, DFIRM, and Hazus based depth grids used in Hazus Analysis
  - Flood losses by County 1978-2018
  - Number of flood insurance claims by County
  - Total building exposure to flooding (1% annual chance) by County
  - Buildings impacted by flooding (1% annual chance) by County
  - Flood insurance coverage by County
  - Number of flood insurance policies by County
  - NFIP participation status by County
  - Number of state facilities impacted by flooding (1% annual chance) by County
  - Critical facilities impacted by flooding (1% annual chance) by County

DRAFT

Hazard Profile

Hazard Description

A flood is partial or complete inundation of normally dry land areas. Riverine flooding is defined as the overflow of rivers, streams, drains, and lakes due to excessive rainfall, rapid snowmelt, or ice. There are several types of riverine floods, including headwater, backwater, interior drainage, and flash flooding. The areas adjacent to rivers and stream banks that carry excess floodwater during rapid runoff are called floodplains. A floodplain is defined as the lowland and relatively flat area adjoining a river or stream. The terms "base flood" and "100- year flood" refer to the area in the floodplain that is subject to a one percent or greater chance of flooding in any given year. Floodplains are part of a larger entity called a basin, which is defined as all the land drained by a river and its branches.

Flooding caused by dam failure is discussed in **Section 3.4.1.** It will not be addressed in this section.

A flash flood occurs when water levels rise at an extremely fast rate as a result of intense rainfall over a brief period, sometimes combined with rapid snowmelt, ice jam release, frozen ground, saturated soil, or impermeable surfaces. Flash flooding can happen in Special Flood Hazard Areas (SFHAs) as delineated by the National Flood Insurance Program (NFIP) and can also happen in areas not associated with floodplains.

Ice jam flooding is a form of flash flooding that occurs when ice breaks up in moving waterways, and then stacks on itself where channels narrow. This creates a natural dam, often causing flooding within minutes of the dam formation.

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

Most flash flooding is caused by slow-moving thunderstorms or thunderstorms repeatedly moving over the same area. Flash flooding is a dangerous form of flooding which can reach full peak in only a few minutes. Rapid onset allows little or no time for protective measures. Flash flood waters move at very fast speeds and can move boulders, tear out trees, scour channels, destroy buildings, and obliterate bridges. Flash flooding can result in higher loss of life, both human and animal, than slower developing river and stream flooding.

In certain areas, aging storm sewer systems are not designed to carry the capacity currently needed to handle the increased storm runoff. Typically, the result is water backing into basements, which damages mechanical systems and can create serious public health and safety concerns. This combined with rainfall trends and rainfall extremes all demonstrate the high probability, yet generally unpredictable nature of flash flooding in the planning area.

Although flash floods are somewhat unpredictable, there are factors that can point to the likelihood of flash floods occurring. Weather surveillance radar is being used to improve monitoring capabilities of intense rainfall. This, along with knowledge of the watershed characteristics, modeling techniques, monitoring, and advanced warning systems has increased the warning time for flash floods.

Geographic Location

Riverine flooding is most likely to occur in Special Flood Hazard Areas (SFHA). Below in **Figure 3.45** is a map of Washington County showing the floodplain boundaries. Following the county-wide map are FIRMs for Caledonia, Irondale, Mineral Point, and Potosi (**Figure 3.46 through Figure 3.49**). **Figure 3.50** shows a map of the school districts in Washington County with an overlay of the SFHA. There are no school districts within the county that have school building located in the floodplain. **Table 3.40** shows Washington County NCEI flood events by location between 2001 and 2020.

DRAFT

Figure 3.45. Map of Washington County with Special Flood Hazard Areas.

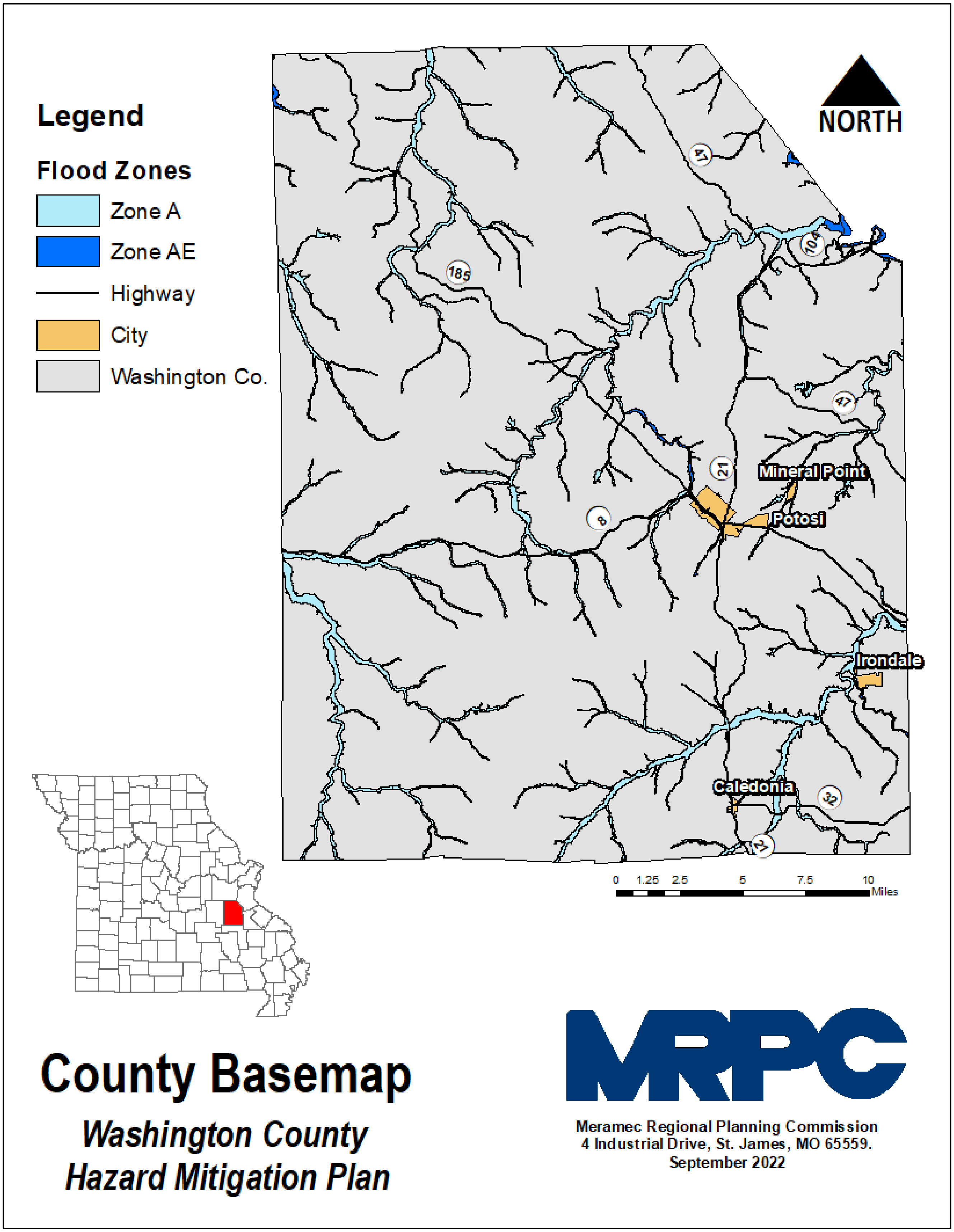


Figure 3.46. Caledonia, Missouri Special Flood Hazard Areas (SFHAs)

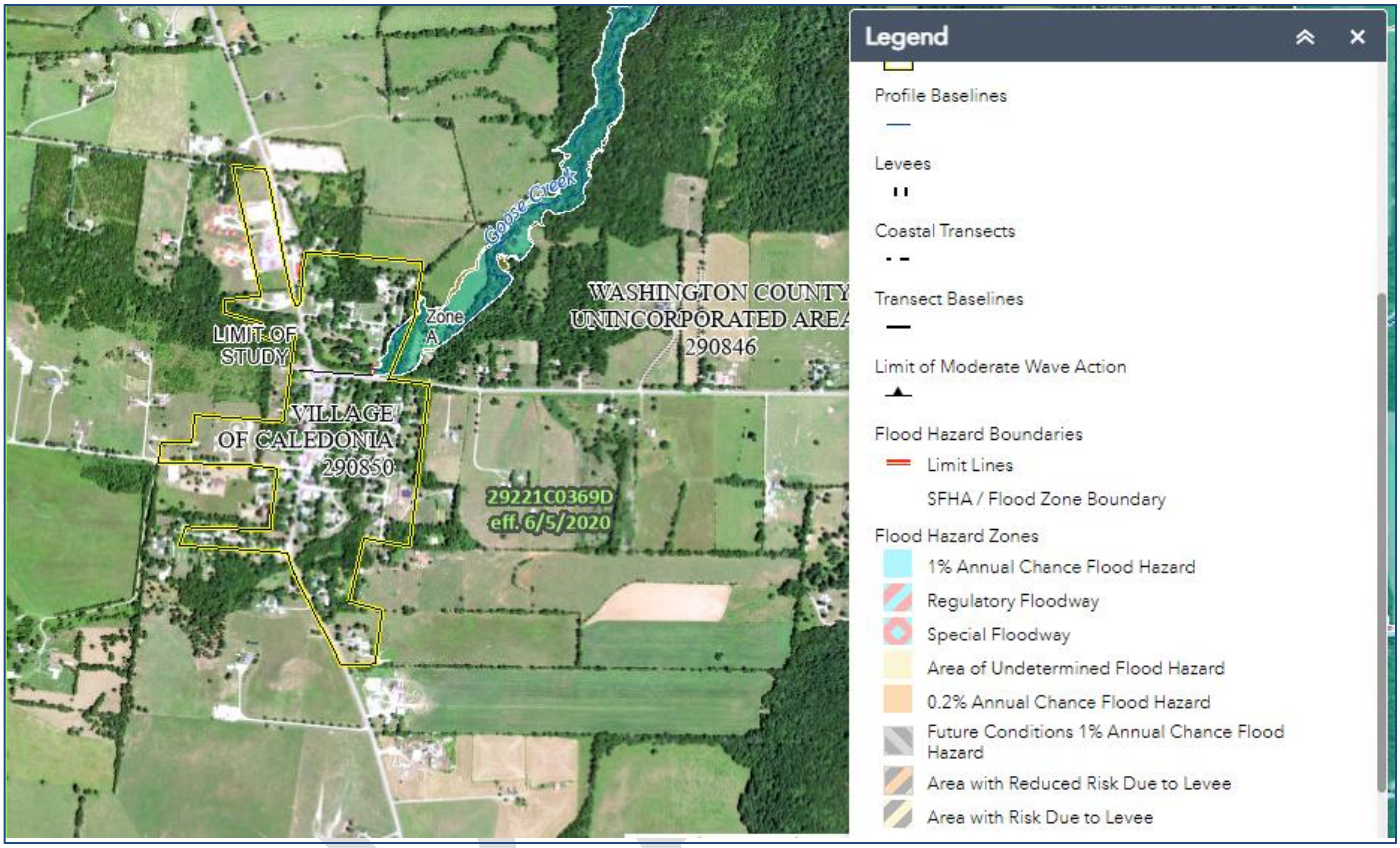


Figure 3.47. Irondale, Missouri Special Flood Hazard Areas (SFHAs)

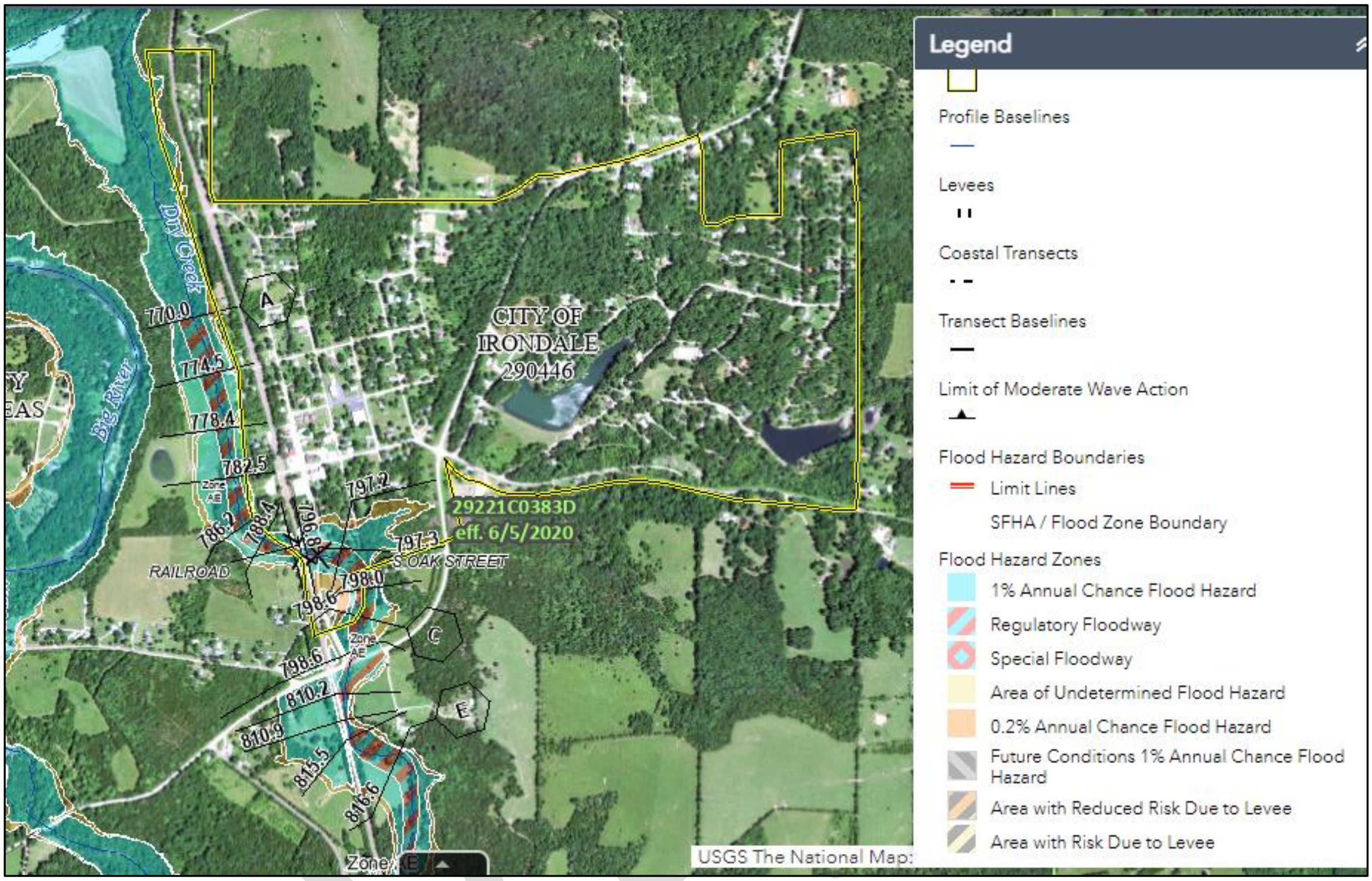


Figure 3.48. Mineral Point, Missouri Special Flood Hazard Areas (SFHAs)

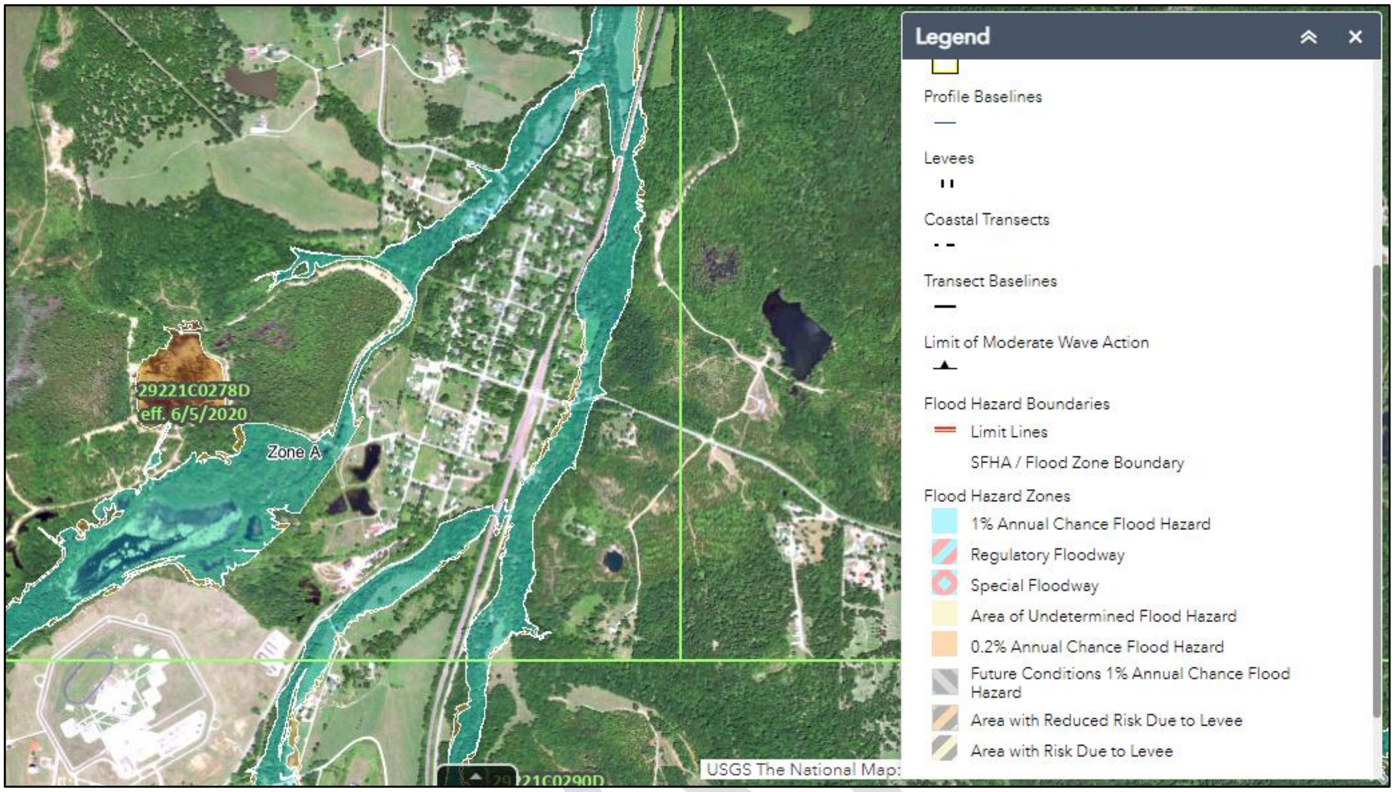


Figure 3.49. Potosi, Missouri Special Flood Hazard Areas (SFHAs)

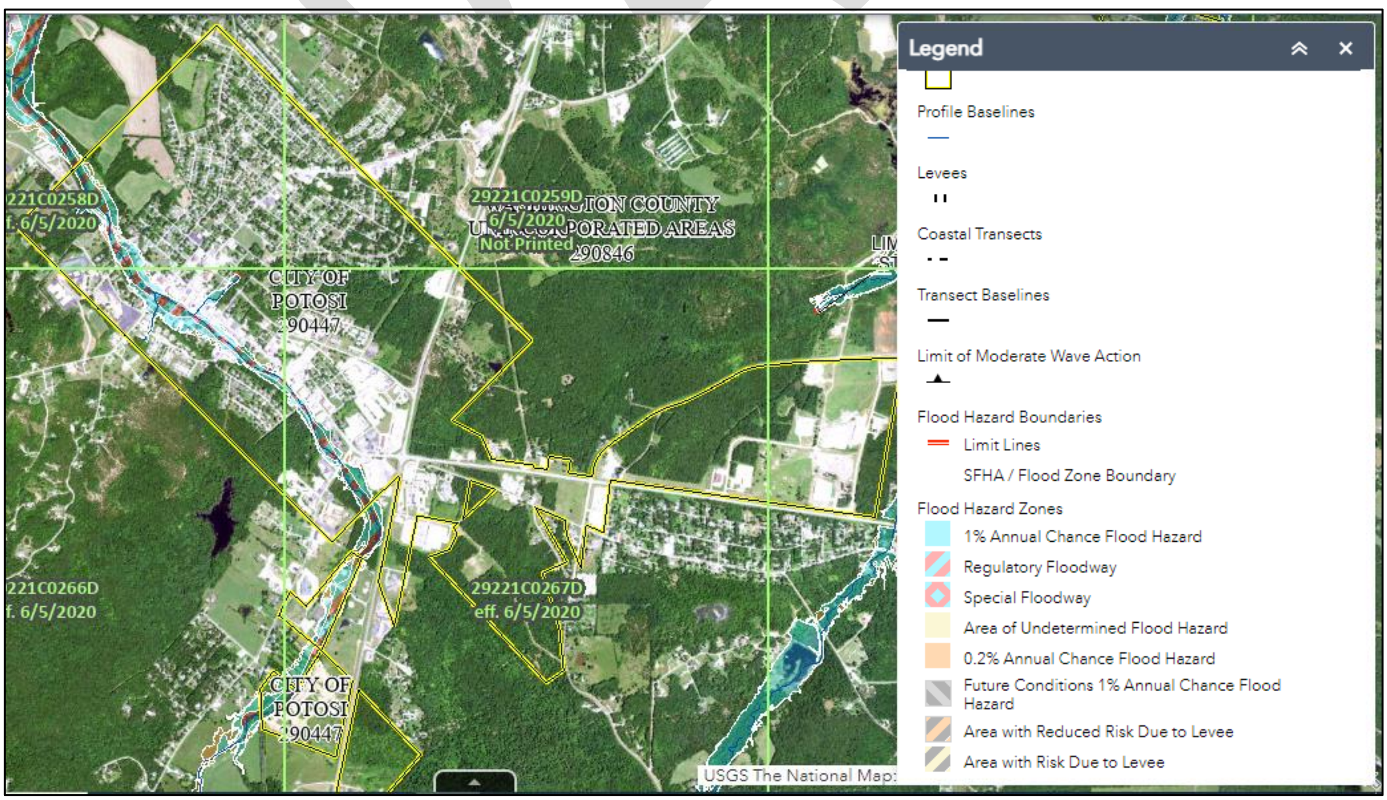


Figure 3.50. Washington County School Districts and Special Flood Hazard Areas (SFHAs)

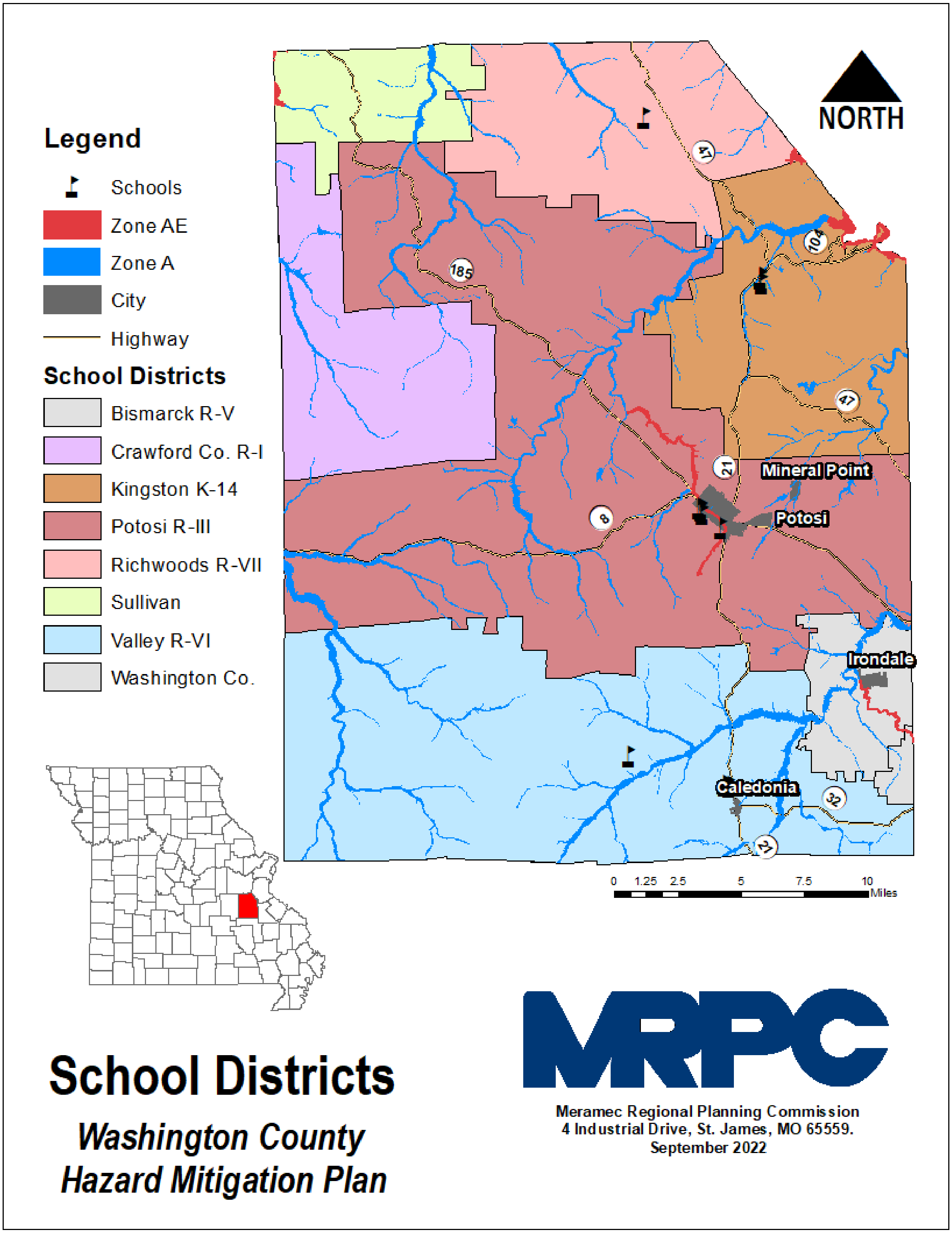


Table 3.40. Summary of Washington County NCEI Flood Events by Location, 2001-2020

Location	# of Events
Potosi	1
Pea Ridge	1

Source: National Centers for Environmental Information Storm Events Database

Flash flooding occurs in SFHAs and locations in the planning area that are low-lying. They also occur in areas without adequate drainage to carry away the amount of water that falls during intense rainfall events. **Table 3.41** provides information in regards to flash flood events between 2001 and 2020.

Table 3.41. Washington County NCEI Flash Flood Events by Location, 2001-2020

Location	# of Events
Washington County - Countywide	3
Springtown	1
Pea Ridge	1
Maryden	2
Baryties	1
Potosi	2
Aptus	1
Trout	2
Richwoods	1
Hopewell	1
Courtois	2
Cruise	1

Source: National Centers for Environmental Information

Severity/Magnitude/Extent

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

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

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

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

DRAFT

bridges can be found in **Section 3.2.2**.

Between 2001 and 2020, there were no recorded flood-related crop insurance claims due to flooding within Washington County[29].

National Flood Insurance Program (NFIP) Participation

Table 3.42 depicts jurisdictions within the planning area that participate in NFIP. In addition, **Table 3.43** provides the number of policies in force, amount of insurance in force, number of closed losses, and total payments for Washington County.

Table 3.42. NFIP Participation in Washington County

Community ID #	Community Name	NFIP Participant (Y/N)	Current Effective Map Date	Regular-Emergency Program Entry Date
290850	Caledonia	Y	06/05/20 (M)	04/15/16
290446	Irondale	Y	06/05/20	07/15/03
290571	Mineral Point	Y	06/05/20 (M)	03/15/93
290447	Potosi	Y	06/05/20 (M)	09/04/85
290646	Washington County	Y	06/05/20 (M)	05/24/10

Source: NFIP Community Status Book, 10/06/2021; BureauNet, https://www.fema.gov/flood-insurance/work-with-nfip/community-status-book; M= No elevation determined – all Zone A, C, and X: NSFHA = No Special Flood Hazard Area; E=Emergency Program;

Table 3.43. NFIP Policy and Claim Statistics as of 06/23/2022

Community Name	Policies in Force	Insurance in Force	Closed Losses	Total Payments
Washington County	15	$2,695,000	1	$0.00
Mineral Point	0	0	3	$15,338.16
Potosi	8	$1,026,000	12	$86,672.46

Source: NFIP Community Status Book, [08/12/2020]; SEMA
**Closed Losses are those flood insurance claims that resulted in payment.*

Washington County has the highest number of policies in the planning area however, Potosi has the highest number of losses and total payments with $86,672.46 compared to the county's 1 loss with no payment.

RiskMAP

Risk mapping, assessment, and planning is a FEMA program which provides communities with flood information and tools to enhance their mitigation plan and take action to better protect their citizens. The project kick-off meeting for RiskMAP in Washington County was held in November of 2016 and

29 http://www.rma.usda.gov/data/cause.html

flood study review meeting was held in September of 2017.

Repetitive Loss/Severe Repetitive Loss Properties

Repetitive Loss Properties (RL) are those properties with at least two flood insurance payments of $1,000 or more in a 10-year period.

According to SEMA, as of 09/24/2021, there are 2 repetitive loss properties in Washington County that have had 4 losses with total payments of $51,420.52. The city of Mineral Point has one repetitive loss property which has had two losses with total payments of $15,338.16. The city of Potosi has one repetitive loss properties which have had two losses with total payments of $36,082.36. According to SEMA, no repetitive loss properties in the planning area have been mitigated.

Table 3.44. Repetitive Loss Properties in Washington County*

Jurisdiction	# of Properties	# Mitigated	Building Payments	Content Payments	Total Payments	# of Losses
Mineral Point	1	0	$11,014.82	$4,323.34	$15,338.16	2
Potosi	1	0	$31,082.36	$5,000.00	$36,082.36	2

** Due to Federal restrictions on data sharing, the state was unable to provide full Repetitive Loss data or current Severe Repetitive Loss data.*

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

There are no Severe Repetitive Loss properties in Washington County.

Previous Occurrences

Table 3.45 provides information regarding Presidential Flooding Disaster Declarations between 2001 and 2020 for Washington County.

Table 3.45. Washington County Presidential Flooding Disaster Declarations 2001 to 2020

Declaration No.	Date	State	Incident Description
DR-1463	05/06/2003	Missouri	Severe Storms, Tornadoes, and Flooding
DR-1631	03/16/2006	Missouri	Severe Storms, Tornadoes, and Flooding
DR-1749	03/19/2008	Missouri	Severe Storms, and Flooding
DR-1847	06/19/2009	Missouri	Severe Storms, Tornadoes, and Flooding
DR-1980	5/9/2011	Missouri	Severe Storms, Tornadoes, Flooding
DR-4238	08/07/2015	Missouri	Severe Storms, Tornadoes, Straight-line Winds, and Flooding
EM-3374	01/02/2016	Missouri	Severe Storms, Tornadoes, Straight-Line Winds, and Flooding
DR-4250	01/21/2016	Missouri	Heavy Rains, Widespread Flash Flooding, and Flooding

DRAFT

DR-4317	05/24/17	Missouri	Severe Storms, Tornadoes, Straight-line Winds and Flooding

Source: FEMA, Disaster Declarations for Missouri, Flooding

Data was obtained from the NCEI regarding flash and river flooding over the last 20 years. **Table 3.46** and **Table 3.47** provide this information. Additionally, narratives available for each event are included.

Table 3.46. NCEI Washington County Riverine Flood Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2007	1	0	0	0	0
2015	1	0	0	0	0

Source: NCEI, data accessed [10/06/2021]

Narratives on flood events:

1. **01/13/2007:** Several inches of rain caused flooding of small creeks and streams and low-water crossings mainly across southern Washington County.

2. **06/16/2015:** The Missouri Highway Patrol reported a vehicle attempted to cross a flooded low water crossing. The vehicle was swept into the stream and overturned. The drive was killed.

Table 3.47. NCEI Washington County Flash Flood Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages ($)	Crop Damages ($)
2002	1	0	0	0	0
2005	1	0	0	0	0
2006	1	0	0	0	0
2008	2	0	0	0	0
2009	1	0	0	0	0
2011	3	0	0	0	0
2013	2	0	0	0	0
2014	1	0	0	0	0
2015	3	0	0	0	0
2016	2	0	4	0	0
2017	1	0	0	0	0
Total	**18**	**0**	**4**	**0**	**0**

Source: NCEI, data accessed [10/06/2021]

Narratives on flash flood events:

1. **05/12/2002:** Some of the worst flash flooding in recent years hit on Sunday, Mother's Day, and continued into early Monday. Around 6 inches of rain fell on ground already saturated by previous rain. For several counties, it was the worst flooding in memory. Iron County was especially hard hit. Virtually every creek and small stream flooded closing roads throughout the county. There were numerous water rescues as people were trapped in their cars. Emergency shelters in the County were opened to help stranded motorists and people who

DRAFT

were flooded out of homes. The story was similar in Reynolds County as Highways 49 and 21 had to be closed. In Fredericktown, in Madison County, many city streets flooded. Several people were stranded in flooded vehicles and could not be reached for an hour or so. Numerous roads were flooded across Crawford, St. Francois, Ste. Genevieve and Washington Counties as well. The only death that occurred happened in Iron County near Ironton. A 43 year old man was trying to cross Stouts Creek on foot to get to his home to rescue his dogs. He was knocked down, but managed to grab hold of a tree. He was swept away and drowned by the rising water before rescue workers could reach him.

2. **04/21/2005:** Heavy rain from several thunderstorms caused flash flooding in Washington County, mainly in the central part of the county. Some areas around Potosi reported up to 7 inches of rain. Flooding was reported on Highway F 10 miles north of Potosi. Breton Creek in Potosi flooded, closing all the road crossings over the creek. There were reports of some basements flooded, otherwise there was no major damage.

3. **03/12/2006:** Several rounds of thunderstorms moved through the area dumping between 3 and 5 inches of rain in a short amount of time. Numerous county roads were closed. State Highway E was closed near Potosi. Also, Britton Creek in Potosi was out of its banks causing flooding of several streets in town.

4. **02/05/2008:** Two to four inches of rain fell over portions of Washington county causing flash flooding. Old Mines Creek rose quickly and flooded a portion of Highway 21 for a brief time. Also, numerous low water crossings, ditches and creeks in the Potosi area were out of their banks for a time.

5. **03/18/2008:** Two to three inches of rain fell onto already saturated soils in Washington county from the evening hours of March 17th through March 18th. Numerous roads and low water crossings were flooded including streets in Potosi, Highway 47 at Kingston Road northwest of Cruise Mill, and New Diggins Road in Springtown.

6. **05/08/2009:** Up to three inches of rain fell in a short amount of time causing flash flooding. Numerous roads were flooded for a time including Mill and Jefferson streets in Potosi and New Diggins Road southeast of Potosi. Also, the Big River overtopped its banks and flooded portions of Highway M northeast of Caledonia.

7. **04/24/2011:** Between 4 and 6 inches of rain fell over several days causing flash flooding. Numerous roads were flooded including Route E.

8. **06/26/2011:** Up to two inches of rain fell in a short amount of time causing flash flooding. Several roads were flooded including Highway E between Blackwell and Cadet.

9. **07/13/2011:** Up to two inches of rain fell in a short amount of time causing flash flooding. Several roads were flooded including Highway F north northwest of Potosi.

10. **05/31/2013:** Up to five inches of rain fell in a short amount of time causing flash flooding. Highway 135 was flooded in several spots southeast of the intersection with Highway T for about a four mile stretch.

11. **06/01/2013**: Up to five inches of rain fell in a short amount of time causing flash flooding. Highway 135 was flooded in several spots southeast of the intersection with Highway T for about a four mile stretch.

DRAFT

12. **04/03/2014:** Up to five inches of rain fell in a short amount of time causing flash flooding. Several roads were flooded including Highway 185 between Pea Ridge and Caseyville.

13. **04/07/2015**: Up to three inches of rain fell in a short amount of time causing flash flooding. Several roads were flooded including Route U near intersection with John Smith Road.

14. **04/08/2015:** Up to three inches of rain fell in a short amount of time causing flash flooding in Potosi. Mine A Breton Creek overflowed its banks in town onto Jefferson Street. Several water rescues had to be made in this area.

15. **08/10/2015:** Up to five inches of rain fell in a short amount of time causing flash flooding. Numerous roads were flooded. Highway C, three miles east northeast of Courtois, was closed both ways due to Cub Creek well out of its banks.

16. **05/11/2016**: Up to four inches of rain in a short amount of time caused flash flooding across the northern portions of Washington County. Several water rescues had to be performed around the Richwoods area. Numerous roads were closed due to flooding including Highway 47 near Richwoods. Four people were treated for minor injuries.

17. **08/15/2016:** Up to 6 inches of rain fell over already saturated soil causing flash flooding. Numerous roads were flooded across the southeastern and eastern portions of Washington County. Holiday Shores Road was flooded and a water rescue had to be performed in this area. Also, Mounts Road (County Road 511) bridge over the Big River was under about 4 feet of water. The intersection of Highways 21 and 32 in Caledonia was flooded.

18. **04/29/2017:** Between 5 and 7 inches of rain fell causing widespread flash flooding. Numerous roads were flooded including Route CC between Highway 21 and Route E.

Probability of Future Occurrence

From the data obtained from the NCEI[30], there were 2 riverine flood events (**Table 3.46)** over a period of 20 years. This information was utilized to determine the annual average percent probability of riverine flooding (**Table 3.48**). The probability of riverine flooding in Washington County per year is 10% percent (2 events/20 years x 100). Furthermore, data was obtained for flash flooding within the county. Washington County endured 18 flash flooding events (**Table 3.47**) over a 20 year period. The probability of flash flooding in Washington County per year is 90% (18 events/20 years x 100) (**Table 3.49**).

Table 3.48. Annual Average % Probability of Riverine Flooding in Washington County

Location	Annual Avg. % P
Washington County	10%

*P = probability; see page 3.24 for definition.

Table 3.49. Annual Average % Probability of Flash Flooding in Washington County

Location	Annual Avg. % P

[30] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

Washington County	90%

*P = probability; see page 3.24 for definition.

Vulnerability

Vulnerability Overview

For the vulnerability analysis of flooding for Washington County, data was obtained from the 2018 Missouri State Hazard Mitigation Plan. The 2018 Plan used the most recent release of Hazus, version 4.0, to model flood vulnerability and estimate flood losses due to the depth of flooding. Additional hazard data inputs were utilized, as available, to perform Hazus Level 2 analyses. This included the extensive use of the FEMA special flood hazard area data and RiskMAP flood risk datasets.

For the Hazus analysis, the flood hazard area and depth of flooding was determined for each county using one of three methods – depending on the data available for that county. Washington County does have digital FIRMS, the regulatory special flood hazard area was utilized. Next, depth grids were generated using cross sections from the FIRM database and/or hydraulic models in combination with the terrain elevation data from which the DFIRM was derived.

This method was preferred of the three methods, along with RiskMAP flood risk datasets.

In addition to the DFIRM, SEMA analyzed National Flood Insurance Program (NFIP) flood-loss data to determine areas of Missouri with the greatest flood risk. Missouri flood-loss information was obtained from BureauNet which documents losses from 1978 to the present (November 30, 2017, for the State Plan). With this flood-loss data there are limitations noted, including:

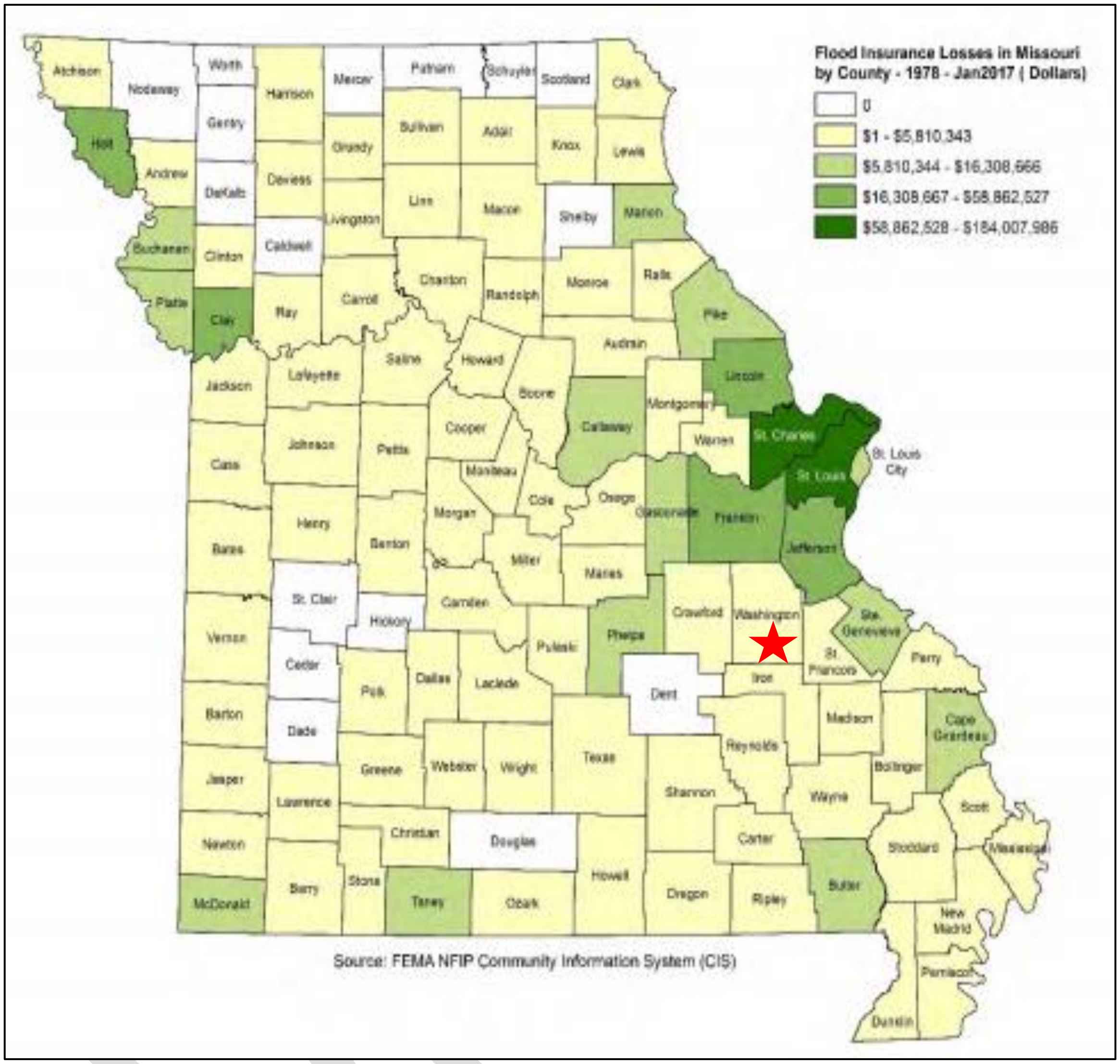
- Only losses to participating NFIP communities are represented
- Communities joined the NFIP at various times since 1978
- The number of flood insurance policies in effect may not include all structures at risk to flooding
- Some of the historic loss areas have been mitigated with property buyouts

Figure 3.51 depicts the amount of flood insurance losses in Missouri by county for the period 1978-January 2017. Washington County falls in the $1 - $5,810,343 range of payments.

Figure 3.51. Map of Funds Paid Historically for Flood Insurance Losses in Missouri by

DRAFT

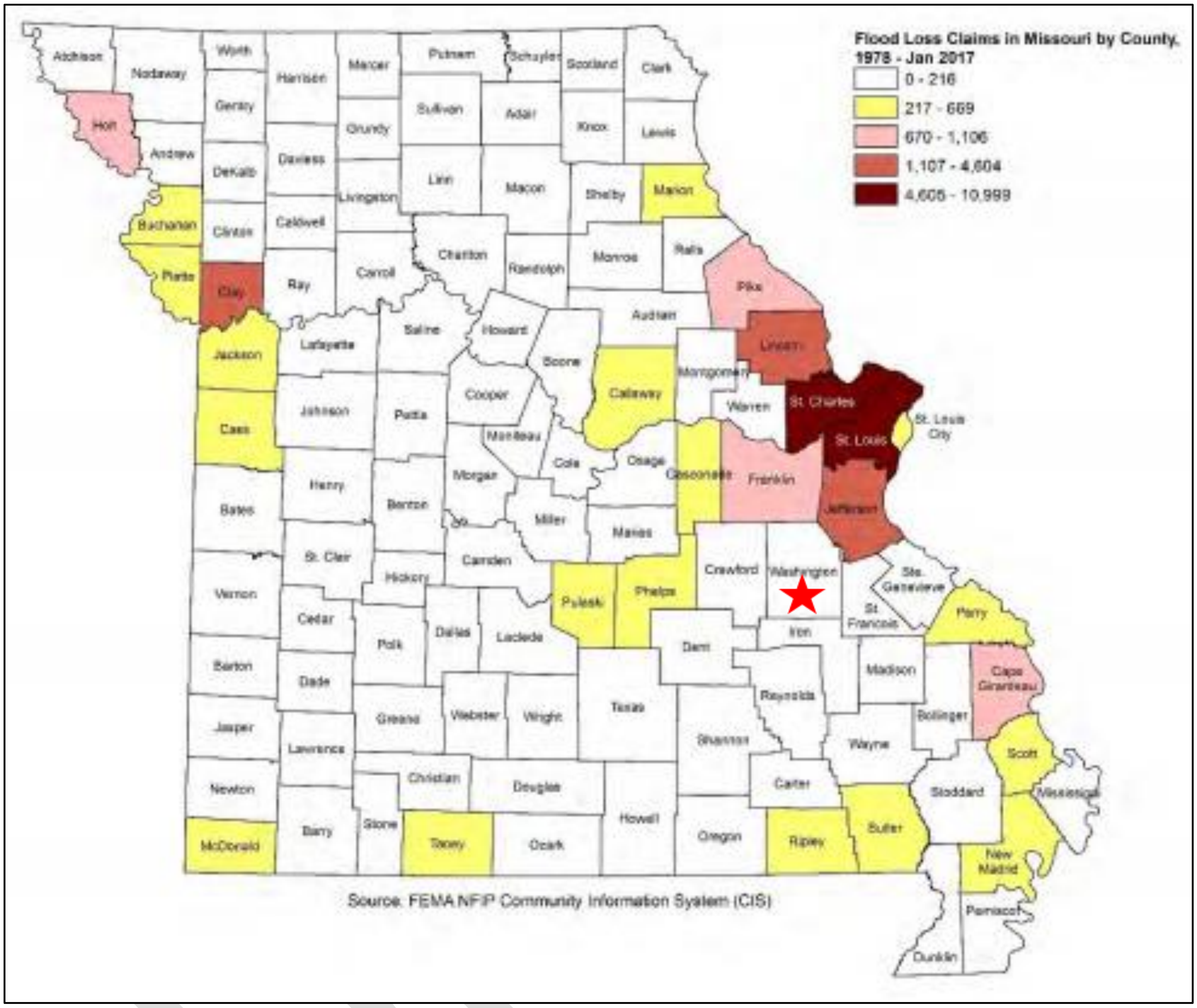
County 1978 - January 2017



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.52 illustrates the number of flood loss claims made in Missouri during the same time period. Washington County had 0 - 216 claims during that timeframe.

Figure 3.52. Flood Loss Claims in Missouri by County, 1978 – January 2017



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Furthermore, the state analyzed potential loss estimates to flooding. The purpose of the analysis is to determine where flood losses can occur and the degree of severity using consistent methodology. These results were generated from DFIRM data and Hazus floodplain data. **Table 3.50** provides information regarding total direct building loss and income loss to Washington County. **Table 3.51** provides information on exposure of buildings. According to the Missouri Spatial Data Information Service (MSDIS) there are 117 residential structures at risk of flood. Hazus shows the number of building exposed to flood damage at 12, with 4 potentially substantially damaged in a one percent annual chance of a flood. This same analysis indicates that 431 people would be displaced in Washington County and 58 would need to be sheltered in the event of a major flood.

Table 3.50. Total Direct Building Loss and Income Loss to Washington County

County-wide Building Loss	Structural Damage	Contents Loss	Inventory Loss	Total Direct Loss	Total Income Loss	Total Direct and Income Loss	Calc. Loss Ratio
$1,730,986,000	$8,962,000	$5,033,000	$122,000	$14,117,000	$10,000	$14,127,000	0.52

Source: 2018 Missouri State Hazard Mitigation Plan

Table 3.51. Washington County Structures Exposure

# MSDIS Residential Structures Exposed	# Hazus Buildings Exposed	# Substantially Damaged
117	12	4

Source: 2018 Missouri State Hazard Mitigation Plan

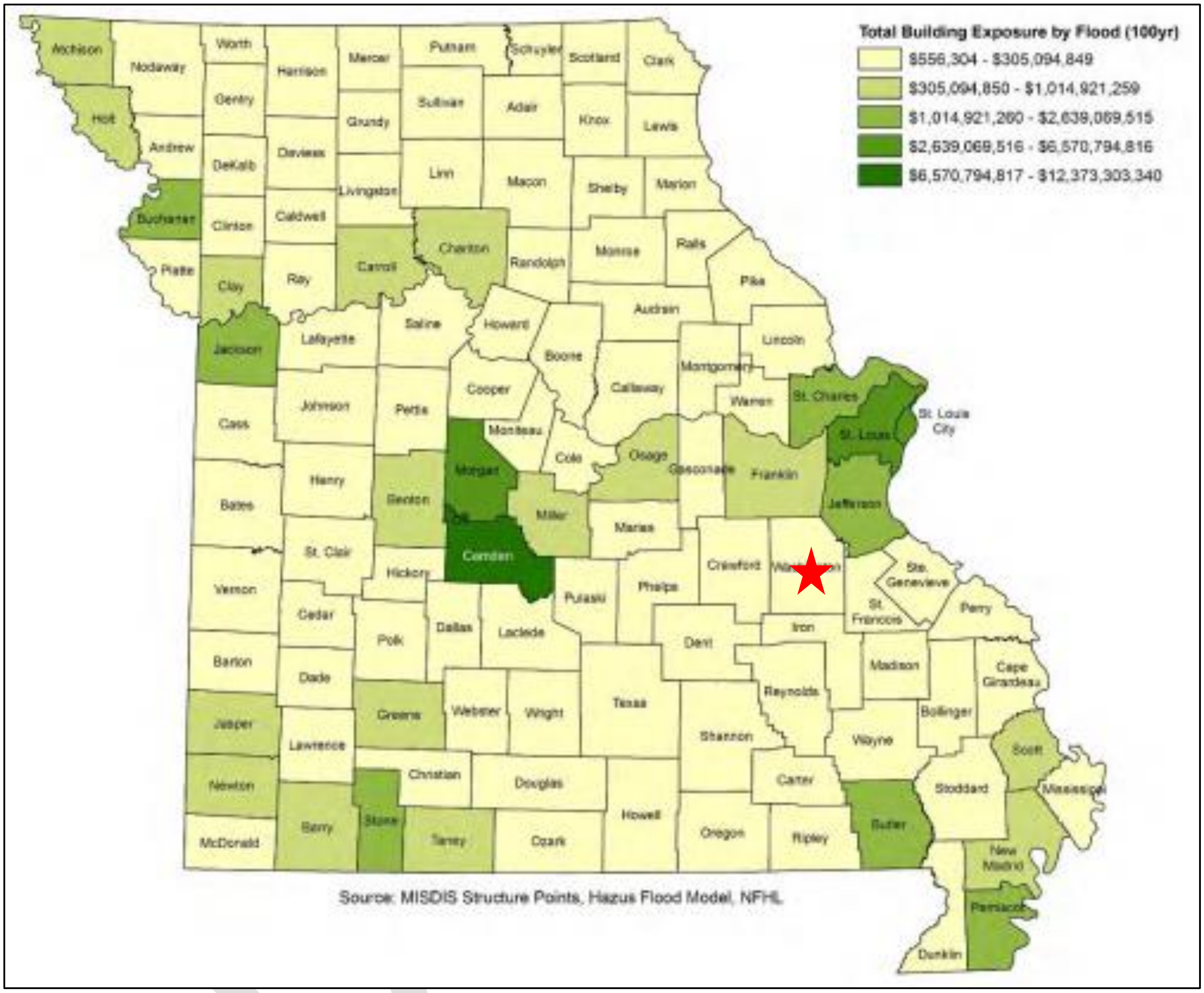
Table 3.52 presents the results of the primary indicators for Washington County – residential, agricultural, commercial, education, government and industrial. This table illustrates the number of affected structures and estimated losses. **Figure 3.53** shows the building exposure for the Hazus Base-Flood Scenario. **Figure 3.54** illustrates the building impacted ratio for a 100-year flood.

Table 3.52. Washington County Total Building Loss and Income Loss

# Residential Structures	Total $$ of Loss	# Agriculture Structures	Total $$ of Loss	# Commercial Structures	Total $$ of Loss	# of Education Structures	Total $$ of Loss	# of Government Structures	Total $$ of Loss	# of Industrial Structures	Total $$ of Loss	Total # Population Affected	Total Loss – Hazus Layer
117	$18,879,941	221	$118,756	30	$6,536,319	0	$0	4	$1,044,178	4	$1,386,173	312	$27,965,367

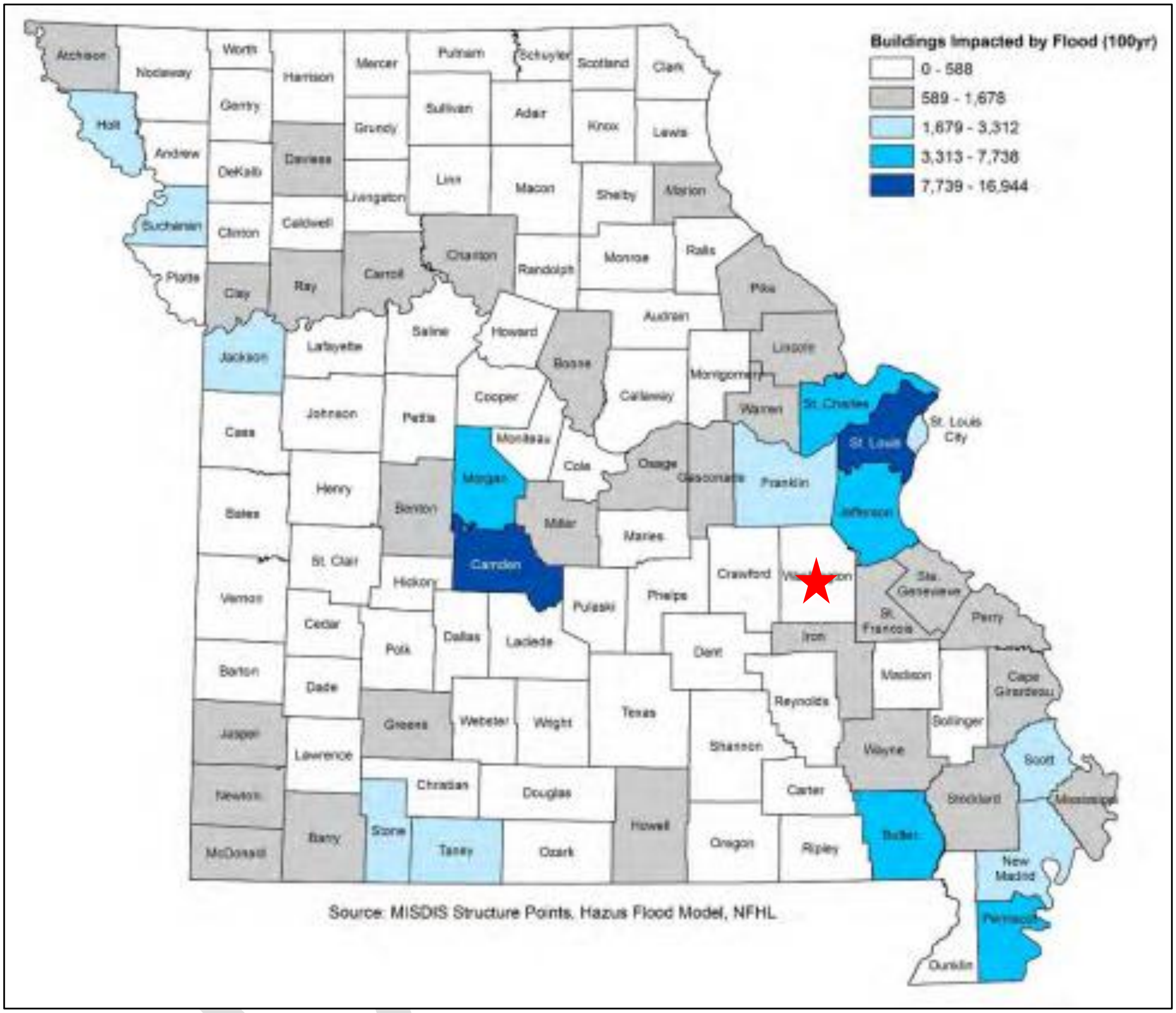
Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.53. Hazus Countywide Base-Flood Scenarios: Building Exposure



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.54. Hazus Countywide Base-Flood Scenarios: Building Impacted Ratio



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

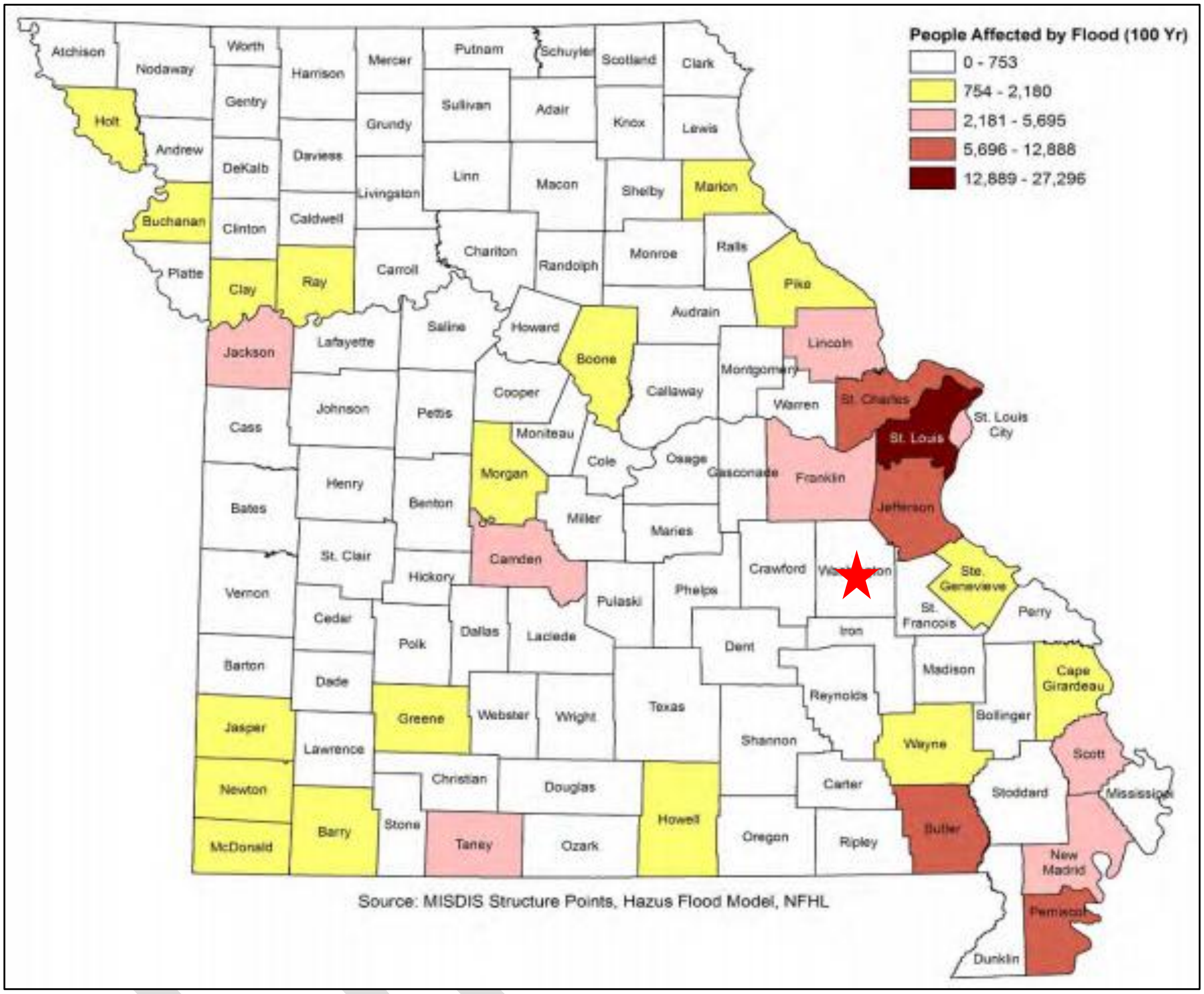
Lastly, the State determined the estimated number of displaced households and need for shelters within Washington County in the event of a 100-year flood. **Table 3.53** and **Figure 3.55** illustrate this information.

Table 3.53. Estimated Displaced People and Shelter Needs for Washington County

County	Displaced People	Displaced Population Requiring Shelter
Washington	431	58

Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.55. Hazus Countywide Base-Flood Scenarios: Displaced People



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Potential Losses to Existing Development

Every jurisdiction in the county contains a portion of the 100 Year Floodplain. According to the HAZUS model, Washington County has a building loss ratio of 0.52 percent for countywide base-flood scenarios. However, the unprecedented flooding in 2013 suggests that future flood events could cause significant disruption in the county. The August 2013 flash flood caused significant damages to property ($1,000,000). The statewide average building loss ratio is 1.40 which makes Washington County's ratio in the low range. Additionally, the county has 2 repetitive loss properties, Potosi has 1 repetitive loss property, and Mineral Point has one repetitive loss property. With the annual average probability for flooding at 10 percent and 90 percent for flash floods, Washington County's existing development is vulnerable to flood. Especially development located in low-lying areas, near rivers or streams, or where drainage systems are not adequate are prone to flooding.

Impact of Future Development

Impact of future development is correlated to floodplain management and regulations set forth by the county and jurisdictions. Future development within low-lying areas near rivers and streams, or where interior drainage systems are not adequate to provide drainage during heavy rainfall events should be avoided. Additionally, future development would also increase impervious surface causing additional water run-off and drainage problems during heavy rainfall events.

Hazard Summary by Jurisdiction

Vulnerability to flooding slightly varies across the planning area. The jurisdictions most vulnerable to flooding include Unincorporated Washington County and Potosi. Other jurisdictions within the planning area are not as vulnerable; however, some do have a few properties within the floodplain.

Problem Statement

The county has adopted a Floodplain Management Ordinance that regulates construction in the floodplain. Local governments should make a strong effort to further improve emergency warning systems to ensure that future deaths and injuries do not occur. Local governments should consider making improvements to roads and low water crossings that consistently flood by placing them on a hazard mitigation projects list, and actively seek funding to successful complete the projects.

DRAFT

3.4.6 Land Subsidence/Sinkholes

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.5, Page 3.218 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- http://www.dnr.mo.gov/geology/geosrv/envgeo/sinkholes.htm
- http://www.businessinsider.com/where-youll-be-swallowed-by-a-sinkhole-2013-3
- http://water.usgs.gov/edu/sinkholes.html
- http://pubs.usgs.gov/fs/2007/3060/
- Missouri hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  http://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9NOu-oPFWi9hkst/view - User Guide
    - Total number of sinkholes by County
    - Vulnerability to sinkholes by County
    - Total number of mines by County
    - Vulnerability to mines by County
    - Total value of structures impacted by sinkholes by County
    - Total population impacted by sinkholes by County

Hazard Profile

Hazard Description

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

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

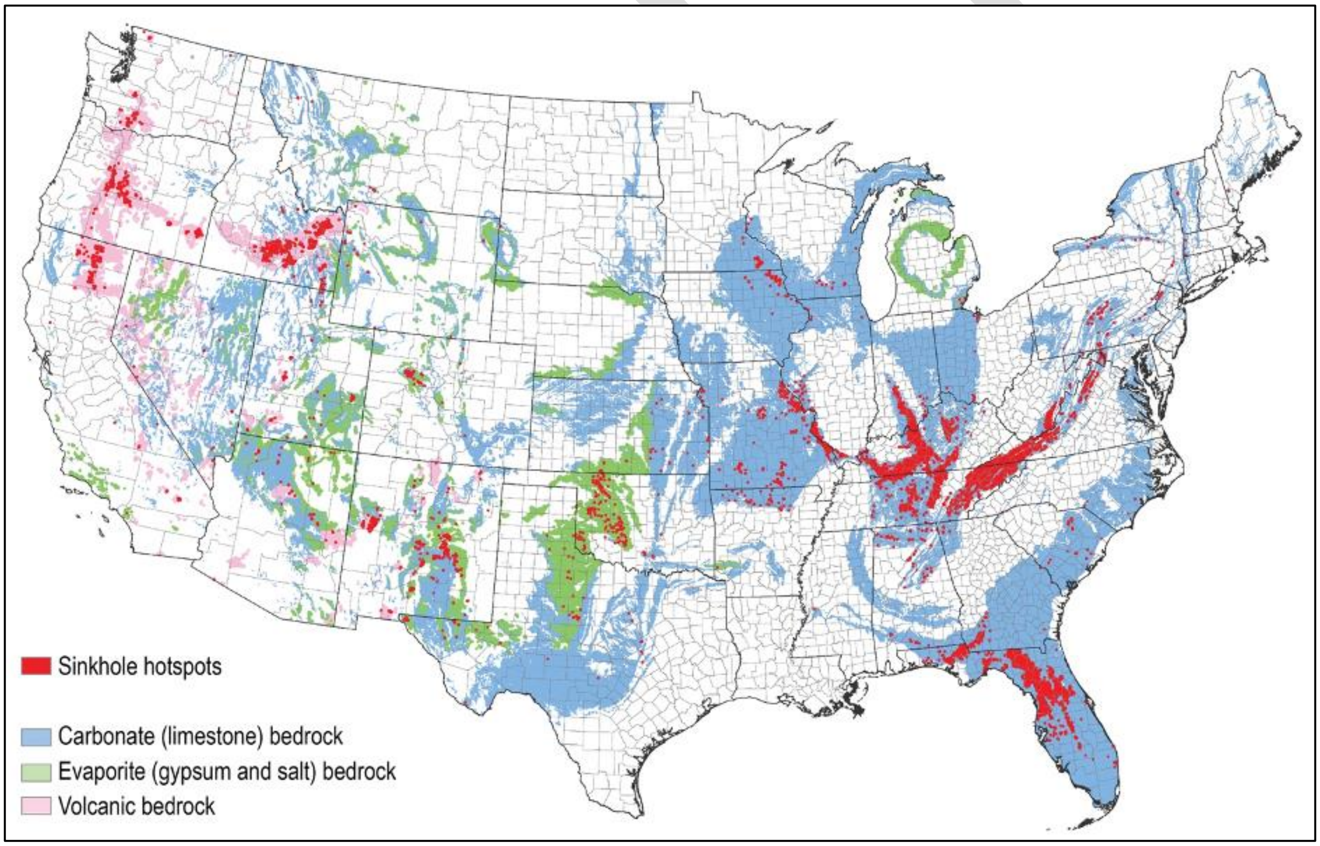
In the case of sinkholes, the rock below the surface is rock that has been dissolving by circulating groundwater. As the rock dissolves, spaces and caverns form, and ultimately the land above the spaces collapse. In Missouri, sinkhole problems are usually a result of surface materials above openings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

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

Geographic Location

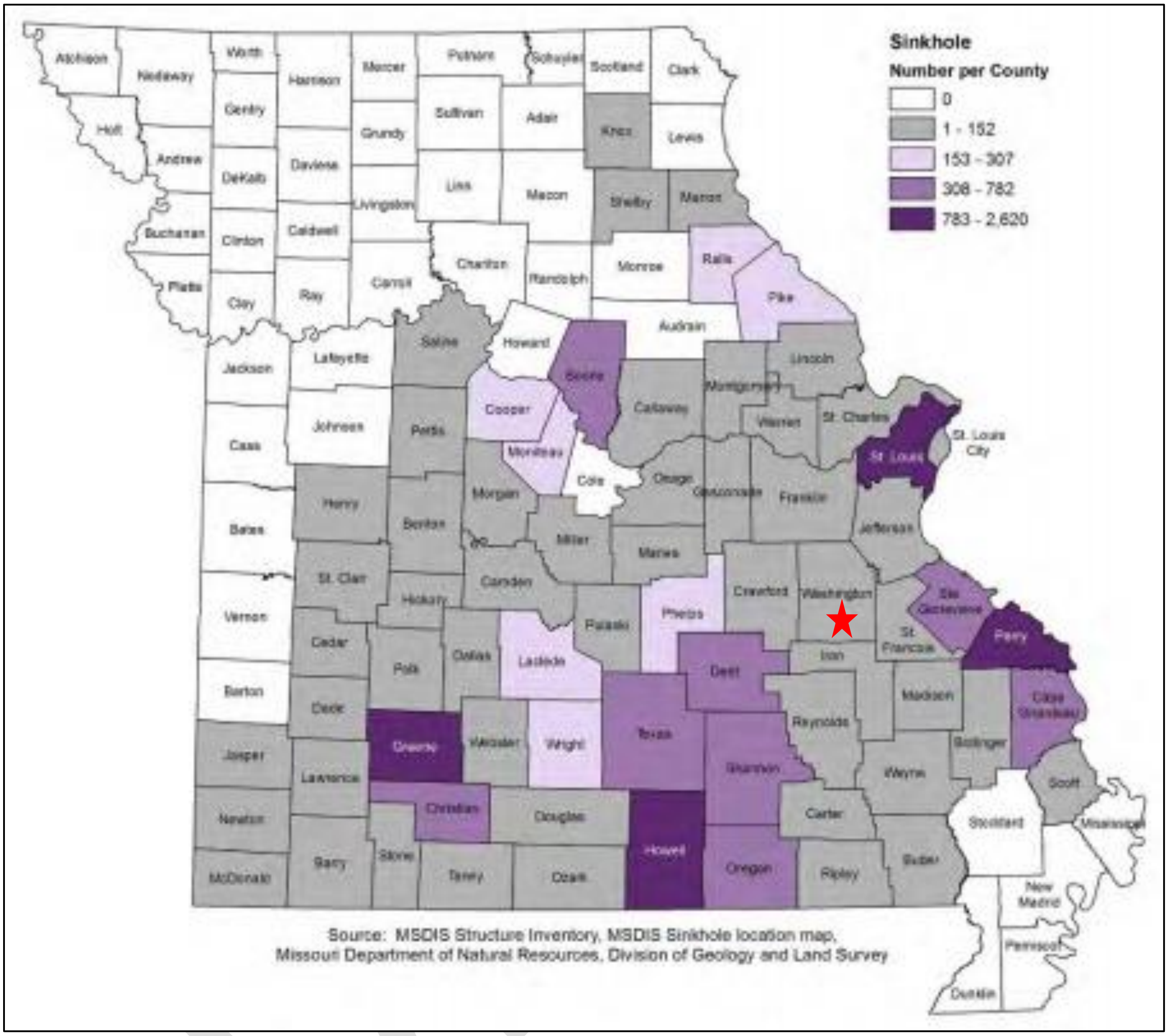
Figure 3.56 depicts karst topography across the United States. Missouri's karst topography is comprised of carbonate rocks such as limestone, dolomite, and marble. Variability in areas prone to sinkholes does not differ greatly across the county. According to the 2018 Missouri State Hazard Mitigation Plan there are 15 sinkholes that have been recorded within Washington County (**Figure 3.57**). In addition, the Plan states that there are 1,566 mines in Washington County - as shown in **Figure 3.58**. According to the Missouri Department of Natural Resources, Washington County primarily produces refractory clay but has deposits of barite with lead, sedimentary limonite, and hematite. Activities such as mining or drilling are known to be responsible for the formation of sinkholes.

Figure 3.56. Karst Map of the Conterminous United States - 2020



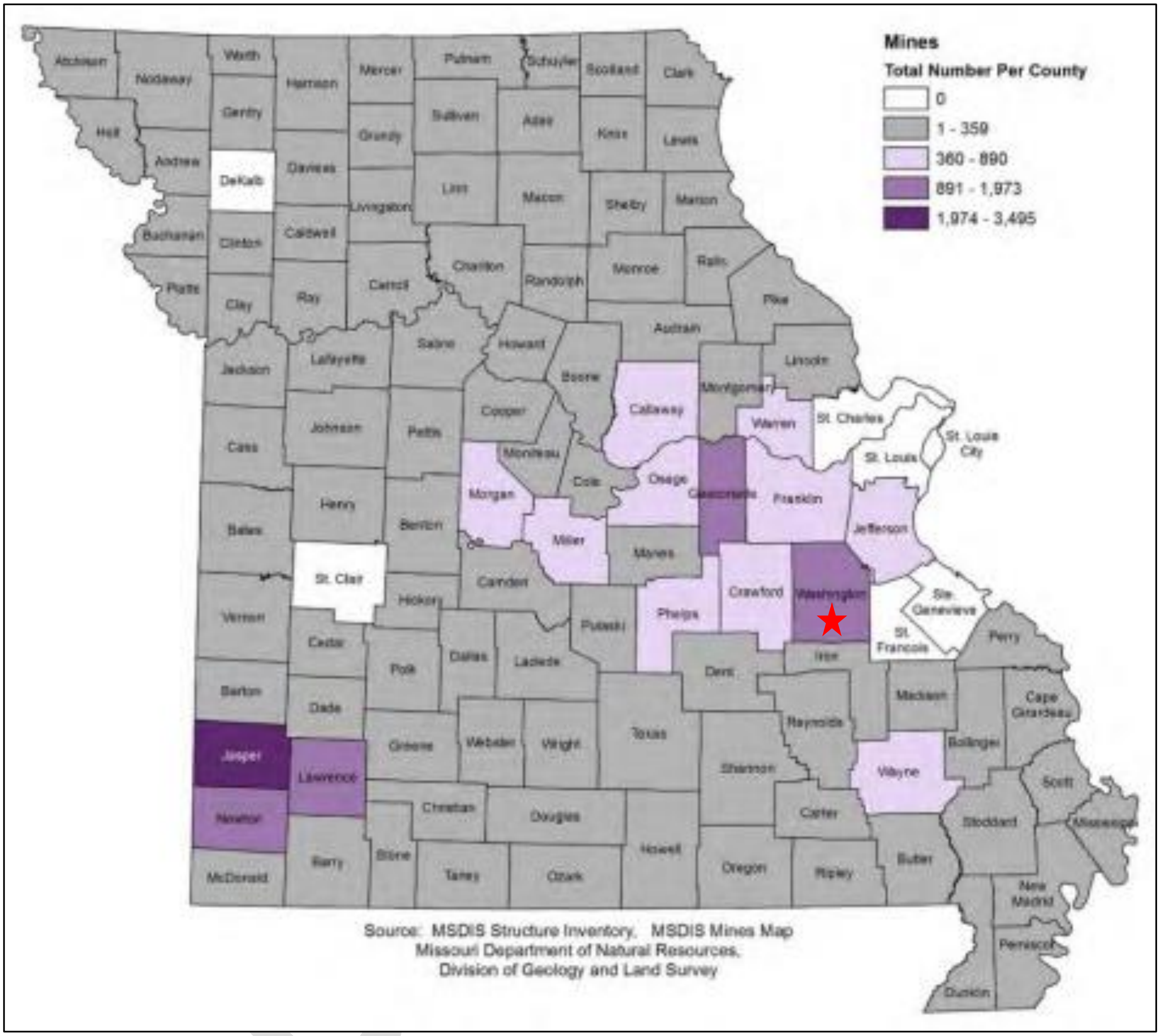
Source: https://www.usgs.gov/media/images/karst-map-conterminous-united-states-2020

Figure 3.57. Sinkholes Counts per County



*Source: 2018 Missouri Hazard Mitigation Plan; *Red star indicates Washington County*

Figure 3.58. Mines Counts Per County



*Source: 2018 Missouri Hazard Mitigation Plan; *Red star indicates Washington County*

Severity/Magnitude/Extent

Unlike earthquakes or other geologic hazards, there currently is no scale for measuring or determining the severity of sinkholes. However, geological and mining parameters can affect the magnitude and extent of sinkhole subsidence. As previously noted, natural sinkholes develop in areas where the rock below the surface is limestone, carbonate rock, salt beds or any type of rock that can naturally be dissolved by groundwater circulating through it. Artificial sinkholes form due to groundwater pumping, water main and sewer collapses and mine collapses.[31]

[31] 2018 Missouri Hazard Mitigation Plan

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

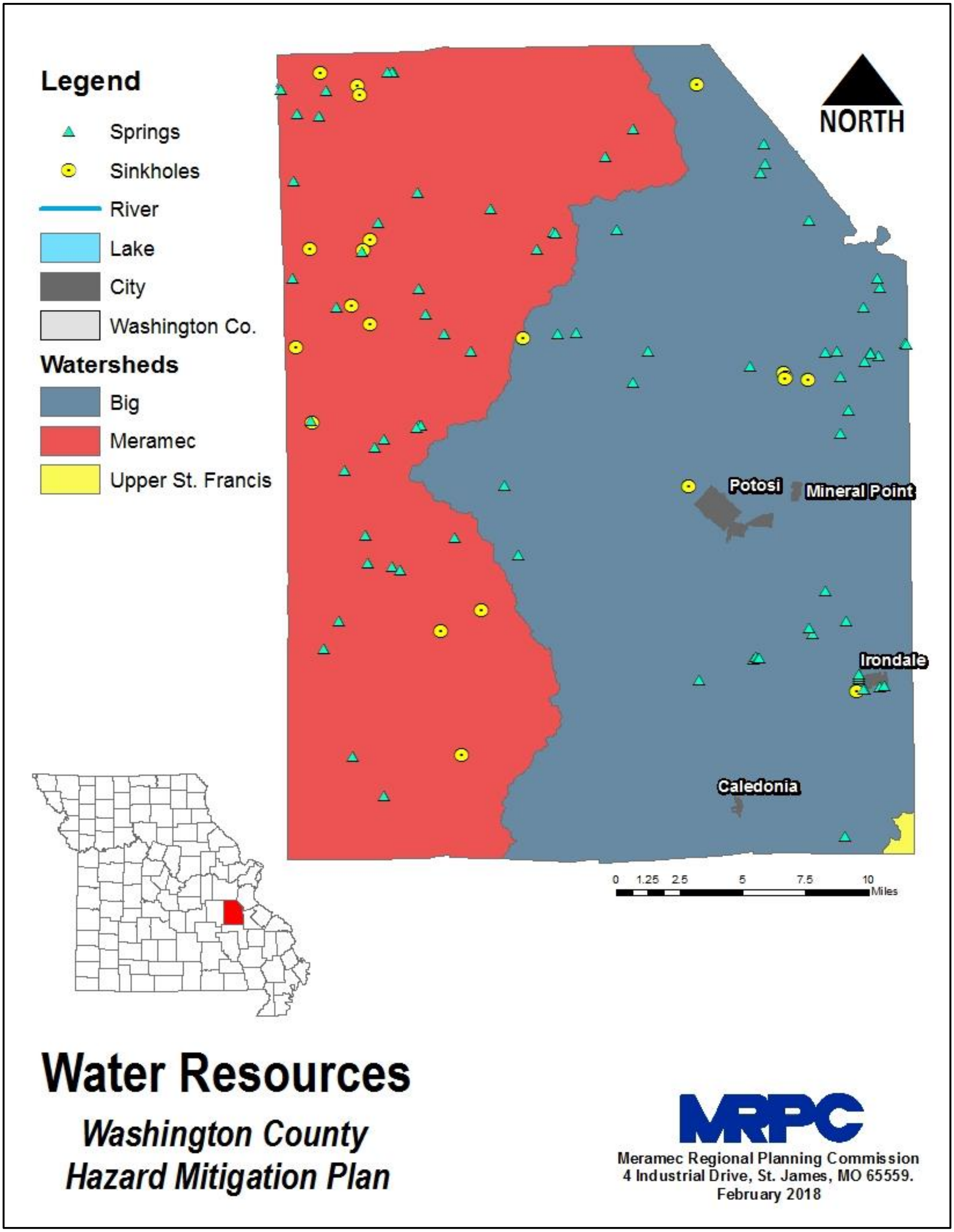
The 2018 State Plan mentions 18 documented sinkhole "notable events". The plan stated that sinkholes are common to Missouri and the probability is high that they will occur in the future. To date, Missouri sinkholes have rarely had major impacts on development, nor have they caused serious damage.

Previous Occurrences

Although there are few sinkholes and sinkhole areas in Washington County, incidents have occurred in other parts of southern Missouri. Fortunately, there are no recorded incidents of death due to sinkholes in the county. Historically, it was noted in the 2013 Missouri State Hazard Mitigation Plan that a mine collapse occurred in Washington County; specific information was not available. Based on **Figure 3.57**, recorded sinkholes are rural in nature and reside within unincorporated parts of the county.

DRAFT

Figure 3.59.   Washington County Watershed/Water Resources



Probability of Future Occurrence

Due to the lack of data for previous sinkhole events in Washington County, a probability could not be calculated.

Vulnerability

Vulnerability Overview

Unfortunately, no statistics are available for the number of subsurface locations that may potentially collapse in the future, forming a sinkhole. According to the state plan, if a county has 201-400 sinkholes, the risk is considered 2 – low-medium. For mines, the state plan calculates that Washington County's risk is rated as 5 – high. See **Table 3.54**. **Figure 3.60** and **Figure 3.61** further illustrate the sinkhole and mining rating values respectively.

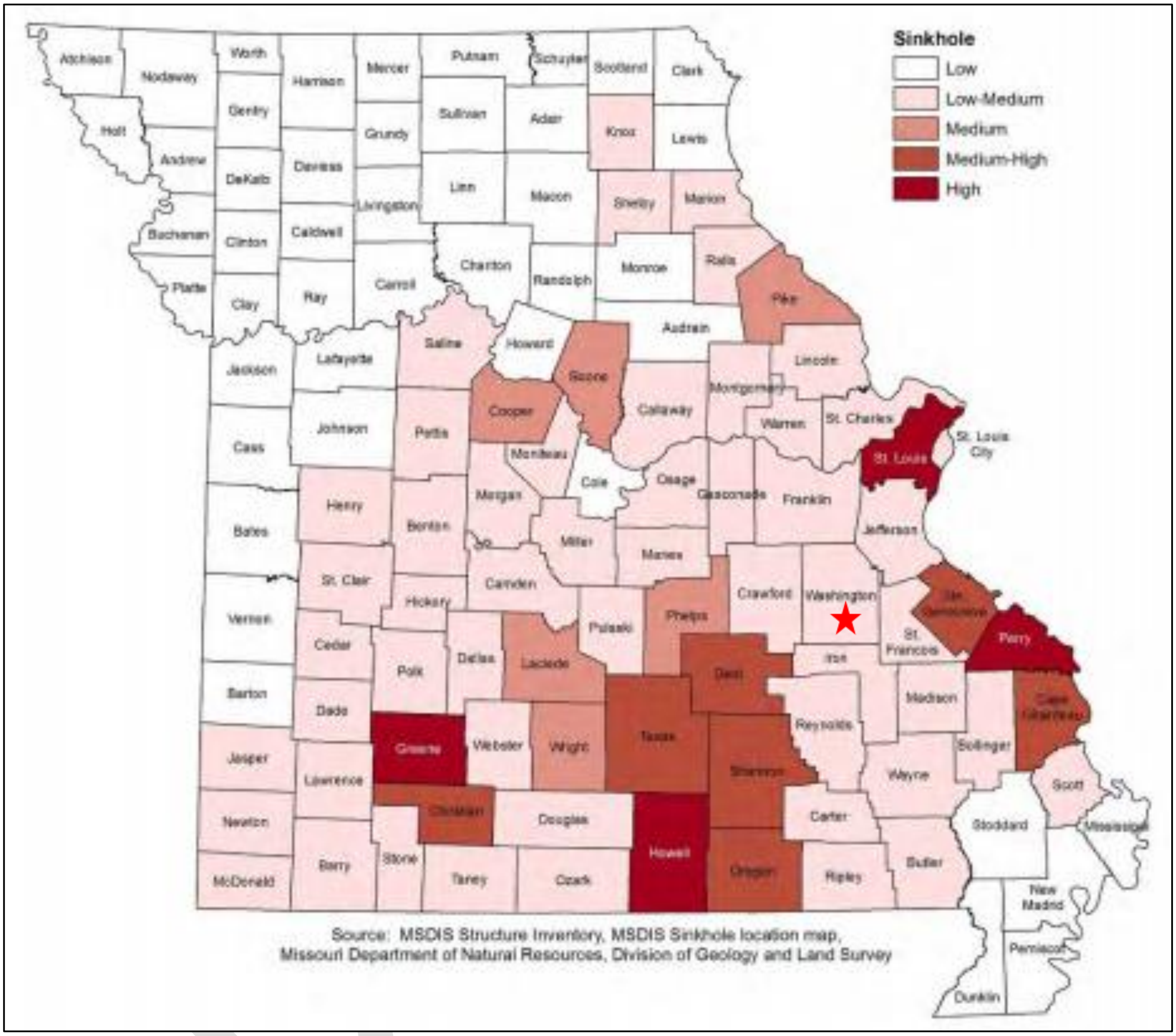
Table 3.54. Sinkhole/Mine Rating Values for Washington County

Factor	1 (Low)	2 (Low-medium)	3(Medium)	4 (Medium-high)	5 (High)
Sinkholes per county	0	1-200	201-400	401-800	801+
Mines per county	0-100	101-250	251-500	501-750	751+

Source: 2018 Missouri Hazard Mitigation Plan, Yellow highlight shows values for Washington County

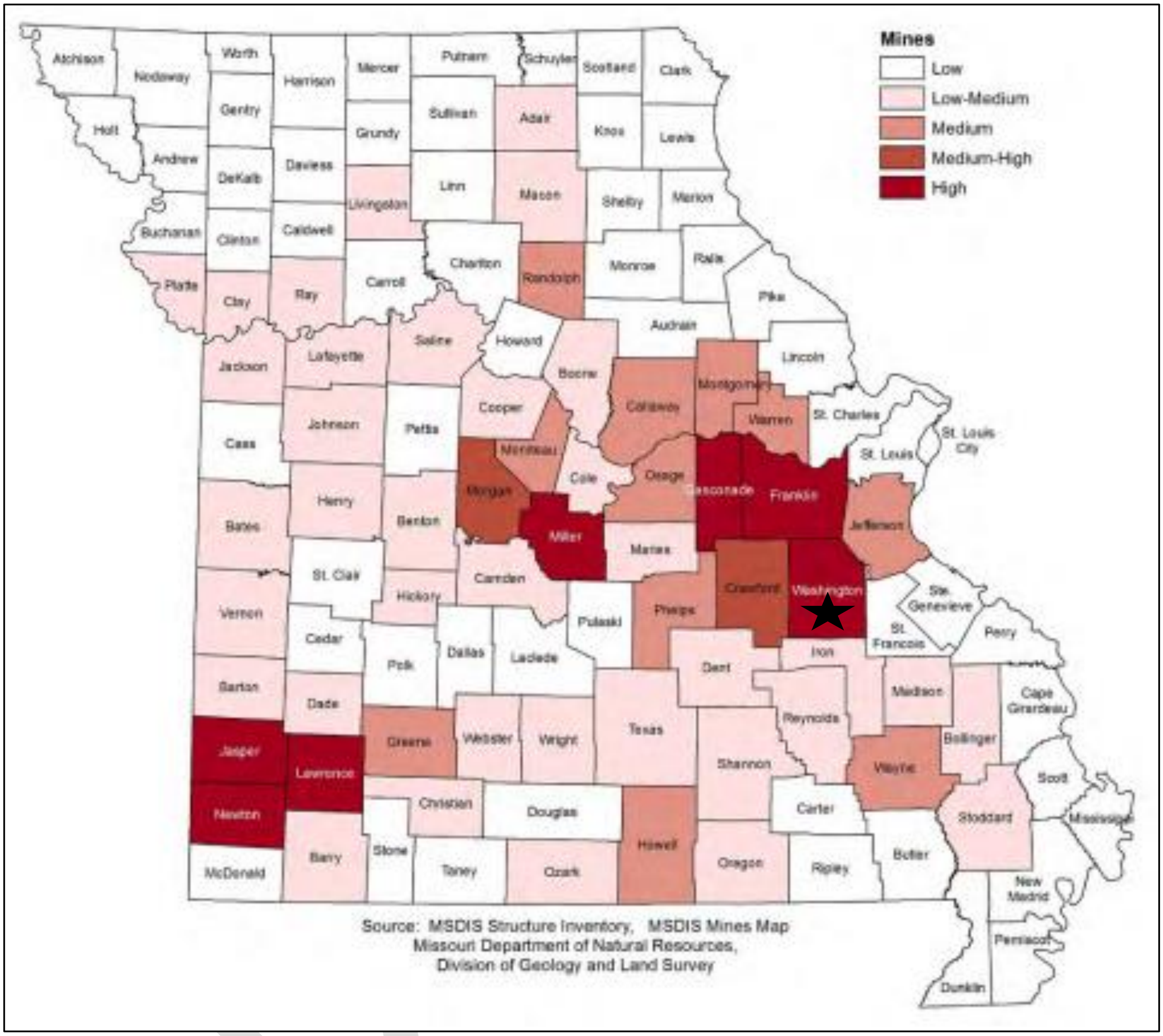
DRAFT

Figure 3.60. Sinkhole Rating Value by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.61. Mine Rating Value by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Black star indicates Washington County*

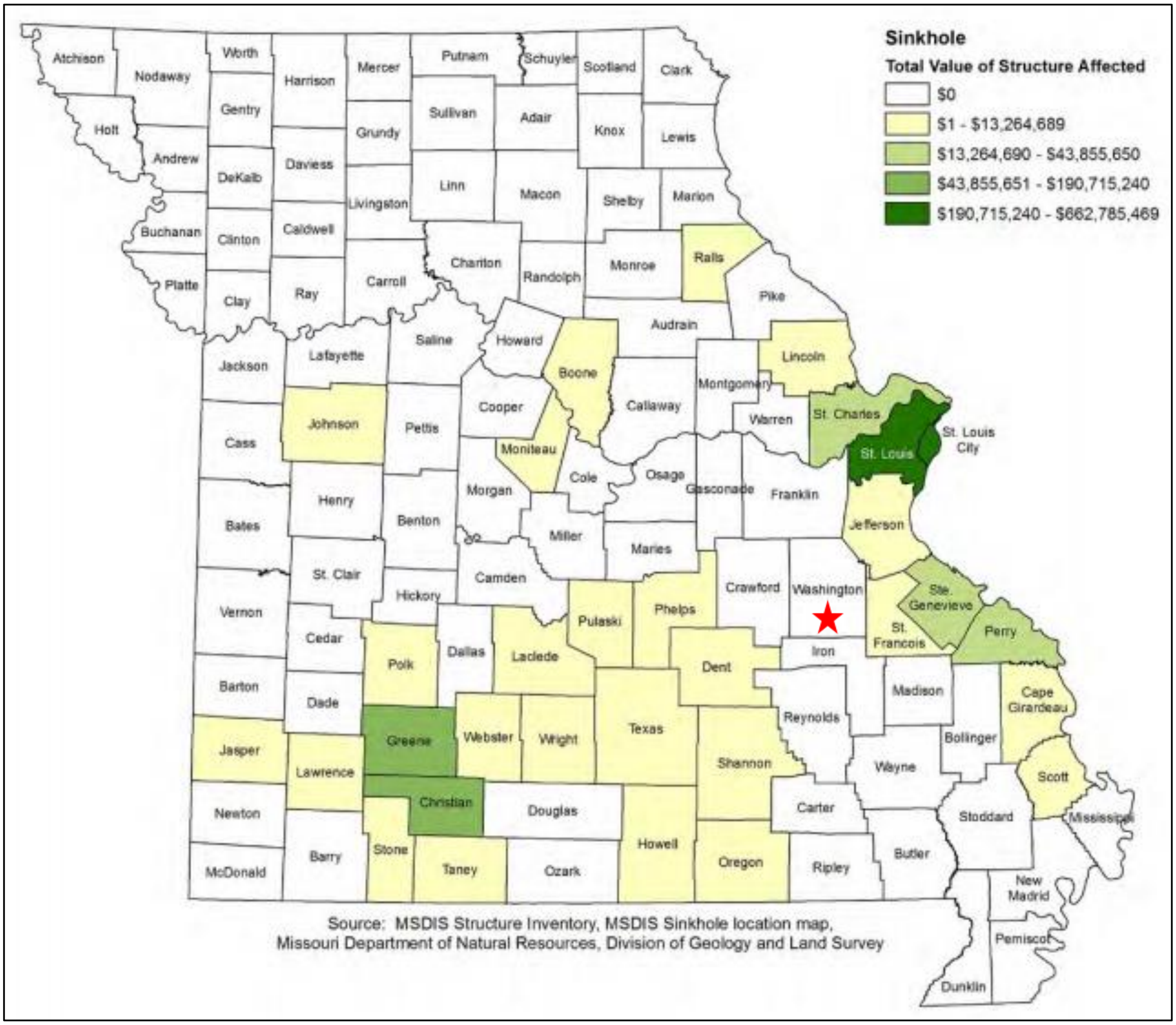
Potential Losses to Existing Development

The most likely type of damage to occur in conjunction with a sinkhole collapse is property damage related to foundation disturbance. Signs include cracks in interior and exterior walls; doors and windows that no longer sit square or open and close properly; depressions forming in the yard; cracks in the street, sidewalk, foundation or driveway; and turbidity in local well water. All of these can be early indicators that a sinkhole is forming in the vicinity[32]. In the event of a sudden collapse, an open sinkhole can form in a matter of minutes and swallow lawns, automobiles, and homes. This has occurred in some parts of Missouri, particularly in the southwest part of the state, but there have been no dramatic incidents like this in Washington County.

[32] http://sinkhole.org/commonsigns.php

The 2018 Missouri Hazard Mitigation Plan devised a method of estimating potential losses using GIS data. **Figure 3.62** shows the ranking of structures that could potentially be impacted by sinkholes by county. This map shows that Washington County has $0 total value of structures affected.

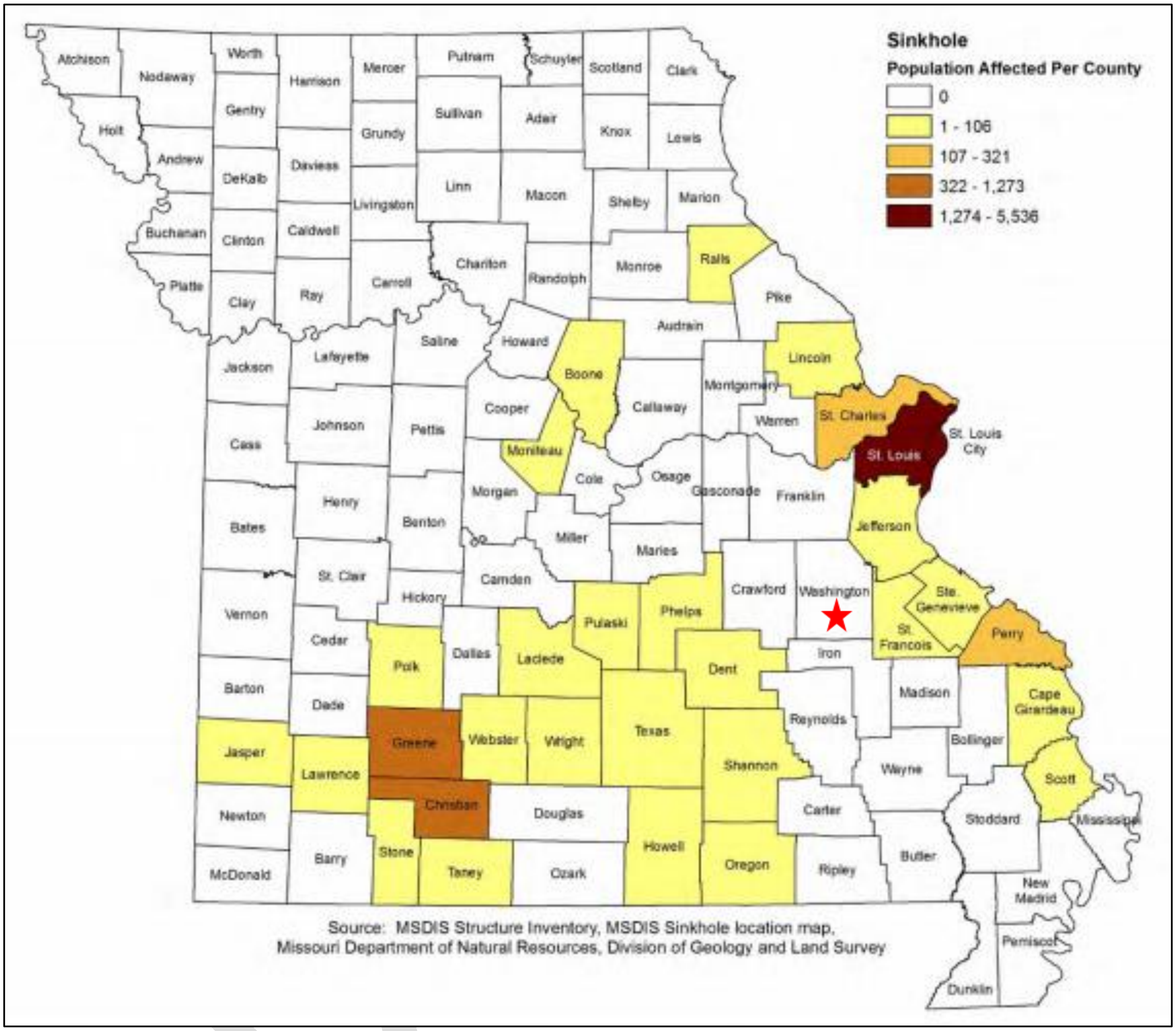
Figure 3.62. Ranking of Structures Potentially Impacted by Sinkholes by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.63 shows the population potentially impacted by sinkholes and again, Washington County shows that zero people with be affected by sinkholes.

Figure 3.63. Ranking of Population Potentially Impacted by Sinkholes by County



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Impact of Future Development

Future development over or near abandoned mines and in locations at risk of sinkhole formation will increase the hazard vulnerability. Information regarding regulations limiting construction near sinkholes is very limited. According to the state plan, Washington County's risk in regards to these hazards is moderately low.

Hazard Summary by Jurisdiction

According to the state plan, Washington County's risk is low to moderate. Based on the location of known sinkholes, the communities and school districts have less vulnerability than the unincorporated areas of the county. The jurisdiction most likely to be impacted by sinkholes is the city of Irondale. The other jurisdictions, both cities and school districts, are located in areas of the county where the concentration of sinkholes is much lower.

Problem Statement

Sinkholes and sinkhole/mining areas are well documented by both the US Geological Survey and the Missouri Department of Natural Resources Geologic Resources Section. The risk of sinkhole collapse can be lessened by avoiding the construction of structures in these areas and avoiding those activities that significantly alter the local hydrology, such as drilling and mining. In addition, communities should avoid leaking water and sewer lines through appropriate maintenance and monitoring. Local residents should be educated on the risks associated with sinkholes and mines and advised to avoid placing themselves and their property in danger by building in sinkhole/mining areas. Communities with building codes should include prohibitions on building in known sinkhole/mining areas.

DRAFT

3.4.7 Severe Thunderstorms Including High Winds, Hail, and Lightning

Some Specific Sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.8, Page 3.280 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- FEMA 320, Taking Shelter from the Storm, 3rd edition, http://www.weather.gov/media/bis/FEMA_SafeRoom.pdf
- Lightning Map, National Weather Service, https://www.vaisala.com/sites/default/files/documents/WEA-MET-Annual-Lightning-Report-2020-B212260EN-A.pdf
- Death and injury statistics from lightning strikes, National Weather Service.
- Wind Zones in the U.S. map, FEMA, https://www.fema.gov/pdf/library/ism2_s1.pdf;
- Annual Windstorm Probability (65+knots) map U.S. 1980-1994, NSSL, http://www.nssl.noaa.gov/users/brooks/public_html/bigwind.gif
- Hailstorm intensity scale, The Tornado and Storm Research Organization (TORRO), https://www.torro.org.uk/research/hail/hscale;
- NCEI data;
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss;
- National Severe Storms Laboratory – hail map, http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  http://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Average annual high wind events by County
  - Average annual hail events by County
  - Average annual lightning events by County
  - Vulnerability to severe thunderstorm event by County
  - Annualized property loss for high wind events by County
  - Annualized property loss for lightning events by County
  - Annualized property loss ratio for high wind events by County
  - Annualized property loss ratio for hail events by County
  - Annualized property loss ratio for lightning events by County

Hazard Profile

Hazard Description

Thunderstorms

A thunderstorm is defined as a storm that contains lightning and thunder which is caused by unstable atmospheric conditions. When cold upper air sinks and warm moist air rises, storm clouds or ‘thunderheads’ develop resulting in thunderstorms. This can occur singularly, as well as in clusters or lines. The National Weather Service defines a thunderstorm as “severe” if it includes hail that is one inch or more, or wind gusts that are at 58 miles per hour or higher. At any given moment across the world, there are about 1,800 thunderstorms occurring. Severe thunderstorms most often occur in Missouri in the spring and summer, during the afternoon and evenings, but can occur at any time. Other hazards associated with thunderstorms are heavy rains resulting in flooding (**Section 3.4.5**) and tornadoes (**Section 3.4.9**)

High Winds

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

Lightning

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

Hail

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

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

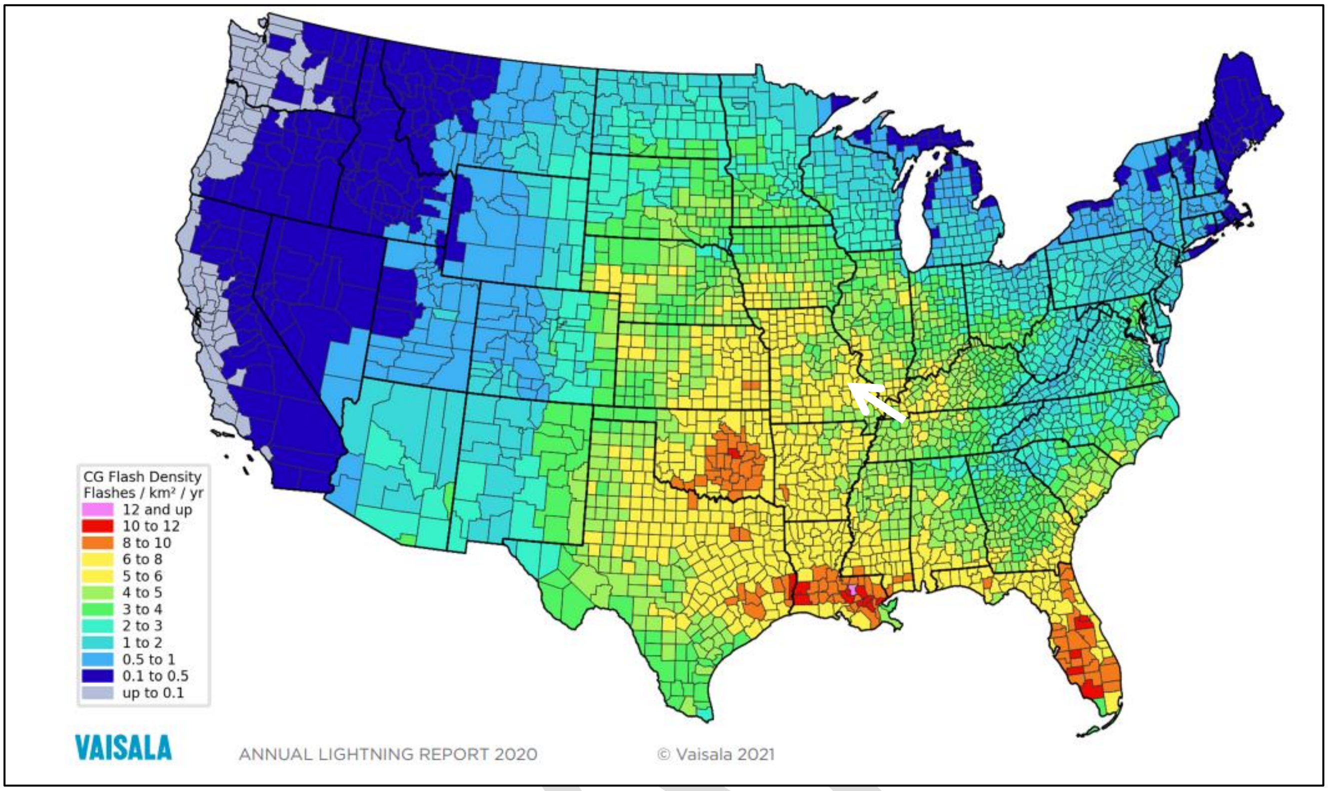
Geographic Location

Thunderstorms, high winds, hail, and lightning events are an area-wide hazard that can take place anywhere across the United States. Furthermore, these events do not vary greatly across the planning area; they are more frequently reported in urbanized areas. Additionally, densely developed urban areas are more likely to experience damaging events.

Figure 3.64 depicts the location and frequency of lightning in Missouri. Additionally, the map indicates that the flash density of Washington County ranges between 12 and 20 flashes per square kilometer per year.

DRAFT

Figure 3.64. Location and Frequency of Lightning in Missouri

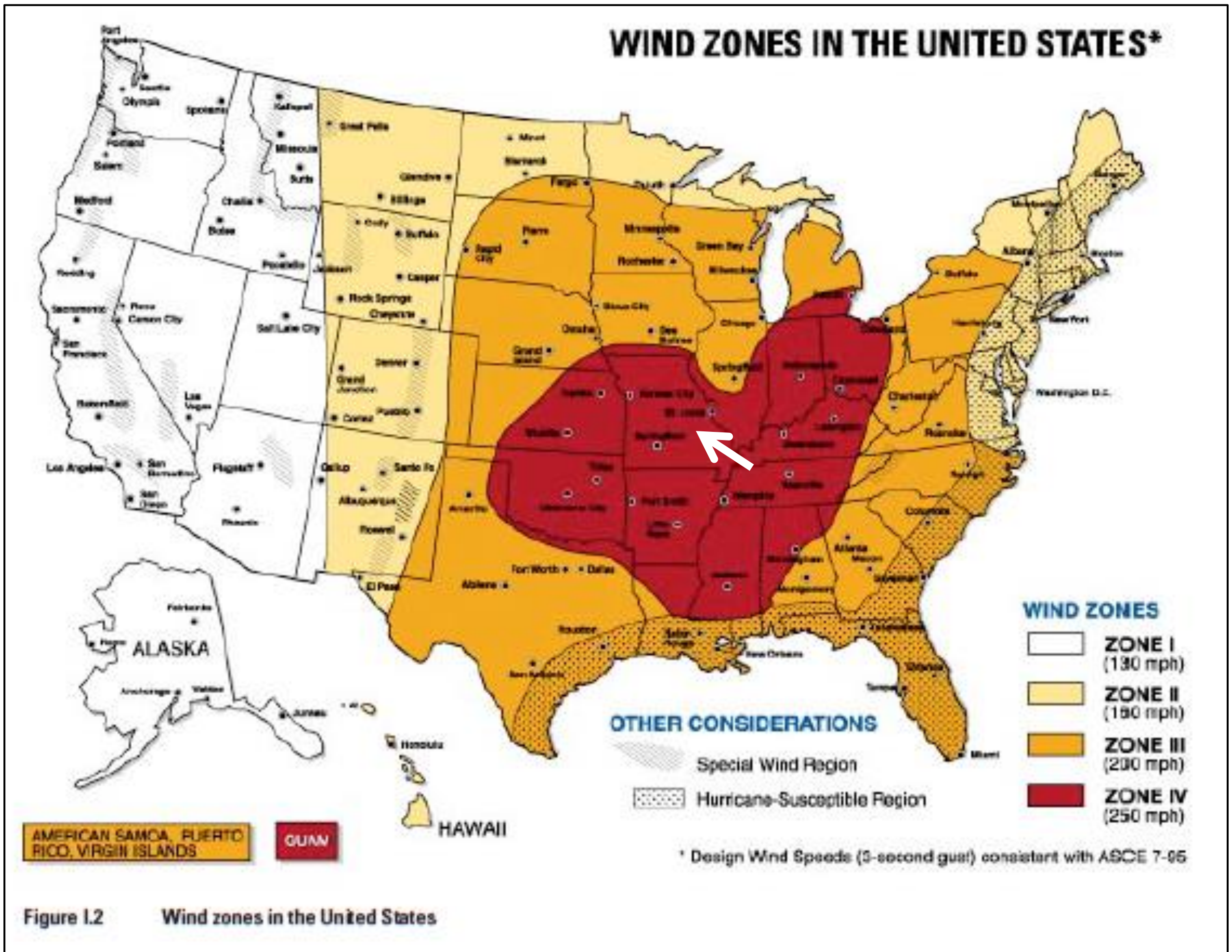


Source: National Weather Service, https://www.vaisala.com/sites/default/files/documents/WEA-MET-Annual-Lightning-Report-2020-B212260EN-A.pdf *Washington County is indicated by a white arrow.

There are four wind zones that are characterized across the United States. These zones range from Zone I to Zone IV. All of Missouri as well as most of the Midwest fall within Zone IV. Within Zone IV, winds can reach up to 250 mph (**Figure 3.65**).

DRAFT

Figure 3.65. Wind Zones in the United States



Source: FEMA 320, Taking Shelter from the Storm, 3rd edition, https://www.fema.gov/pdf/library/ism2_s1.pdf
**Washington County is indicated by a white arrow.*

Severity/Magnitude/Extent

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

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

Most lightning damages occur to electronic equipment located inside buildings. But structural damage can also occur when a lightning strike causes a building fire. In addition, lightning strikes can cause damages to crops if fields or forested lands are set on fire. Communications equipment and warning transmitters and receivers can also be knocked out by lightning strikes.

Based on information provided by the Tornado and Storm Research Organization (TORRO), **Table 3.55** below describes typical damage impacts of the various sizes of hail.

Table 3.55. Tornado and Storm Research Organization Hailstorm Intensity Scale

Intensity Category	Diameter (mm)	Diameter (inches)	Size Description	Typical Damage Impacts
Hard Hail	5 - 9	0.2 - 0.4	Pea	No damage
Potentially Damaging	10 - 15	0.4 - 0.6	Mothball	Slight general damage to plants, crops
Significant	16 - 20	0.6 - 0.8	Marble, grape	Significant damage to fruit, crops, vegetation
Severe	21 - 30	0.8 - 1.2	Walnut	Severe damage to fruit and crops, damage to glass, plastic structures, paint and wood scored
Severe	31 - 40	1.2 – 1.6	Pigeon's egg > squash ball	Widespread glass damage, vehicle bodywork damage
Destructive	41 – 50	1.6 – 2.0	Golf ball > pullet's egg	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries
Destructive	51 - 60	2.0 - 2.4	Hen's egg	Bodywork of grounded aircraft dented, brick walls pitted
Destructive	61 – 75	2.4 – 3.0	Tennis ball > cricket ball	Severe roof damage, risk of serious injuries
Destructive	76 – 90	3.0 – 3.5	Large orange > soft ball	Severe damage to aircraft bodywork
Super Hailstorms	91 – 100	3.6 – 3.9	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.
Super Hailstorms	>100	4.0+	Melon	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.

Source: Tornado and Storm Research Organization (TORRO), Department of Geography, Oxford Brookes University
Notes: In addition to hail diameter, factors including number and density of hailstones, hail fall speed and surface wind speeds affect severity. https://www.torro.org.uk/research/hail/hscale

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

Between 2001 and 2020, there were zero recorded crop insurance claims for Thunderstorms, lightning, high wind, and hail in Washington County.

DRAFT

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

Previous Occurrences

Due to the lack of available parameters, heavy rain is utilized in the place of thunderstorms in **Table 3.56**. Moreover, thunderstorm wind and strong wind was included with high winds. NCEI data was obtained for lightning, and hail events between 2001 and 2020 as well (**Table 3.57** and **Table 3.58).** However, limitations to the use of NCEI reported lightning events include the fact that only lightning events that result in fatality, injury and/or property and crop damage are in the NCEI.

Table 3.56. NCEI Washington County Heavy Rain Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Rainfall (Inch)
2009	1	0	0	0	4.20
2013	1	0	0	0	4.00
2015	2	0	0	0	5.04
2016	1	0	0	0	4.68
2017	1	0	0	0	1.00
2018	6	0	0	0	3.57
2019	5	0	0	0	5.10
Total	17	0	0	0	-

Source: NCEI, data accessed [10/06/2021]

Table 3.57. NCEI Washington County High Wind Events Summary, 2001 to 2020 (Thunderstorm)

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Estimated Gust (kts.)
2001	1	0	0	0	-
2002	3	0	0	0	52
2003	3	0	0	-	65
2004	1	0	0	-	50
2005	4	0	0	7K	55
2006	9	0	0	17K	60
2008	2	0	0	15K	58

2009	2	0	0	1.05M	70
2010	1	0	0	-	52
2011	7	0	0	10K	52
2012	5	0	0	3.5K	52
2013	1	0	0	5K	52
2014	4	0	0	0	52
2017	1	0	0	25K	70
2018	6	0	0	24K	556
2019	5	0	0	26K	52
Total	**55**	**0**	**0**	**1.183M**	**-**

Source: NCEI, data accessed [10/06/2021]

Table 3.58. NCEI Washington County Lightning Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Crop Damage
-	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**

Source: NCEI, data accessed [10/06/2021]

Table 3.59. NCEI Washington County Hail Events Summary, 2001 to 2020

Year	# of Events	# of Deaths	# of Injuries	Property Damages	Max Hail Size (inch)
2001	1	0	0	0	1.00
2002	4	0	0	10K	1.75
2003	4	0	0	0	2.75
2004	1	0	0	0	1.75
2005	1	0	0	0	1.00
2006	10	0	0	0	1.75
2007	3	0	0	0	2.00
2008	11	0	0	0	2.50
2009	6	0	0	0	1.75
2011	5	0	0	10K	1.75
2012	1	0	0	0	0.75
2014	1	0	0	0	1.50
2015	1	0	0	0	1.00
2016	7	0	0	0	1.25
2017	6	0	0	0	2.00
2018	5	0	0	0	1.00
2019	1	0	0	0	1.00
2020	3	0	0	0	1.25
Total	**71**	**0**	**0**	**20K**	**-**

Source: NCEI, data accessed [10/06/2021]

DRAFT

Agriculture is an important piece of the economy for Washington County. The tables below (**Table 3.60**) summarize past crop damages as indicated by crop insurance claims. The tables illustrate the magnitude of the impact on the planning area's agricultural economy. It should be noted that the USDA Risk Management Agency data does not align directly with the breakdown of hazards listed here. The claims database only listed "Excessive Moisture/Precipitation/ Rain" and "Wind/Excessive Wind" as two causes of loss categories that align with this hazard. Between 2001 and 2020 no insurance claims were paid out for damages due to moisture/precipitation/rain.

For the time period 2001-2020, there were no crop insurance claims made for wind and excessive wind damage.

Table 3.60. Crop Insurance Claims Paid In Washington County from Excessive Moisture/ Precipitation/Rain 2001-2020

Crop Year	Crop Name	Cause of Loss Description	Insurance Paid
-	-	-	-
Total	**0**	-	**0**

Source: USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss

Probability of Future Occurrence

From the data obtained from the NCEI [33], annual average percent probabilities were calculated for heavy rainfall, high winds, lightning, and hail. Heavy rainfall has an 85 percent annual average percent probability of occurrence (17 events/20 years x 100) (**Table 3.61**). Heavy rainfall events can be found in **Table 3.56**.

The annual average percent probability for high winds within the county is 100 percent (55 event/20 years * 100) with an average 2.75 events per year (**Table 3.62).** High wind events can be found in **Table 3.57.**

Lightning events have a 0 percent annual average percent probability of occurrence **(Table 3.63)** (0 events/20 years x 100) Lightning events can be found in **Table 3.58**.

Lastly, the annual average percent probability of hail occurrence is 100 percent (71 events/20 years x 100) with an average of 3.55 events per year (**Table 3.64**). Hail events can be found in **Table 3.59**.

Table 3.61. Annual Average % Probability of Heavy Rain in Washington County

Location	Annual Avg. % P
Washington County	85%

*P = probability; see page 3.24 for definition.

[33] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

Table 3.62. Annual Average % Probability of High Winds in Washington County

Location	Annual Avg. % P	Avg. # of Events
Washington County	100%	2.75

*P = probability; see page 3.24 for definition.

Table 3.63. Annual Average % Probability of Lightning in Washington County

Location	Annual Avg. % P
Washington County	0%

*P = probability; see page 3.24 for definition.

Table 3.64. Annual Average % Probability of Hail in Washington County

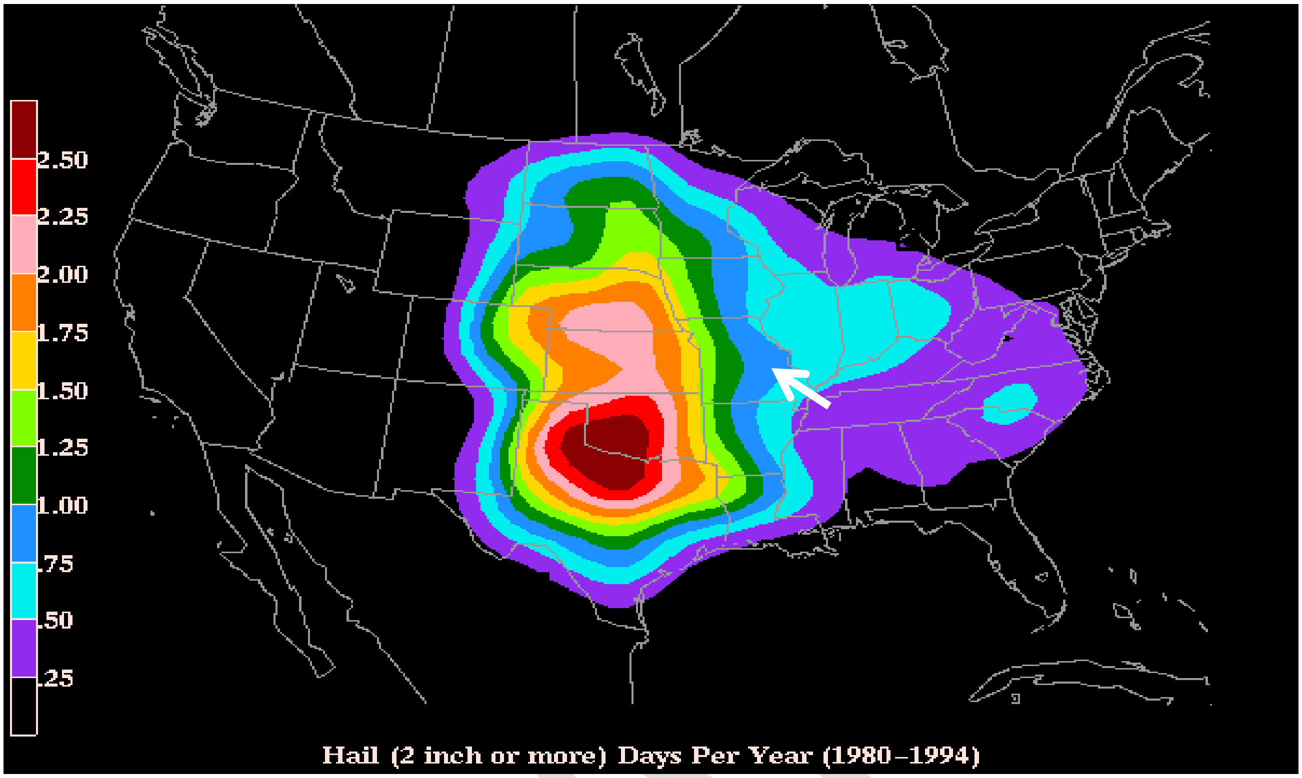
Location	Annual Avg. % P	Avg. # of Events
Washington County	100%	3.55

*P = probability; see page 3.24 for definition.

Figure 3.66 depicts a map based on hailstorm data from 1980-1994. It shows the probability of hailstorm occurrence (2" diameter or larger) based on number of days per year. The location of Washington County is identified with a white arrow.

DRAFT

Figure 3.66. Annual Hailstorm Probability (2" diameter or larger), 1980 - 1994



Source: NSSL,http://www.nssl.noaa.gov/users/brooks/public_html/bighail.gif
** White arrow indicates Washington County*

Vulnerability

Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for vulnerability overview and analysis. Since severe thunderstorms occur frequently throughout Missouri, the method used to determine vulnerability to severe thunderstorms was statistical analysis of data from several sources including: National Centers for Environmental Information (NCEI) storm events data (1996 to December 31, 2016 – which will differ slightly from data collected for the Washington County plan which is 2001-2020), HAZUS Building Exposure Value data, housing density and mobile home data from the U.S. Census (2015 ACS), and the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina.[34]

From the data collected, six factors were considered in determining vulnerability to lightning as follows: housing density, building exposure, percentage of mobile homes, social vulnerability, likelihood of occurrence and average annual property loss. A rating value of one through five was assigned to each factor. Rating values are as follows:

1) Low
2) Low-medium
3) Medium

[34] 2018 Missouri Hazard Mitigation Plan

4) Medium-high
5) High

Figure 3.65 illustrates the factors considered and ranges for the rating values assigned.

Once the ranges were determined and applied to all factors considered in the analysis for wind, hail, and lightning, they were rated individually and factored together to determine an overall vulnerability rating for thunderstorms. **Table 3.66** provides the calculated ranges applied to determine overall vulnerability of Missouri counties to severe thunderstorms.

DRAFT

Table 3.65. Ranges for Severe Thunderstorm Vulnerability Factor Ratings

Factors Considered	Low (1)	Low Medium (2)	Medium (3)	Medium High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2836.23
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Percent Mobile Homes	0.2-4.5%	4.6-8.8%	8.9-14%	14.1-21.2%	21.3-33.2%
Social Vulnerability	1	2	3	4	5
					Wind
Likelihood of Occurrence (# of events/ yrs. of data)	0.90 - 2.90	2.91 - 4.57	4.58 - 7.00	7.01 - 12.05	12.06 - 20.86
Average Annual Property Loss (annual property loss/ yrs of data)	$0.00 – $81,047.62	$81,047.63 – $200,428.57	$200,428.58 – $363,500.00	$363,500.01 – $837,242.86	$837,242.87 – $2,481,809.52
					Hail
Likelihood of Occurrence (# of events/ yrs. of data)	1.19 - 2.76	2.77 - 4.86	4.87 - 7.81	7.82 - 12.38	12.39 - 18.10
Average Annual Property Loss (annual property loss/ yrs. of data)	$0.00 - $41,547.62	$41,547.63 – $171,980.95	$171,980.96 – $467,857.14	$467,857.15 – $9,714,523.81	$9,714,523.82 – $40,594,285.71
					Lightning
Likelihood of Occurrence (# of events/ yrs. of data)	0-.05	.06-0.14	0.15-0.29	0.30-0.43	0.44-0.67
Average Annual Property Loss (annual property loss/ yrs. Of data)	$0-$476.19	$476.20-$1,904.76	$1,904.77-$7,476.19	$7,476.20-$13,142.86	$13,142.87-$57,000

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.66. Ranges for Severe Thunderstorm Combined Vulnerability Rating

	Low (1)	Low Medium (2)	Medium (3)	Medium High(4)	High (5)
Severe Thunderstorm Combined Vulnerability	12-16	17-19	20-23	24-29	30-36

Source: 2018 Missouri Hazard Mitigation Plan

According to the Hazus data included in the 2018 state plan, Washington County has total building exposure to severe thunderstorms of $1,730,986,000. **Figure 3.67** shows housing density, building exposure, SOVI and mobile home data for Washington County. The county's building exposure and housing density rating is medium, while the percent of mobile homes in the county is rated as high at 33.2 percent of the housing stock. **Table 3.68**, also pulled from the state plan, provides data on the number of events and likelihood of occurrence and occurrence rating for high wind, hail, and lightning.

Table 3.67. Washington County Housing Density, Building Exposure, SOVI and Mobile Home Data

Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Ranking Rating	Percent Mobile Homes	Percent Mobile Homes Rating
$1,730,986,000	1	14.34	1	Medium	3	33.2	5

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.68. Number of High Wind, Hail and Lightning Events, Likelihood of Occurrence and Associated Ratings for Washington County

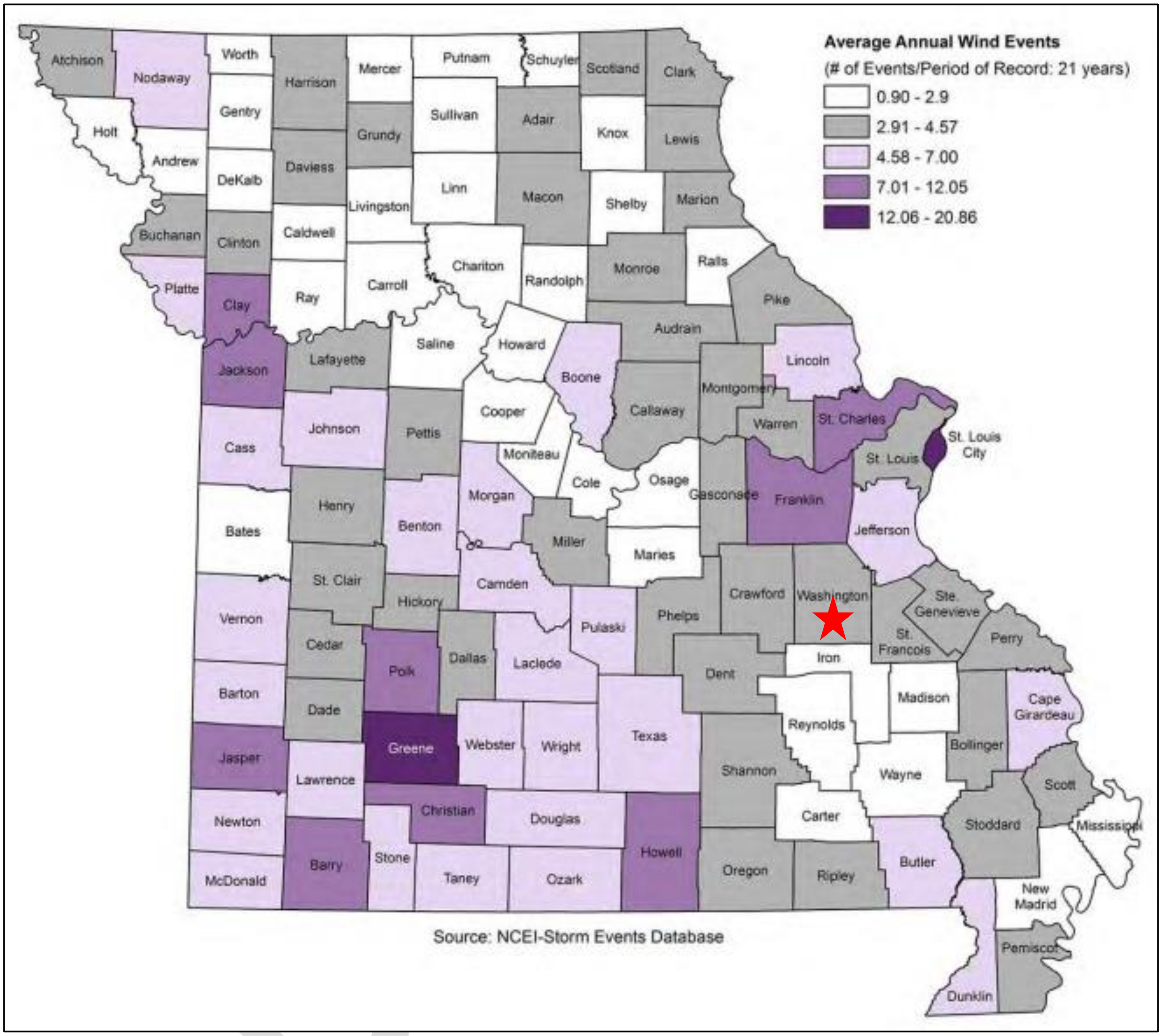
High Wind			Hail			Lightning		
Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Number of Events	Likelihood of Occurrence	Likelihood of Occurrence Rating
70	3.333	2	126	6.000	3	0	0.000	1

Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.67 through **Figure 3.69** have been pulled from the 2018 Missouri Hazard Mitigation Plan and further depict the average annual likelihood of occurrence of high winds, hail, and lightning events in Missouri.

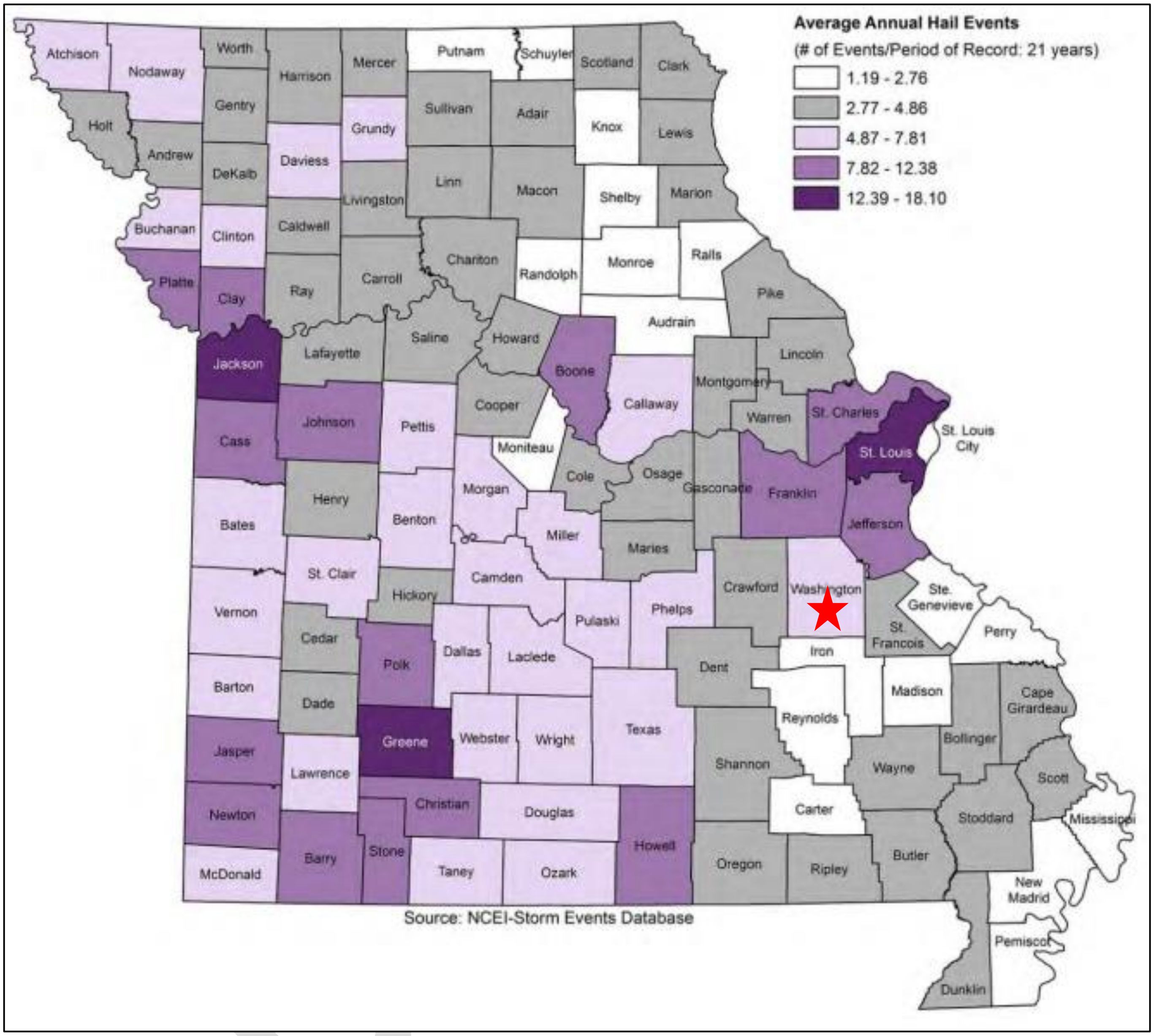
DRAFT

Figure 3.67. Average Annual High Wind Events (40 MPH and Higher)



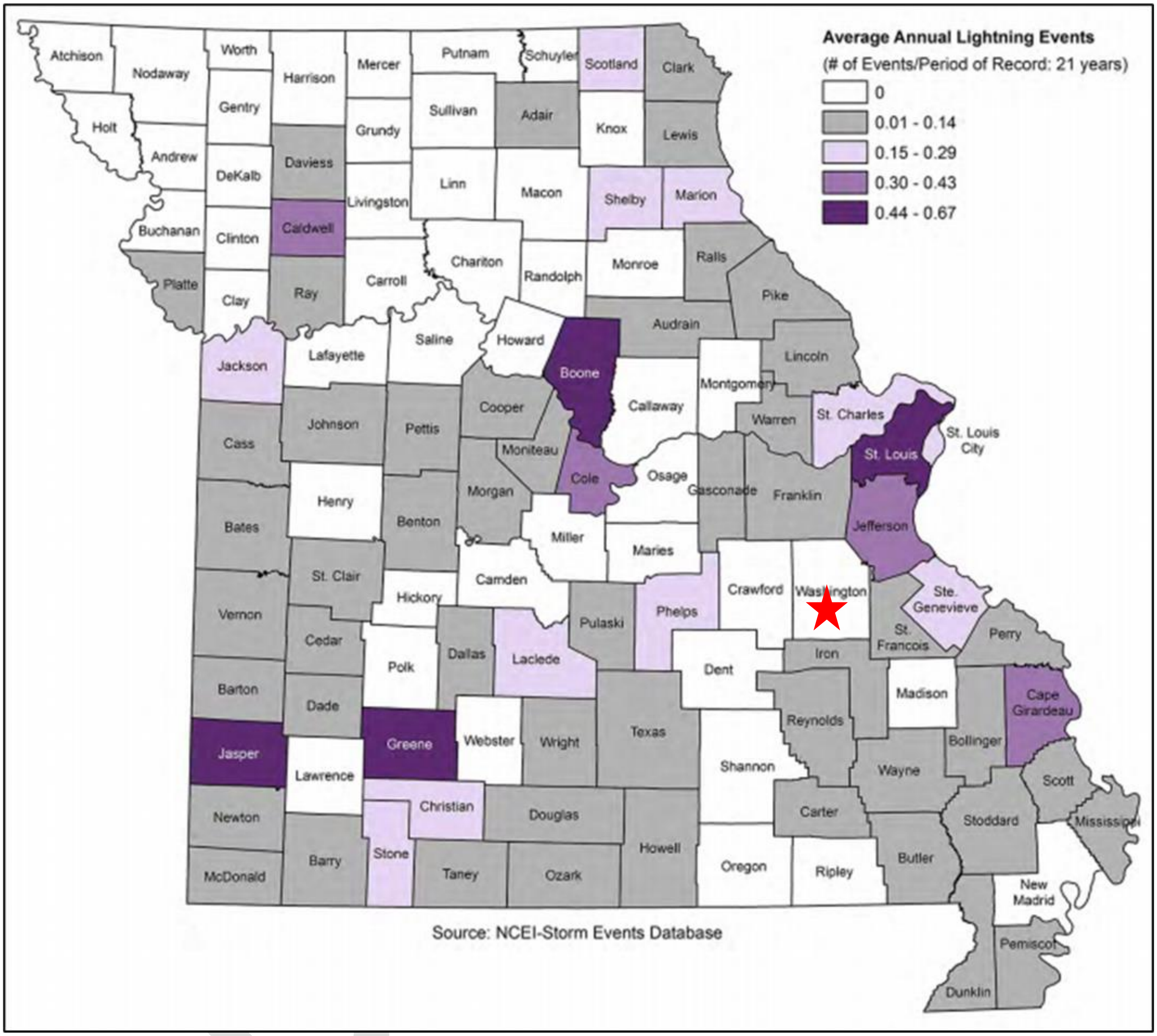
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.68. Average Annual Occurrence of Damaging Hail Events



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.69. Average Annual Occurrence of Lightning Events



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Table 3.69 provides additional data obtained from the National Centers for Environmental Information for property loss to complete the overall vulnerability analysis.

Table 3.69. Annualized Property Loss and Associated Ratings for Washington County

High Wind		Hail		Lightning	
Total Annualized Property Loss	Total Annualized Property Loss Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating
$0	1	$0	1	$0	1

Source: 2018 Missouri State Hazard Mitigation Plan

After ranges were applied to all factors in the analysis for wind, hail, and lightning, they were weighted equally and factored together to determine an overall vulnerability rating. Following, a combined vulnerability rating was calculated. The calculated ranges applied to determine overall vulnerability of Missouri counties to severe thunderstorms. **Table 3.70** provides the calculated vulnerability rating for the severe thunderstorm hazard. **Figure 3.70** that follows provides the mapped results of this analysis by county[35].

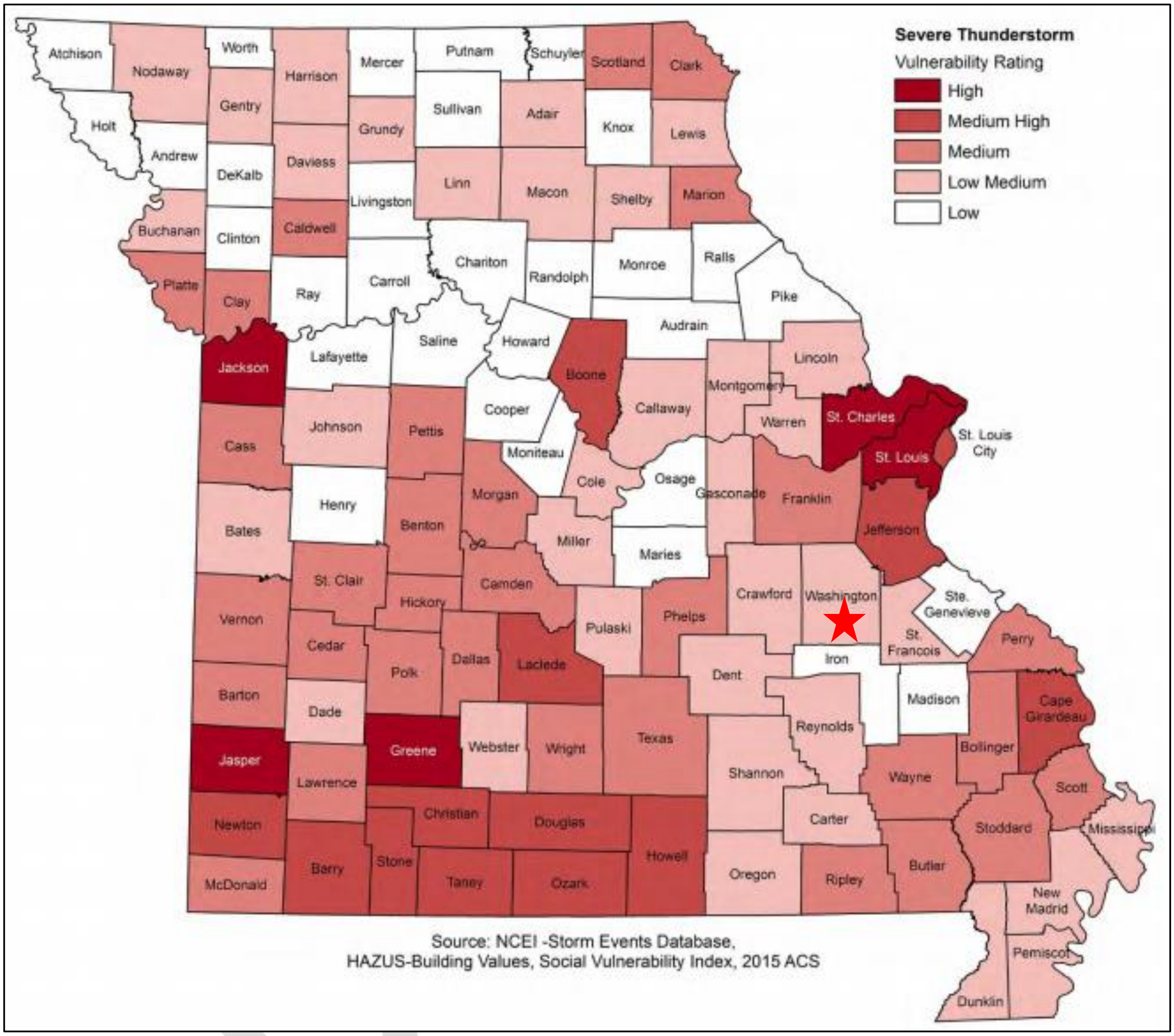
Table 3.70. Severe Thunderstorm Vulnerability Rating for Washington County

Total Sum of All Factor Ratings	Overall Vulnerability Rating for Thunderstorms	Overall Vulnerability Rating for Thunderstorms Description
19	2	Low-Medium

Source: 2018 Missouri State Hazard Mitigation Plan

[35] 2018 Missouri State Hazard Mitigation Plan

Figure 3.70. Vulnerability Summary for Severe Thunderstorms



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Potential Losses to Existing Development

According to the NCEI Washington County experienced approximately $1,203,000 in property damages from severe thunderstorms between 2001 and 2020. This is an average of $60,150 in losses due to this hazard per year. Most of the property damage caused by storms is covered by private insurance and data is not available. In addition, most damage from severe thunderstorms occurs to vehicles, roofs, siding, and windows. However, there is a variety of impacts from severe thunderstorms. Moreover, secondary effects from hazards, falling trees and debris, can cause destruction within the planning area.

Previous and Future Development

Population trends from 2010 to 2020 for Washington County indicate that the population in unincorporated areas has fallen by an estimated 2.17 percent. The city of Potosi's population has increased by a 2.26 percent. The city of Mineral Point has fallen by 34.19 percent. Overall, the county's population has shrunk 6.7 percent. It is difficult to determine future impacts, however, anticipated development in each jurisdiction will result in increased exposure. Likewise, increased development of residential structures will increase jurisdiction's vulnerability to damages from severe thunderstorms/ high winds/lightning/hail.

Hazard Summary by Jurisdiction

Although thunderstorms/high winds/lightning/hail events are area-wide, there are demographics indicating higher losses in one jurisdiction as compared to another. Jurisdictions with high percentages of housing built before 1939 are more prone to damages from severe thunderstorms. The jurisdictions with the highest percent of houses build before 1939 include the city of Caledonia (34.6%) and Irondale (32.9%). Additionally, Unincorporated Washington County has a higher percentage of mobile homes and unsecured buildings, which are more prone to damages.

Problem Statement

The NCEI Storm Events Database notes over 143 thunderstorm and wind events in Washington County since 2001, with over $1,203,000.00 in property and crop damages reported. Early warnings are possibly the best hope for residents when severe weather strikes. Cities that do not already possess warning systems – whether that is storm sirens or automated email/text/phone call systems - should plan to invest in such a system. Additional public awareness also includes coverage by local media sources. Storm shelters are another important means of mitigating the effects of severe thunderstorms. A community-wide shelter program should be adopted for residents who may not have adequate shelter in their homes. Residents should also be encouraged to build their own storm shelters to prepare for emergencies. Local governments should encourage residents to purchase weather radios to ensure that everyone has sufficient access to information in times of severe weather.

DRAFT

3.4.8 Severe Winter Weather

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.9, Page 3.321 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Wind chill chart, National Weather Service, http://www.nws.noaa.gov/om/winter/windchill.shtml;
- Average Number of House per year with Freezing Rain, American Meteorological Society. "Freezing Rain Events in the United States." http://ams.confex.com/ams/pdfpapers/71872.pdf;
- USDA Risk Management Agency, Insurance Claims, https://www.rma.usda.gov/Information-Tools/Summary-of-Business/Cause-of-Loss;
- Any local Road Department data on the cost of winter storm response efforts.
- National Centers for Environmental Information, Storm Events Database, http://www.ncdc.noaa.gov/stormevents/
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  o Average annual severe winter weather events by County
  o Vulnerability to severe winter weather events by County
  o Annualized property loss for severe winter weather events by County
  o Annualized property loss for severe winter weather events by County

Hazard Profile

Hazard Description

A major winter storm can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. The National Weather Service describes different types of winter storm events as follows.

- **Blizzard**—Winds of 35 miles per hour or more with snow and blowing snow reducing visibility to less than ¼ mile for at least three hours.
- **Blowing Snow**—Wind-driven snow that reduces visibility. Blowing snow may be falling snow and/or snow on the ground picked up by the wind.
- **Snow Squalls**—Brief, intense snow showers accompanied by strong, gusty winds. Accumulation may be significant.
- **Snow Showers**—Snow falling at varying intensities for brief periods of time. Some accumulation is possible.
- **Freezing Rain**—Measurable rain that falls onto a surface with a temperature below freezing. This causes it to freeze to surfaces, such as trees, cars, and roads, forming a coating or glaze of ice. Most freezing-rain events are short lived and occur near sunrise between the months of December and March.
- **Sleet**—Rain drops that freeze into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects.

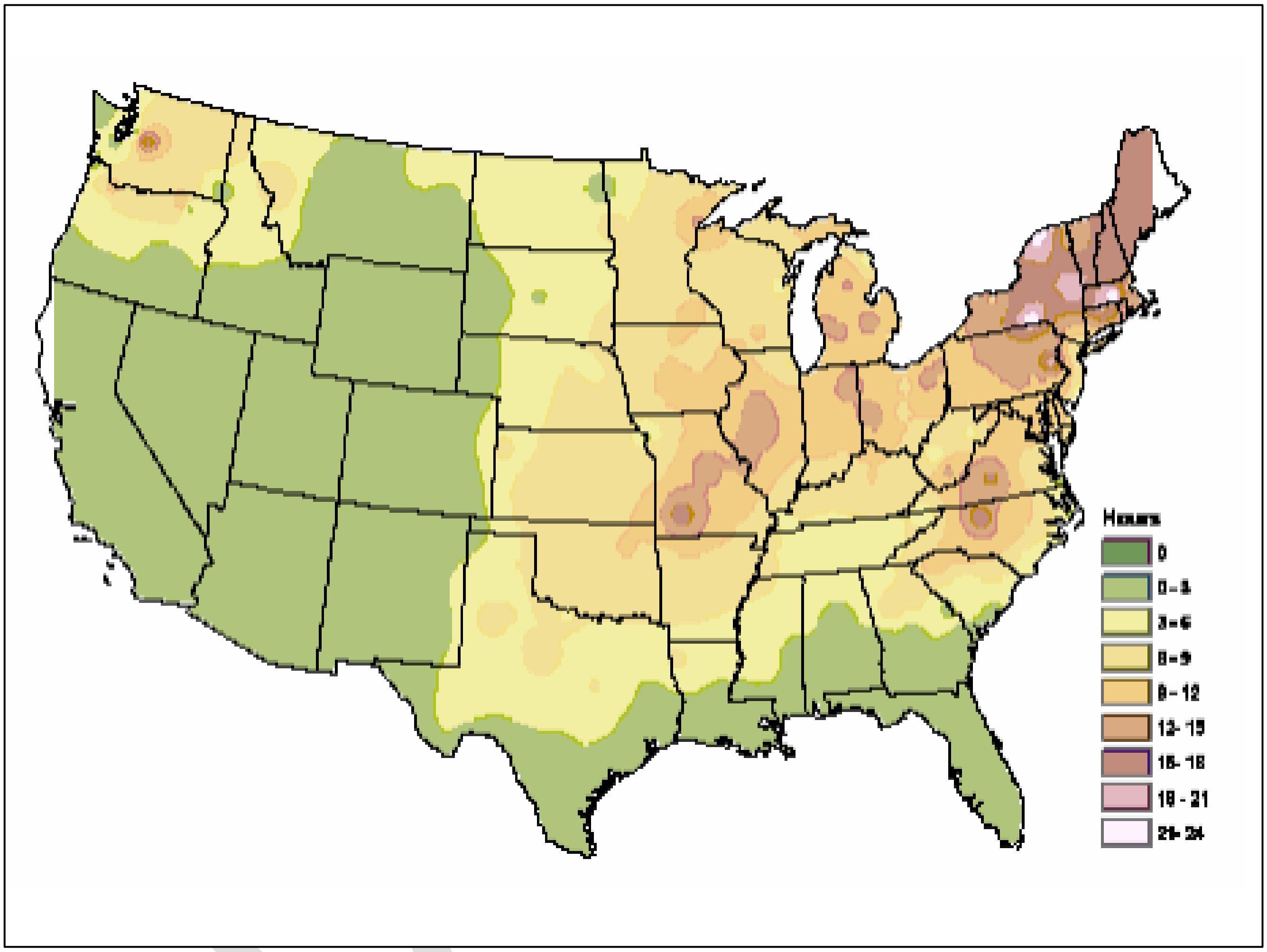
Geographic Location

Severe winter weather typically strikes Missouri more than once every year. Washington County receives winter weather events from heavy snows to freezing rain annually. Major snowstorms typically occur once each year, causing multiple school closings, as well as suspending business and

DRAFT

government activity. Washington County is vulnerable to heavy snow, ice, extreme cold temperatures and freezing rain. **Figure 3.71** illustrates statewide average number of hours per year with freezing rain. Washington County receives approximately 9 to 12 hours.

Figure 3.71. NWS Statewide Average Number of Hours per Year with Freezing Rain



Source: American Meteorological Society. "Freezing Rain Events in the United States."
http://ams.confex.com/ams/pdfpapers/71872.pdf

Strength/Magnitude/Extent

Severe winter storms include extreme cold, heavy snowfall, ice, and strong winds which can push the wind chill well below zero degrees in the planning area. Heavy snow can bring a community to a standstill by inhibiting transportation (in whiteout conditions), weighing down utility lines, and by causing structural collapse in buildings not designed to withstand the weight of the snow. Repair and snow removal costs can be significant. Ice buildup can collapse utility lines and communication towers, as well as make transportation difficult and hazardous. Ice can also become a problem on roadways if the air temperature is high enough that precipitation falls as freezing rain rather than snow.

Extreme cold often accompanies severe winter storms and can lead to hypothermia and frostbite in people without adequate clothing protection. Cold can cause fuel to congeal in storage tanks and supply lines, stopping electric generators. Cold temperatures can also overpower a building's heating system and cause water and sewer pipes to freeze and rupture. Extreme cold also increases the likelihood for ice jams on flat rivers or streams. When combined with high winds from winter storms, extreme cold becomes extreme wind chill, which is hazardous to health and safety.

The National Institute on Aging estimates that more than 2.5 million Americans are elderly and especially vulnerable to hypothermia, with the isolated elders being most at risk. About 10 percent of people over the age of 65 have some kind of bodily temperature-regulating defect, and 3-4 percent of all hospital patients over 65 are hypothermic.

Also, at risk are those without shelter, those who are stranded, or who live in a home that is poorly insulated or without heat. Other impacts of extreme cold include asphyxiation (unconsciousness or death from a lack of oxygen) from toxic fumes from emergency heaters; household fires, which can be caused by fireplaces and emergency heaters; and frozen/burst pipes.

Buildings with overhanging tree limbs are more vulnerable to damage during winter storms when limbs fall. Businesses experience loss of income as a result of closure during power outages. In general, heavy winter storms increase wear and tear on roadways though the cost of such damages is difficult to determine. Businesses can experience loss of income as a result of closure during winter storms.

Overhead power lines and infrastructure are also vulnerable to damages from winter storms. In particular, ice accumulation during winter storms can damage power lines and equipment. Damages also occur to lines and equipment from falling trees and tree limbs weighted down by ice. Potential losses could include cost of repair or replacement of damaged facilities and lost economic opportunities for businesses.

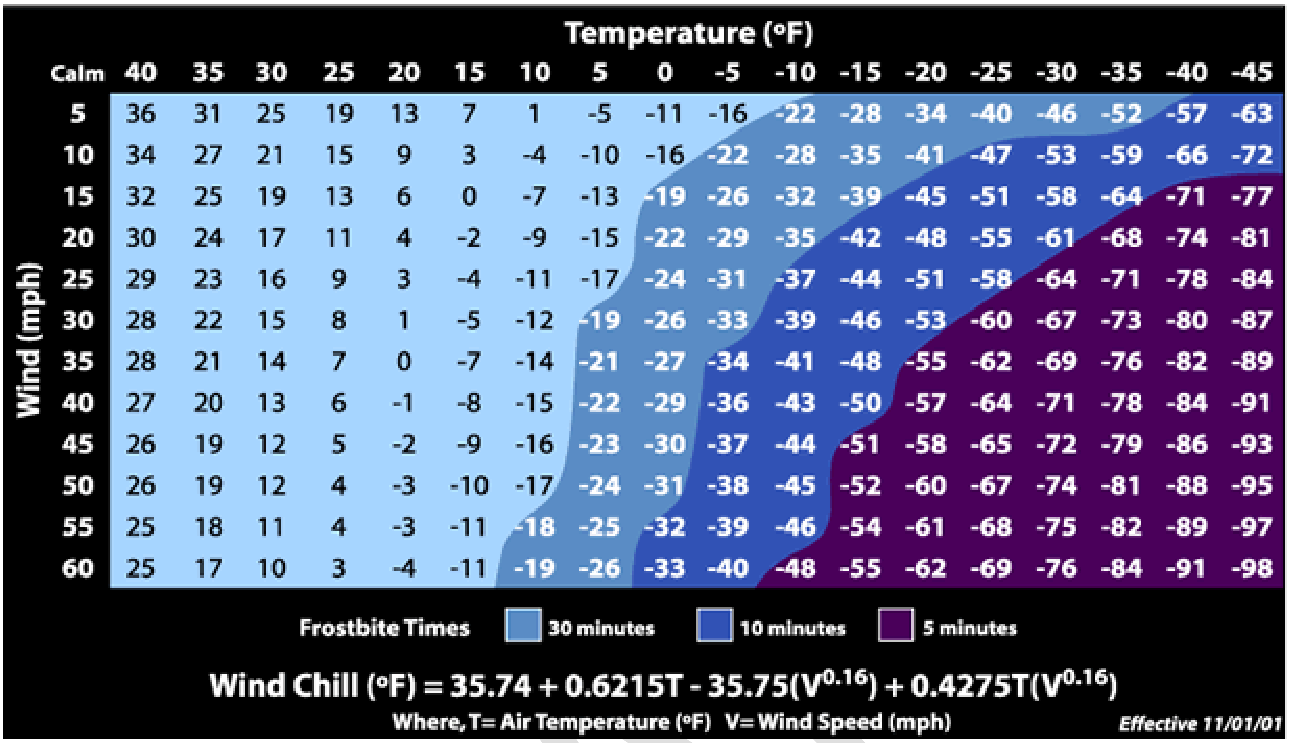
Secondary effects from loss of power could include burst water pipes in homes without electricity during winter storms. Public safety hazards include risk of electrocution from downed power lines. Specific amounts of estimated losses are not available due to the complexity and multiple variables associated with this hazard. Standard values for loss of service for utilities reported in FEMA's 2009 BCA Reference Guide, the economic impact as a result of loss of power is $126 per person per day of lost service.

Wind can greatly amplify the impact of cold ambient air temperatures. Provided by the National Weather Service, **Figure 3.72** below shows the relationship of wind speed to apparent temperature and typical time periods for the onset of frostbite.

Winter storms, cold, frost, and freeze all can influence or negatively impact crop production. However, data obtained from the USDA's Risk Management Agency for insured crop losses indicates that there were no claims paid in Washington County between 2001 and 2020 for severe winter weather.

DRAFT

Figure 3.72. Wind Chill Chart



Temperature (ºF)

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

Wind Chill (ºF) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$

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

Effective 11/01/01

Source: National Weather Service, http://www.nws.noaa.gov/om/winter/windchill.shtml

Previous Occurrences

Data was obtained from the NCEI for winter weather reported events and damages between 2001 and 2020 (**Table 3.71**). This data includes variables such as blizzard, cold/wind chill, extreme cold/wind chill, heavy snow, ice storm, sleet, winter storm, and winter weather. Additionally, narratives for specific events are listed below.

Table 3.71. NCEI County A Winter Weather Events Summary, 2001 - 2020

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Ice Storm	2/21/2001	0	0	0
Winter Storm	2/25/2002	0	0	0
Winter Storm	12/4/2002	0	0	0
Winter Storm	12/24/2002	0	0	0
Winter Storm	2/23/2003	0	0	0
Winter Storm	2/23/2003	0	0	0
Winter Storm	12/13/2003	0	0	0
Winter Storm	1/25/2004	0	0	0
Winter Storm	12/8/2005	0	0	0

Type of Event	Inclusive Dates	# of Injuries	Property Damages	Crop Damages
Winter Storm	11/30/2006	0	100000	0
Winter Storm	12/1/2006	0	215000	0
Winter Weather	12/8/2007	0	0	0
Heavy Snow	12/15/2007	0	0	0
Sleet	2/21/2008	0	0	0
Winter Weather	2/23/2008	0	0	0
Winter Storm	3/3/2008	0	0	0
Winter Storm	1/26/2009	0	0	0
Cold/Wind Chill	1/1/2010	0	0	0
Winter Storm	1/31/2011	0	0	0
Winter Storm	2/1/2011	0	0	0
Winter Storm	2/21/2013	0	0	0
Winter Storm	12/5/2013	0	0	0
Winter Storm	1/5/2014	0	0	0
Cold/Wind Chill	1/6/2014	0	0	0
Winter Storm	3/1/2014	0	0	0
Heavy Snow	2/20/2015	0	0	0
Ice Storm	1/13/2017	0	0	0
Heavy Snow	1/11/2019	0	0	0
Winter Storm	12/15/2019	0	0	0
Total	**29**	**0**	**$315K**	**0**

Source: NCEI, data accessed [10/06/2021]

DRAFT

Notable Winter Narratives:

1. **02/21/2001:** A fast moving winter storm put a coating of ice on a portion of southeast Missouri. The freezing rain changed over to sleet and snow leaving 2 to 3 inches of snow on top of the ice. Trees and power lines were down throughout the area. Transportation was brought to a halt from the evening of the 21st through the 22nd.

2. **02/25/2002:** Snowfall of 1 to 4 inches hit portions of Central and Eastern Missouri from late night on February 25 to the early morning hours of February 26. In addition, strong winds developed during the morning hours of the 26th causing some drifting snow. The heaviest snow, 3 to 4 inches, primarily fell from just south and west of St. Louis to the St. Louis area. Many schools across the region were closed on the 26th. Numerous auto accidents occurred during the event.

3. **12/04/2002:** The first winter storm of the season dropped from between 3 to 6 inches of snow across parts of South Central and Southeast Missouri. Virtually all area schools were closed

through Thursday as many rural roads remained very hazardous to travel.

4. **12/24/2002:** A Christmas Eve snowstorm hit parts of Southeast Missouri dropping from between 7 to 12 inches of snow across the area

5. **02/23/2003:** Yet another winter storm struck Southeast Missouri on the 23rd - 24th. Snowfall amounts ranged from between 6 - 8 inches across the area. Virtually all schools were closed on Monday the 24th. Due to all the school closings over the winter, many schools in the area were going to have to remain in session well into June.

6. **12/13/2003:** The first snow of the season hit much of East Central and parts of Southeast Missouri on the 13th. Snowfall was mostly in the 2-to-3-inch range.

7. **01/25/2004:** A combination of freezing rain, sleet and snow fell bringing the region to a standstill. The event started with a period of freezing rain early Sunday morning. Some places received 1/4 to 1/2 inch of freezing rain. The freezing rain changed to sleet by mid-morning with some locations in Central and East Central Missouri receiving between 1 to 2 inches of sleet. By afternoon, the sleet changed to snow and accumulated another 1 to 2 inches. Luckily it was a Sunday, as transportation was brought to a halt across the region. Some power outages were also reported in Central Missouri. Many schools across the region were closed into mid-week as another fast-moving storm brought another inch or two of snow Monday night and early Tuesday.

8. **12/08/2005:** The first significant winter storm of the season hit the area dropping between 2 to around 6 inches of snow. Most of Central Missouri picked up about 2 inches, East Central and Southeast Missouri saw 2 - 4 inches, and Northeast Missouri received from 2 to near 6 inches.

9. **11/30/2006**: A major winter storm hit Central, Northeast, East Central and parts of Southeast Missouri from November 30 through December 1. Over a foot of snow fell across parts of Central Missouri while a major ice storm hit parts of East Central and Southeast Missouri, including the St. Louis area. Ice accumulations of 1 inch or more downed trees and power lines resulting in at least 300,000 electric customers losing service for up to a week. Downed limbs and trees damaged homes and automobiles across the area as well. Many rural schools were closed for several days due to slick roads and power outages. The National Guard was called out to several counties to assist with debris removal and other emergency services. Officials reported seven people suffered from carbon monoxide poisoning. The City of Potosi lost water service for a couple of days due to the power outage.

10. **12/08/2007:** Light freezing rain and sleet fell across southeast Missouri the weekend of December 8th into the early part of the next week. From between 1/8 to 1/4 inch of ice accumulated along with light amounts of sleet. Travel was disrupted across the area, but overall, the region fared well with little damage and few power outages reported.

11. **12/15/2007:** Snowfall up to 8 inches fell across east central Missouri. Travel was disrupted through the weekend.

12. **02/21/2008:** Another winter storm dropped freezing rain, sleet and some light snow across Central, Southeast, and East Central Missouri starting during the early morning hours on the 21st and finally ending shortly after midnight on the 22nd.

13. **02/23/2008:** Between two to four inches of snow fell across Central and Southeast Missouri from the evening of the 23rd into the early morning of the 24th. The heaviest band which

DRAFT

produced three to four inches of snow fell from Moniteau, Cole and Osage counties and then curved southeast into Gasconade, Crawford, Washington, Iron, and Reynolds counties.

14. **03/03/2008:** An early March winter storm dropped between 6 to 13 inches of snow across eastern and parts of southeast Missouri. Parts of southeast Missouri also received a quarter inch of ice from freezing rain and close to 1 inch of sleet. Transportation was brought to a halt in most areas and schools in rural areas of southeast Missouri were closed once again for several days. The event started overnight on March 3rd with freezing rain and sleet across southeast Missouri and light snow across east central counties. By midday on the 4th, a band of heavy snow developed from south central Missouri in Crawford County northeast across the St. Louis Metro area into southwest Illinois. This band of snow brought snowfall at the rate of two to three inches per hour at times.

15. **01/26/2009:** A winter storm dropped between 6 to 8 inches of mainly snow across Eastern and Southeast Missouri. The precipitation started with a mix of freezing rain and sleet. An average of 6 to 7 inches mainly snow fell across Washington County.

16. **01/01/2010:** The first twelve days of January 2010 was one of the coldest outbreaks in many years. For some locations, it was the first time the temperature dropped below zero in about 10 years.

17. **01/31/2011:** The first true blizzard in many years hit from Central to Northeast Missouri. Up to 20 inches of snow fell along with winds gusting over 40 mph. For many counties it was a record snowfall event. I-70 was shut down from Warren County to just east of Kansas City. The National Guard was called out to help clear County roads and assist with emergency transportation. The region was brought to a standstill for several days. A Federal disaster declaration was obtained for many counties in order to assist with the cost of snow removal. Light freezing rain and sleet started on Monday 1/31 with an inch of sleet accumulating by the early morning hours of Tuesday (2/1). By midday Tuesday (2/1) the precipitation had changed to snow and the wind began increasing. By late Tuesday (2/1) afternoon travel became extremely dangerous.

18. **02/21/2013:** A combination of freezing rain, sleet, and snow hit Southeast Missouri causing very hazardous conditions. Up to 4 - 5 inches of snow, mixed with sleet, fell across the northern part of the area. The southern part received 1 - 3 inches along with an inch of sleet and some freezing rain.

19. **01/05/2014:** A very strong winter storm dropped 6 - 12 inches of snow across East Central Missouri. Strong northerly winds produced snow drifts of 2 to 5 feet. All schools and most businesses were closed on the 5th and 6th, with many schools remaining closed for several days due to very cold temperatures and wind chills. The winter storm that brought heavy snow to much of the area followed that up with the coldest temperatures in 20 years. Wind Chill values the morning of the 6th ranged from -25 to -33.

20. **03/01/2014:** An early March winter storm dropped between .5 to 2 inches of sleet across East Central and Southeast Missouri. Some locations also picked up a couple of inches of snow.

21. **02/20/2015:** A winter storm brought a mix of winter weather to the region. One inch of sleet and some light freezing rain created hazardous winter weather conditions.

22. **01/13/2017:** An Ice Storm hit parts of Northeast, East Central and Southeast Missouri on Martin Luther King Weekend. The areas hardest hit were across Washington, Jefferson and the

DRAFT

northern half of St. Francois County. Numerous power outages were reported. There were also transportation issues, however they were minimized due to almost all schools and businesses closing on Friday, the first day of the event.

23. **01/11/2019:** Several rounds of heavy snow fell across Washington County beginning during the afternoon hours of January 11th through the early morning hours of January 13th. The co-op observer 4 southwest of Potosi reported 5.9 inches of snow with this event. A trained spotter 3.2 miles west of Potosi reported a storm total of 6.9 inches with this event.

24. **12/15/2019:** A winter storm moved into the region on Sunday, December 15th with snow moving into central Missouri by mid-morning. The snow spread west to east through the day and into the evening hours before tapering off. Snowfall rates during this period were between 1 to 2 inches an hour in some locations, especially along the I-70 corridor. Then most of the area saw some light freezing drizzle through Monday morning, December 16th before a second round of snow developed by mid-morning and persisted through Monday evening. The snow came to an end by midnight. Overall, a widespread 4 to 6 inches of snow fell during this event. Between 4 and 8 inches of snow fell across the county over a two-day period, with the majority of the snow falling in a two hour period on the 16th.

Washington County has been included in two federal disaster declarations for winter weather since 2007.[36]

Probability of Future Occurrence

From the data obtained from the NCEI [37], annual average percent probabilities were calculated for winter weather within Washington County (**Table 3.712**). There were 29 recorded events (**Table 3.711**) over a 20-year period. There is 100 percent annual average probability of winter weather occurrence (29 events/20 years)**,** with an average of 1.45 events per year.

Table 3.72. Annual Average % Probability of Winter Weather in Washington County

Location	Annual Avg. % P	Avg. # of Events
Washington County	100%	1.45

*P = probability; see page 3.24 for definition.

Vulnerability

Vulnerability Overview

Data was obtained from the 2018 Missouri State Hazard Mitigation Plan for vulnerability information regarding Washington County. Various data sources were utilized for statistical analysis including the following:

- National Centers for Environmental Information (NCEI) storm event data (1999 to December 31, 2019)
- HAZUS Building Exposure Value data

[36] https://www.fema.gov/data-visualization-summary-disaster-declarations-and-grants
[37] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

DRAFT

- Housing density data from the U.S. Census (2015 ACS)
- Calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina

From the statistical data collected, five factors were considered in determining overall vulnerability to severe winter weather as follows: housing density, building exposure, social vulnerability, likelihood of occurrence and average annual property loss. A rating value of one through five was assigned to each factor:

1) Low
2) Low-medium
3) Medium
4) Medium-high
5) High

Table 3.73 provides the factors considered and the ranges for the rating values assigned. After the individual ratings were determined for the common factors, a combined vulnerability rating was computed for severe winter weather. Those can be seen in **Table 3.74**. The housing density, building exposure and SOVI data for Washington County can be found in **Table 3.75**.

Table 3.73. Ranges for Severe Winter Weather Vulnerability Factor Ratings

Factors Considered	Low (1)	Low Medium (2)	Medium (3)	Medium High (4)	High (5)
Common Factors					
Housing Density (# per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2836.23
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Social Vulnerability	1	2	3	4	5
Likelihood of Occurrence (# of events/ yrs. of data)	1.05-1.43	1.44-1.76	1.77-2.10	2.11-2.67	2.68-4.57
Average Annual Property Loss (annual property loss/ yrs. Of data)	$0-$143,095.24	$143,095.25-$406,666.67	$406,666.68-$1,191,000.95	$1,191,000.96-$3,184,761.90	$3,184,761.91-$5,861,666.67

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.74. Ranges for Severe Winter Weather Combined Vulnerability Rating

	Low (1)	Low-medium (2)	Medium (3)	Medium-high-4	High (5)
Severe Winter Weather Combined Vulnerability	7-8	8-10	10-12	12-15	15-22

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.75. Housing Density, Building Exposure and SOVI Data for Washington County

Total Building Exposure (Hazus)	Building Exposure Rating	Housing Density	Housing Density Rating	SOVI Ranking	SOVI Rating
$1,730,96,000	1	14.34	1	Medium	3

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.71 provides the last piece of the data gathered from NCEI to complete the overall vulnerability analysis and the total overall vulnerability rating for severe winter weather. The total number of winter weather events includes blizzard, heavy snow, ice storm winter storm and winter weather events. The likelihood of occurrence is 1.8571 or 100 percent per year. The total annualized property loss is $15,000, which provides a total annualized property loss rating of two and an overall vulnerability rating of ten – which translates to an overall Low Medium vulnerability rating for the county for severe winter weather.

DRAFT

Table 3.76. Additional Statistical Data Compiled for Vulnerability Analysis for Washington County

Total number of Winter Weather Events	Likelihood of Occurrence	Likelihood of Occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
39	1.8571	3	$15,000	2	10	Low Medium

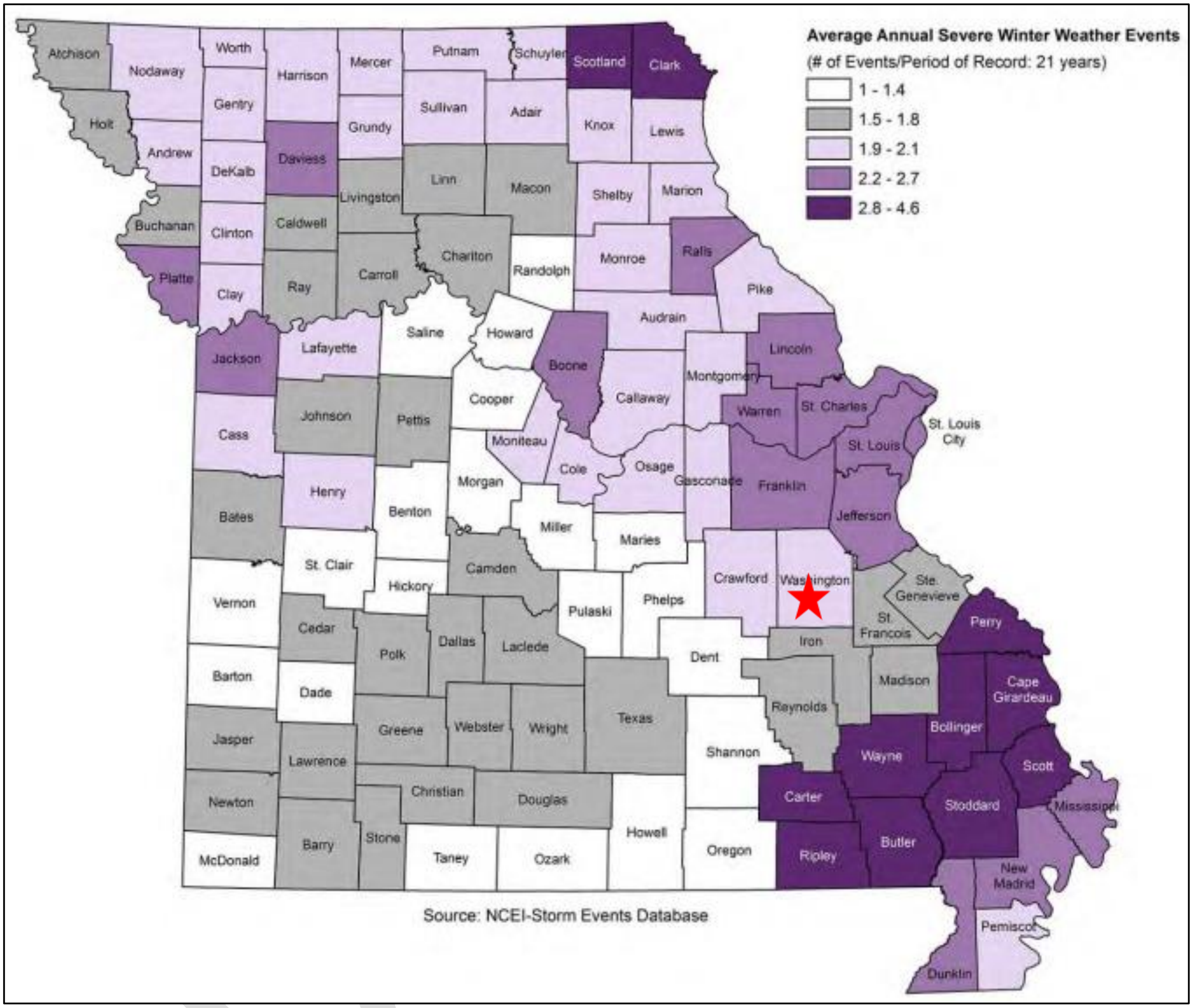
Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.73 illustrates the average annual occurrence of severe winter weather statewide. Washington County falls into the Low category of 1.9 to 2.1 events per year.

Figure 3.74 provides an illustration of the vulnerability summary of all Missouri counties for severe winter weather. Again, Washington County falls into the Low Medium rating for overall vulnerability.

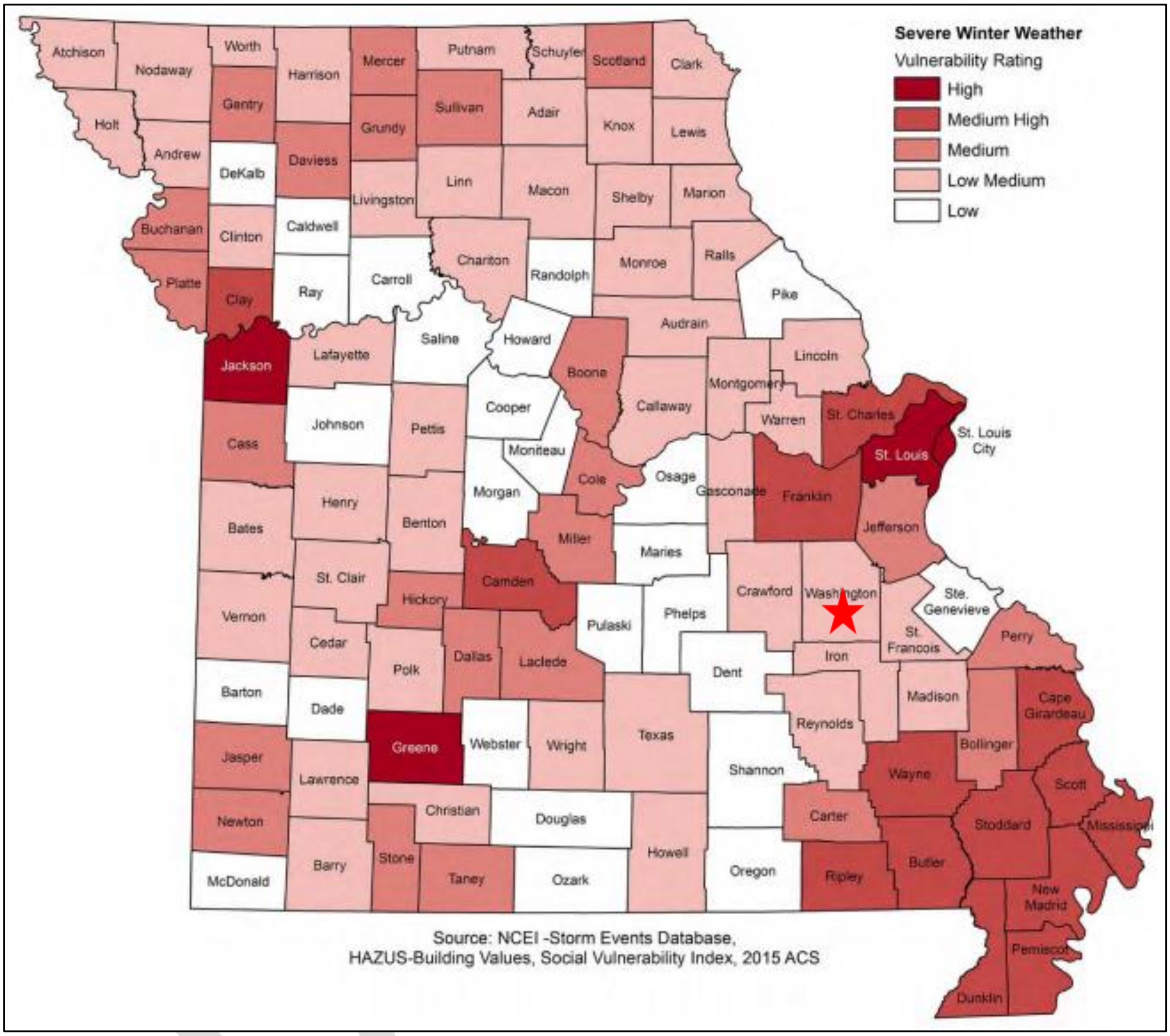
DRAFT

Figure 3.73. Average Annual Occurrence of Severe Winter Weather Events



*Source: 2018 Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.74. Vulnerability Summary for Severe Winter Weather



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Potential Losses to Existing Development

The next severe winter storm will most likely close schools and businesses for multiple days and make roadways hazardous for travel. Heavy ice accumulation may damage electrical infrastructures, causing prolonged power outages for large portions of the region. In addition, freezing temperatures make water lines vulnerable to freeze/thaw. Fallen tree limbs also pose a threat to various structures/infrastructures across the county. According to the 2018 state plan, Washington County can expect annual property losses of $15,000 due to severe winter storms.

Future Development

Data for future development for the planning area is sparse. However, winter weather will affect the county as a whole. Any future development is at risk to damages and increased exposure. In addition, the county's population within the cities is anticipated to increase, which would increase the number of individuals at risk during a winter weather event.

Hazard Summary by Jurisdiction

Variations in impacts are not anticipated for severe winter weather across the planning area. Yet, areas with high number of mobile homes tend to experience increased damages. Unincorporated Washington County has the highest abundance of mobile homes, making the area more prone to increase exposure to damage. In addition, rural areas of the county may be more susceptible to power outages due to more power infrastructure being exposed to the risk of damage from winter storms.

Problem Statement

In summary, Washington County is expected to experience at least one severe winter weather event annually; however, the county has a low vulnerability rating. Jurisdictions should enhance their weather monitoring to be better prepared for severe weather hazards. If jurisdictions monitor winter weather, they can dispatch road crews to prepare for the hazard. County and city crews can also trim trees along power lines to minimize the potential for outages due to snow and ice. Citizens should also be educated about the benefits of being proactive to alleviate property damage as well preparing for power outages.

DRAFT

3.4.9 Tornado

Some specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.10, Page 3.355 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- NWS Enhanced F Scale for Tornado Damage including damage indicators and degrees of damage www.spc.noaa.gov/faq/tornado/ef-scale.html;
- Tornado Activity in the U.S. map (1950-2006), FEMA 320, Taking Shelter from the Storm, 3rd edition;
- Tornado Alley in the U.S. map, http://tornadochaser.com/education/tornado-alley/
- National Centers for Environmental Information, https://www.ncdc.noaa.gov/stormevents/;
- Midwest Regional Climate Center, https://mrcc.purdue.edu/gismaps/cntytorn.htm;
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkc0jgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
  - Number of Tornadoes by County
  - Percentage of Mobile Homes in 2015 by County
  - Average annual tornado events by County
  - Vulnerability to tornado events by County
  - Annualized property loss for tornado events by County
  - Annualized property loss for tornado events by County

Hazard Profile

Hazard Description

The NWS defines a tornado as "a violently rotating column of air extending from a thunderstorm to the ground." It is usually spawned by a thunderstorm and produced when cool air overrides a layer of warm air, forcing the warm air to rise rapidly. Often, vortices remain suspended in the atmosphere as funnel clouds. When the lower tip of a vortex touches the ground, it becomes a tornado.

High winds not associated with tornadoes are profiled separately in this document in **Section 3.4.7,** Severe Thunderstorms Including High Winds, Hail, and Lightning.

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

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

A typical tornado can be described as a funnel-shaped cloud in contact with the earth's surface that is "anchored" to a cloud, usually a cumulonimbus. This contact on average lasts 30 minutes and covers

DRAFT

an average distance of 15 miles. The width of the tornado (and its path of destruction) is usually about 300 yards. However, tornadoes can stay on the ground for upward of 300 miles and can be up to a mile wide. The National Weather Service, in reviewing tornadoes occurring in Missouri between 1950 and 1996, calculated the mean path length at 2.27 miles and the mean path area at 0.14 square mile.

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

Geographic Location

In Missouri, tornadoes occur most frequently between April and June, with April and May usually producing the most tornadoes. However, tornadoes can arise at any time of the year. While tornadoes can happen at any time of the day or night, they are most likely to occur between 3 p.m. and 9 p.m. Furthermore, tornadoes can occur anywhere across the state of Missouri, including Washington County.

Severity/Magnitude/Extent

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

Tornado magnitude is classified according to the EF- Scale (or the Enhanced Fujita Scale, based on the original Fujita Scale developed by Dr. Theodore Fujita, a renowned severe storm researcher). The EF- Scale (**Table 3.77**) attempts to rank tornadoes according to wind speed based on the damage caused. This update to the original F Scale was implemented in the U.S. on February 1, 2007.

Table 3.77. Enhanced F Scale for Tornado Damage

Fujita Scale			Derived EF Scale		Operational Scale	
F #	Fastest 1/4 - Mile (mph)	3 Second Gust (mph)	EF #	3 Second Gust (mph)	EF #	3 Second Gust (mph)
0	40 - 72	45 - 78	0	65 - 85	0	65 - 85
1	73 - 112	79 - 117	1	86 - 109	1	86 - 110
2	113 - 157	118 - 161	2	110 - 137	2	111 - 135
3	158 - 207	162 - 209	3	138 - 167	3	136 - 165
4	208 - 260	210 - 261	4	168 - 199	4	166 - 200
5	261 - 318	262 - 317	5	200 - 234	5	Over 200

Source: The National Weather Service, www.spc.noaa.gov/faq/tornado/ef-scale.html

The wind speeds for the EF scale and damage descriptions are based on information on the NOAA Storm Prediction Center as listed in **Table 3.78.** The damage descriptions are summaries. For the actual EF scale it is necessary to look up the damage indicator (type of structure damaged) and refer to the degrees of damage associated with that indicator.

Table 3.78. Enhanced Fujita Scale with Potential Damage

Enhanced Fujita Scale			
Scale	**Wind Speed (mph)**	**Relative Frequency**	**Potential Damage**
EF0	**65-85**	**53.5%**	Light. Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage (i.e. those that remain in open fields) are always rated EF0).
EF1	**86-110**	**31.6%**	Moderate. Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
EF2	**111-135**	**10.7%**	Considerable. Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes complete destroyed; large trees snapped or uprooted; light object missiles generated; cars lifted off ground.
EF3	**136-165**	**3.4%**	Severe. Entire stores of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations blown away some distance.
EF4	**166-200**	**0.7%**	Devastating. Well-constructed houses and whole frame houses completely levelled; cars thrown and small missiles generated.
EF5	**>200**	**<0.1%**	Explosive. Strong frame houses levelled off foundations and swept away; automobile-sized missiles fly through the air in excess of 300 ft.; steel reinforced concrete structure badly damaged; high rise buildings have significant structural deformation; incredible phenomena will occur.

Source: NOAA Storm Prediction Center, http://www.spc.noaa.gov/efscale/ef-scale.html

Enhanced weather forecasting has provided the ability to predict severe weather likely to produce tornadoes days in advance. Tornado watches can be delivered to those in the path of these storms several hours in advance. Lead time for actual tornado warnings is about 30 minutes. Tornadoes have been known to change paths very rapidly, thus limiting the time in which to take shelter. Tornadoes may not be visible on the ground if they occur after sundown or due to blowing dust or driving rain and hail.

Previous Occurrences

Table 3.79 illustrates NCEI data reported for tornado events and damages from 2001 to 2020 in the planning area.

There are limitations to the use of NCEI tornado data that must be noted. For example, one tornado may contain multiple segments as it moves geographically. A tornado that crosses a county line or state line is considered a separate segment for the purposes of reporting to the NCEI. Also, a tornado that lifts off the ground for less than 5 minutes or 2.5 miles is considered a separate segment. If the tornado lifts off the ground for greater than 5 minutes or 2.5 miles, it is considered a separate tornado. Tornadoes reported in Storm Data and the Storm Events Database are in segments.

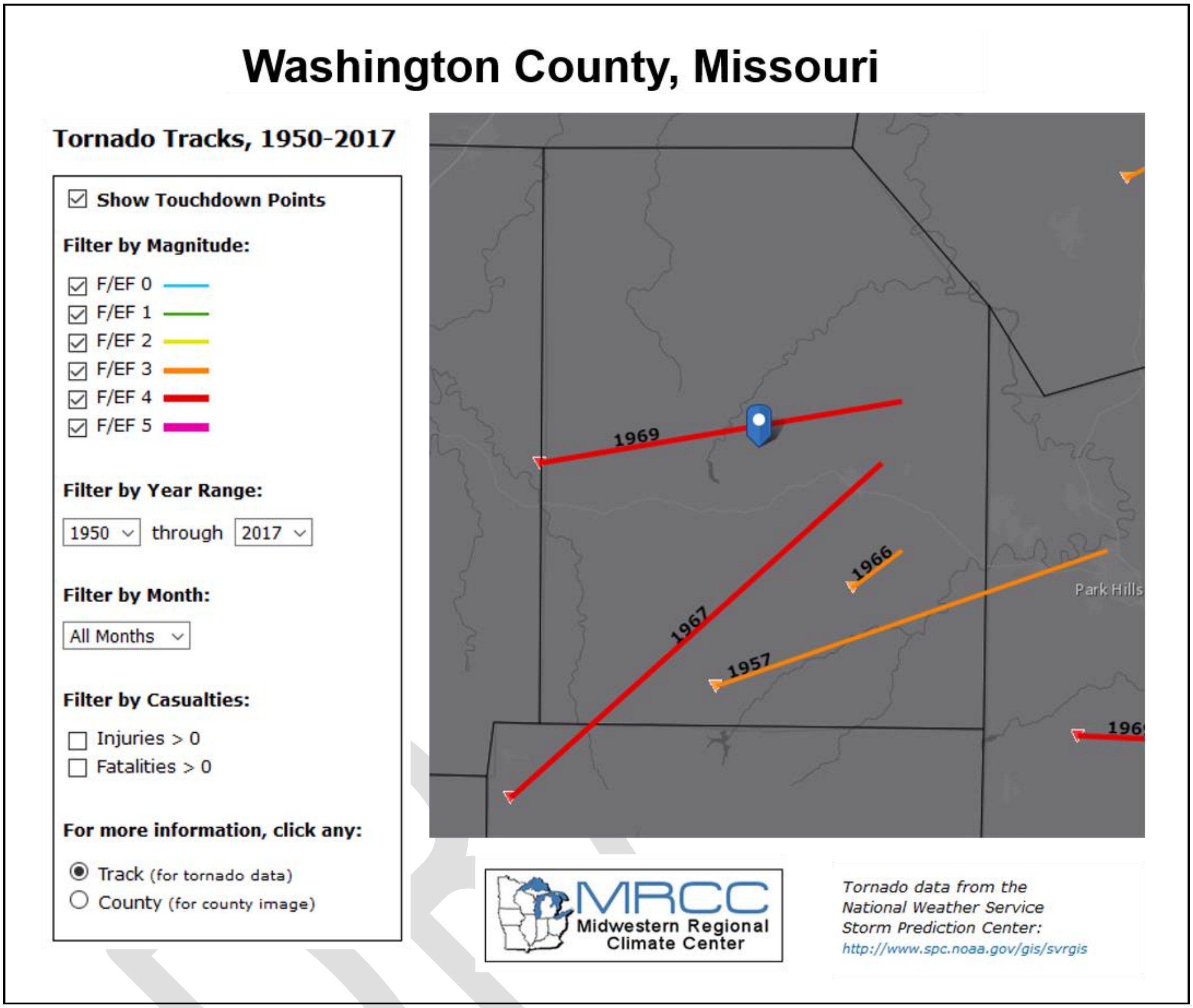
Table 3.79. Recorded Tornadoes in Washington County, 2001– 2020

Date	Beginning Location	Ending Location	Length (miles)	Width (yards)	F/EF Rating	Death	Injury	Property Damage	Crop Damages
4/24/2002	1S Caledonia	1S Caledonia	1	75	F1	0	0	0	0
5/12/2002	37.88/-90.72	Hopewell	0.1	30	F0	0	0	0	0
10/18/2004	1NE Potosi	1NE Potosi	0.2	80	F1	0	7	0	0
10/18/2004	1NE Potosi	2NE Potosi	0.8	50	F0	0	0	0	0
10/18/2004	2ENE Potosi	3ENE Potosi	0.8	40	F0	0	0	0	0
10/18/2004	37.95/-90.73	Mineral Point	0.8	40	F0	0	0	0	0
10/18/2004	37.95/-90.73	1NE Mineral Point	0.8	40	F0	0	0	0	0
9/22/2006	1SW Richwoods	2ENE Richwoods	3.1	150	F1	0	0	0	0
9/22/2006	4E Richwoods	5E Rishwoods	1.4	100	F1	0	0	0	0
4/30/2010	3ENE Richwoods	4ENE Richwoods	0.73	100	EF0	0	0	0	0
4/8/2015	0S Potosi	1S Potosi Washington County AR	4.1	300	EF1	0	0	0	0
7/8/2015	2ENE Caledonia	2ENE Caledonia	0.18	100	EF0	0	0	0	0
3/24/2019	1NNW Cadet	1NNW Cadet	0.01	20	EF0	0	0	0	0
Total	**-**	**-**	**14.02**	**1,125**	**-**	**0**	**7**	**0**	**0**

Source: National Centers for Environmental Information, http://www.ncdc.noaa.gov/stormevents/

Figure 3.75 depicts historic tornado paths across Washington County.

Figure 3.75. Washington County Map of Historic Tornado Paths (1950 – 2017)



Source: https://mrcc.purdue.edu/gismaps/cntytorn.htm

According to the USDA Risk Management Agency's record, there were no insurance payments in Washington County for crop damages as a result of tornadoes between 2001 and 2020.

Probability of Future Occurrence

From the data obtained from the NCEI[38], an annual average percent probability was calculated for tornadoes within Washington County (**Table 3.81**). There is a 65.0 percent annual average probability of a tornado occurrence (13 events/20 years x 100). Tornado events can be found in **Table 3.79**. In addition, **Figure 3.76,** obtained from the 2018 Missouri State Hazard Mitigation Plan, also illustrates tornado probabilities across the United States and further shows Washington County's average probability of 21-41 percent.

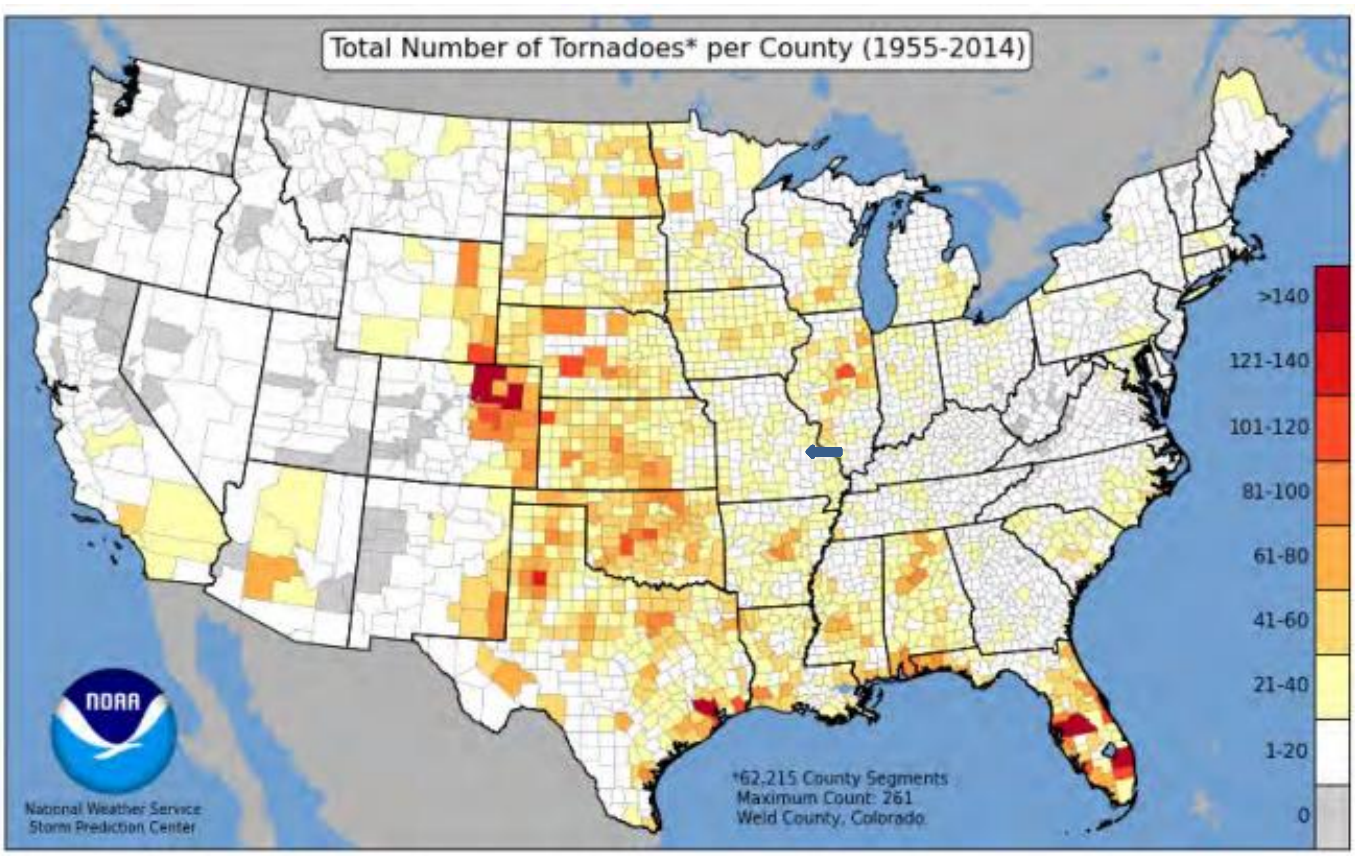
[38] http://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=29%2CMISSOURI

Table 3.80. Annual Average % Probability of Tornadoes in Washington County

Location	Annual Avg. % P
Washington County	65.0%

*P = probability; see page 3.24 for definition.

Figure 3.76. Tornado Activity in the United States



*Source: 2018 Missouri State Hazard Mitigation Plan, *Blue arrow indicates Washington County*

Vulnerability

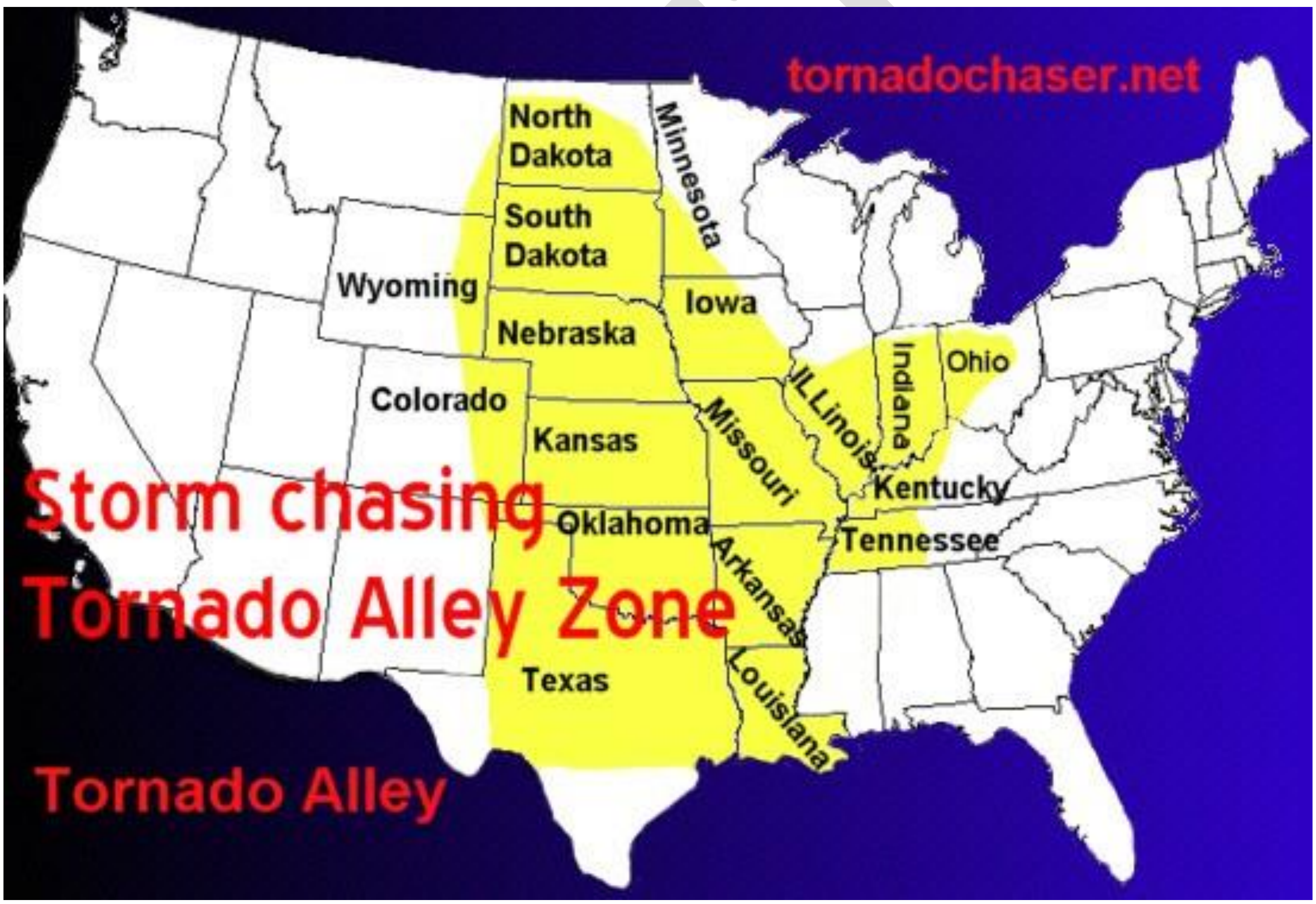
Vulnerability Overview

Many tornadoes are capable of great destruction and every tornado is a potential killer. Tornadoes can topple buildings, destroy mobile homes, uproot trees, hurl people and animals through the air for hundreds of yards and fill the air with lethal, windblown debris. Sticks, glass, roofing material and lawn furniture all become deadly missiles when driven by tornado winds.[39] Washington County resides in a region of the United States that has a high frequency of dangerous and destructive tornadoes. This region seen in **Figure 3.77** is referred to as "Tornado Alley".

[39] 2018 Missouri Hazard Mitigation Plan

The 2018 Missouri Hazard Mitigation Plan used statistical analysis of data from several sources to determine vulnerability to tornadoes across the state. HAZUS building exposure value data, population density and mobile home data from the U.S. Census (2015 ACS), the calculated Social Vulnerability Index for Missouri Counties from the Hazards and Vulnerability Research Institute in the Department of Geography at the University of South Carolina, and storm events data (1950 to December 31, 2016) from the National Centers for Environmental Information (NCEI). One limitation to the NCEI data is that many tornadoes that may have occurred in uninhabited areas and some in inhabited areas, may not have been reported. In addition, NOAA data cannot show a realistic frequency distribution of different Fujita scale tornado events, except for recent years. For these reasons a parametric model based on a combination of many physical aspects of the tornado to predict future expected losses was not used. The statistical model used for this analysis was probabilistic based purely on tornado frequency and historic losses.

Figure 3.77. Tornado Alley in the U.S.



Source: http://tornadochaser.net/

Six factors were considered in determining overall vulnerability to tornadoes as follows: building exposure, population density, social vulnerability, percentage of mobile homes, likelihood of occurrence and annual property loss. Based on natural breaks in the statistical data, a rating value of one through five was assigned to each factor. These rating values correspond to the following descriptive terms:

1) Low
2) Low-medium
3) Medium

4) Medium-high
5) High

Table 3.81 provides the factors used and ranges for the rating values assigned. Once the ranges were established and applied to all factors, the ratings were combined to determine overall vulnerability. **Table 3.82** illustrates the ranges for tornado combined vulnerability rating.

Table 3.81. Ranges for Tornado Vulnerability Factor Ratings

Factors Considered	Low (1)	Low-medium (2)	Medium (3)	Medium-High (4)	High (5)
Common Factors					
Building Exposure ($)	$269,532-$3,224,641	$3,224,642-$8,792,829	$8,792,830-$22,249,768	$22,249,769-$46,880,213	$46,880,214-$138,887,850
Population Density (#per sq. mile)	4.11-44.23	44.24-134.91	134.92-259.98	259.99-862.69	862.70-2,836.23
Social Vulnerability	1	2	3	4	5
Percent Mobile Homes	0.2-4.5%	4.51-8.8%	8.81-14%	14.01-21.2%	21.21-33.2%
Likelihood of Occurrence (# of events/ yrs. of data)	0.119 - 0.208	0.209 - 0.313	0.314 - 0.417	0.418 - 0.552	0.553 - 0.791
Total Annualized Property Loss ($ / yrs. of data)	$974 - $281,874	$281,875 - $991,825	$991,826 - $2,099,000	$2,099,001 - $5,047,474	$5,047,475 - $42,467,109

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.82. Ranges for Tornado Combined vulnerability Rating

	Low (1)	Low-medium (2)	Medium (3)	Medium-High (4)	High (5)
Tornado Combined Vulnerability	7-10	11-12	13-14	15-16	17-21

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.83 provides data on building exposure, population density, SOVI and mobile home data for Washington County that is used to determine overall vulnerability.

Table 3.83. Building Exposure, Population Density, SOVI and Mobile Home Data for Washington County

Total Building Exposure (Hazus)	Exposure Rating	Population Density	Population Rating	SOVI Ranking	SOVI Rating	Percent Mobile Homes	Mobile Home Rating
$1,730,986,000	1	32.62	1	Medium	3	33.2	5

Source: 2018 Missouri Hazard Mitigation Plan

Table 3.84 provides additional data, obtained from the National Centers for Environmental Information to complete the overall vulnerability analysis and the total overall vulnerability rating for tornadoes. **Figure 3.78** shows the percent of mobile homes per county throughout the state with Washington

County determined to have high mobile home density at 21.3 percent to 33.2 percent. **Figure 3.79** provides the average annual occurrence of tornadoes in Missouri and illustrates that Washington County falls into the middle quadrant for historical events – 31 to 41 percentiles. Finally, **Figure 3.80** shows the county's overall vulnerability to tornadoes – Medium-High.

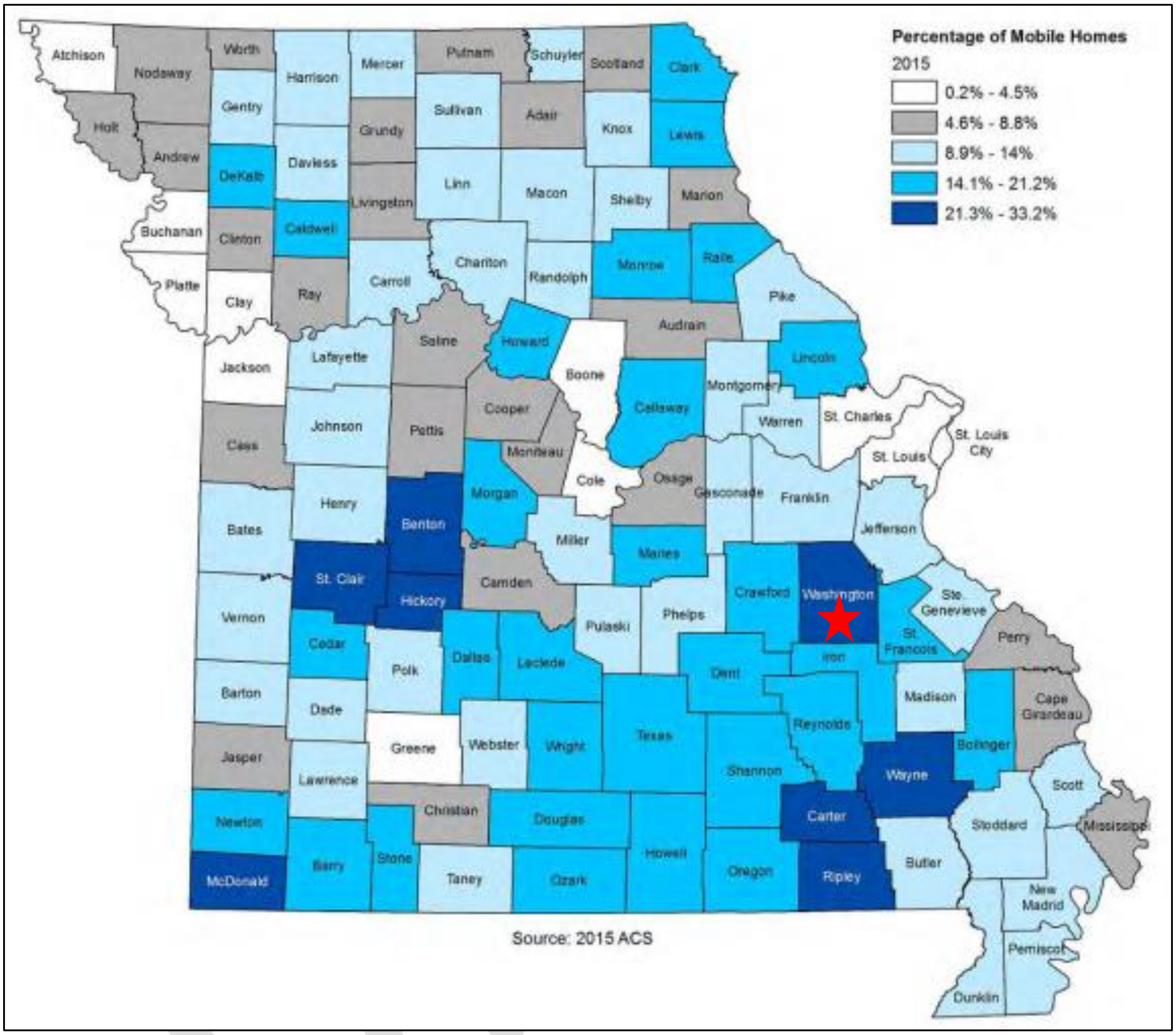
Table 3.84. Likelihood of Occurrence, Annual Property Loss and Overall Vulnerability Rating for Tornadoes for Washington County

Total Number of Tornadoes	Likelihood of Occurrence	Likelihood of occurrence Rating	Total Annualized Property Loss	Total Annualized Property Loss Rating	Overall Vulnerability Rating	Overall Vulnerability Rating Description
25	0.373	3	$840,299	2	15	Medium High

Source: 2018 Missouri Hazard Mitigation Plan

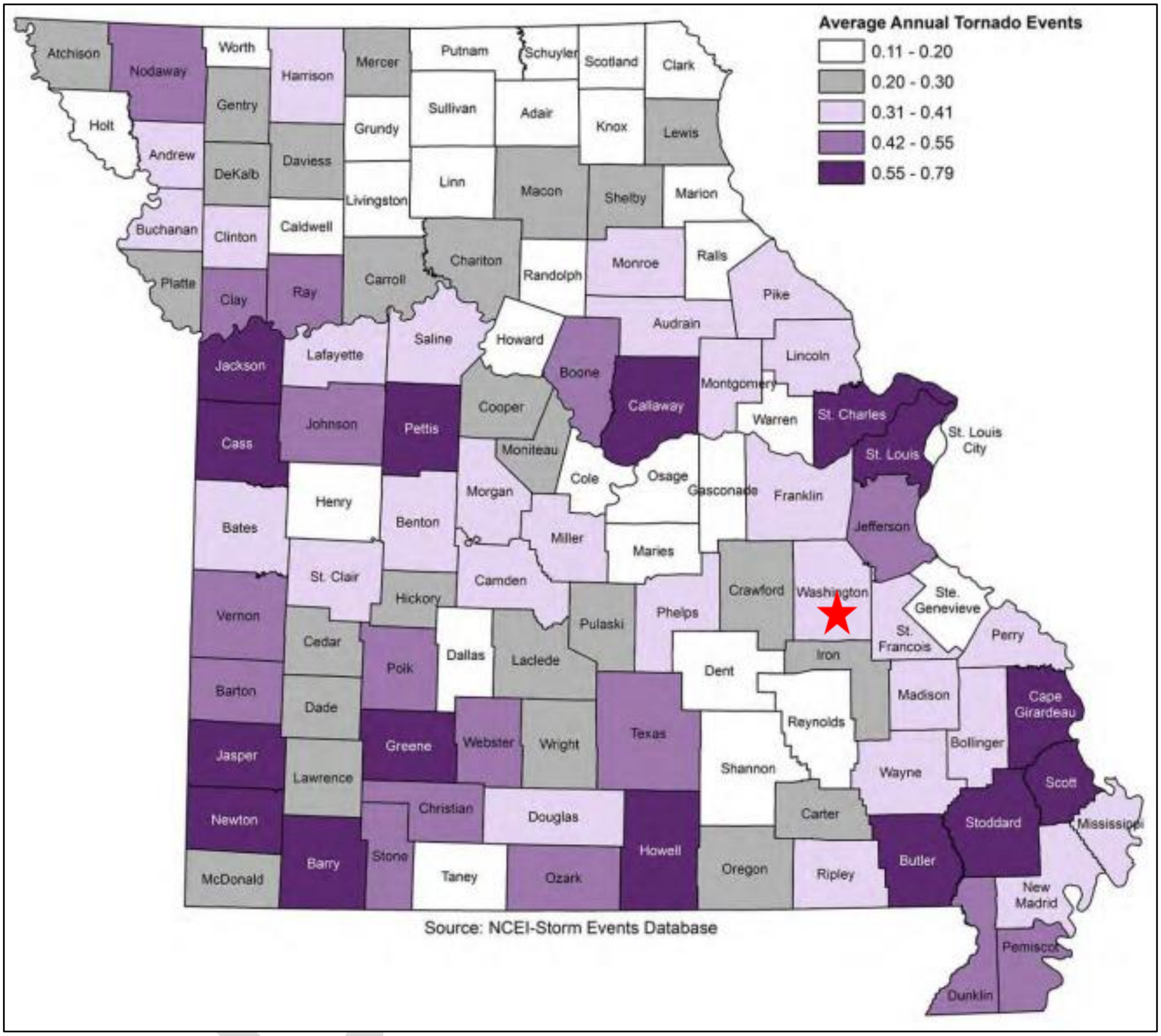
DRAFT

Figure 3.78. Missouri – Percent of Mobile Homes Per County



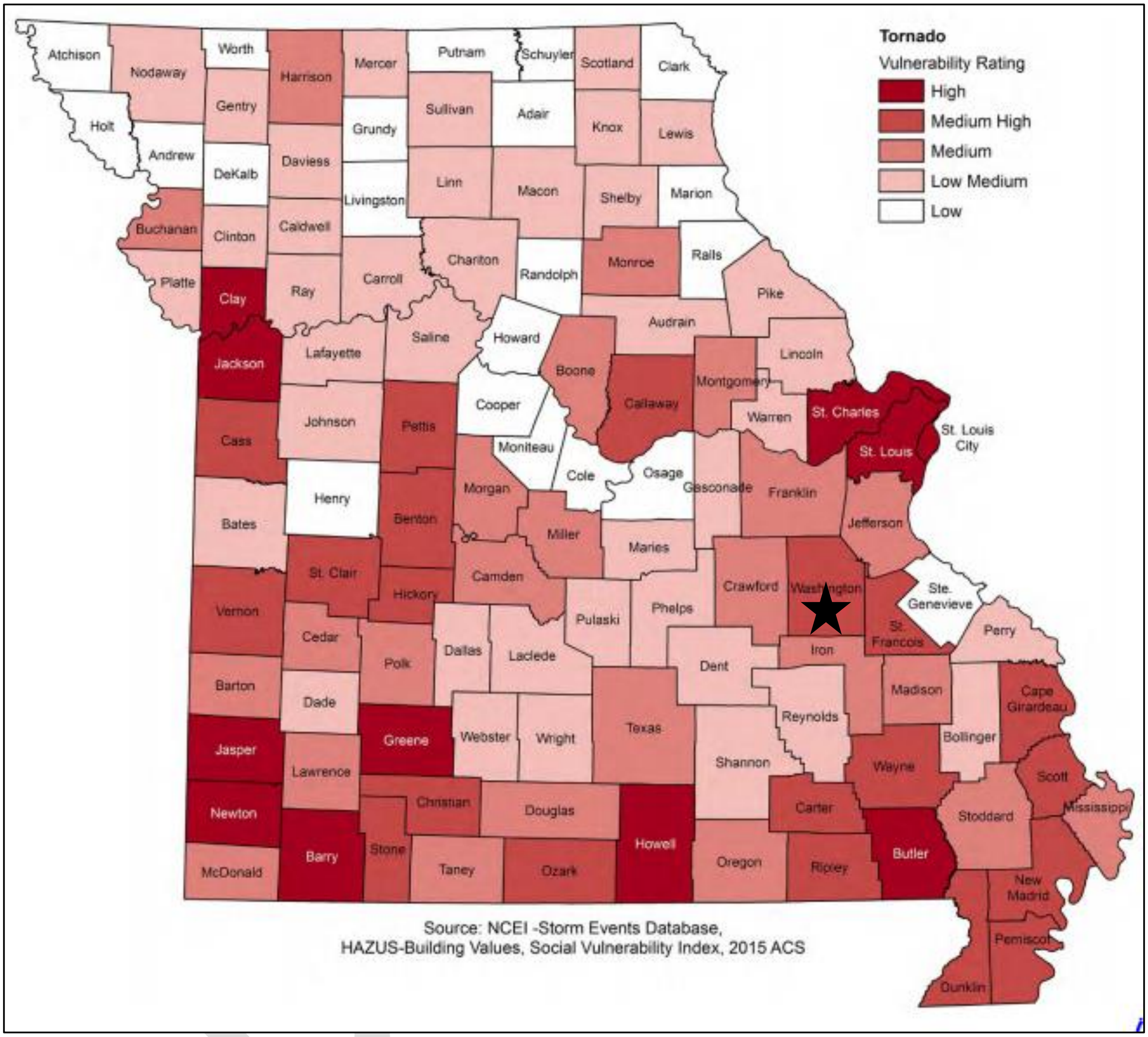
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.79. Average Annual Occurrence for Tornadoes



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.80. Overall Vulnerability to Tornadoes



*Source: 2018 Missouri State Hazard Mitigation Plan, *Black star indicates Washington County*

Potential Losses to Existing Development

The total annualized building losses for Washington County is $840,299 Additionally, the largest recorded tornado in the planning area has been an EF1. Utilizing this information, we can infer that there is potential for another tornado of equivalence.

Future Development

As populations and development increases across the county, the vulnerability will increase as well. In order to protect jurisdictions from increased tornado vulnerabilities future analysis, training, and implementation should be considered at the planning, engineering, and architectural design stages.

Hazard Summary by Jurisdiction

As previously stated, a tornado event could occur anywhere in the planning area. However, some jurisdictions would suffer heavier damages because of the age of housing or high concentration of mobile homes. See **Table 3.33** for jurisdictions most vulnerable to damage due to the age of the structure. Based on structure age, the city of Caledonia would have higher vulnerability due to 34.6 percent of its housing stock being built prior to 1939. Furthermore, data was obtained from the U.S. Census Bureau for the number of mobile homes in Washington County and its jurisdictions. From the information provided in **Table 3.85,** Unincorporated Washington County, with 2,629 mobile homes – 33.8 percent of housing in the count, is most vulnerable to losses due to the number of mobile homes residing within the jurisdiction.

Table 3.85. Percentage of Mobile Homes in Washington County, 2019

Jurisdiction	Number of Mobile Homes	Percentage of Mobile Homes*
Unincorporated Washington County	2,629	33.8
Caledonia	18	19.8
Irondale	38	17.4
Mineral Point	40	32.8
Potosi	5	0.5

Source: U.S. Census Bureau, 2016-2020 5-Year American Community Survey
**Number of mobile homes per jurisdiction/total occupied housing units per jurisdiction*
***Total housing units for all jurisdictions = 9,278*

Problem Statement

Early warnings are possibly the best hope for residents when severe weather strikes. While more than two hours warning is not possible for tornadoes, citizens must immediately be aware when a city will be facing a severe weather incident. Jurisdictions that do not already possess warning systems should plan to purchase a system. Storm shelters are another important means of mitigating the effects of tornadoes. Additional public awareness also includes coverage by local media sources. A community-wide shelter program should be adopted for residents who may not have adequate shelter in their homes. Residents should also be encouraged to build their own storm shelters to prepare for emergencies. Local governments should encourage residents to purchase weather radios to ensure that everyone has sufficient access to information in times of severe weather.

DRAFT

3.4.10 Wildfires

The specific sources for this hazard are:

- 2018 Missouri State Hazard Mitigation Plan, Chapter 3, Section 3.3.11, Page 3.390 https://sema.dps.mo.gov/docs/programs/LRMF/mitigation/MO_Hazard_Mitigation_Plan2018.pdf
- Missouri Department of Conservation Wildfire Data Search at http://mdc4.mdc.mo.gov/applications/FireReporting/Report.aspx
- Statistics, Missouri Division of Fire Safety at https://dfs.dps.mo.gov/;
- National Statistics, US Fire Administration at https://www.usfa.fema.gov/statistics/;
- Fire/Rescue Mutual Aid Regions in Missouri at https://dfs.dps.mo.gov/programs/resources/mutual-aid.php;
- Forestry Division of the Missouri Dept. of Conservation at https://mdc.mo.gov/your-property/fire-management;
- National Fire Incident Reporting System (NFIRS), http://www.dfs.dps.mo.gov/programs/resources/fire-incident-reporting-system.php
- Firewise, www.firewise.org
- University of Wisconsin Slivis Lab, http://silvis.forest.wisc.edu/maps/wui_main
- Missouri Hazard Mitigation Viewer
  http://bit.ly/MoHazardMitigationPlanViewer2018 - Website
  https://drive.google.com/file/d/1bPkcojgF9ofwQLnTL9N0u-oPFWi9hkst/view - User Guide
    - Likelihood of Occurrence of wildfire by County
    - Average annual land burned (acres) by County
    - Number of structures within the WUI Interface/Intermix Area
    - Potential loss, average annual land burned by County

Hazard Profile

Hazard Description

The fire incident types for wildfires include: 1) natural vegetation fire, 2) outside rubbish fire, 3) special outside fire, and 4) cultivated vegetation, crop fire.

The Missouri Division of Fire Safety (MDFS) indicates that approximately 80 percent of the fire departments in Missouri are staffed with volunteers. Whether paid or volunteer, these departments are often limited by lack of resources and financial assistance.

The Forestry Division of the Missouri Department of Conservation (MDC) is responsible for protecting privately owned and state-owned forests and grasslands from wildfires. To accomplish this task, eight forestry regions have been established in Missouri for fire suppression. The Forestry Division works closely with volunteer fire departments and federal partners to assist with fire suppression activities. Currently, approximately 700 rural fire departments in Missouri have mutual aid agreements with the Forestry Division to obtain assistance in wildfire protection if needed. Over 300 have mutual aid agreements with the State to obtain assistance in wildfire protection if needed. A cooperative agreement with the Mark Twain National Forest is renewed annually.

Most of Missouri fires occur during the spring season between February and May. The length and severity of both structural and wildland fires depend largely on weather conditions. Each year, an average of about 3,200 wildfires burn more than 52,000 acres of forest and grassland in Missouri. Spring in Missouri is usually characterized by low humidity and high winds. These conditions result in

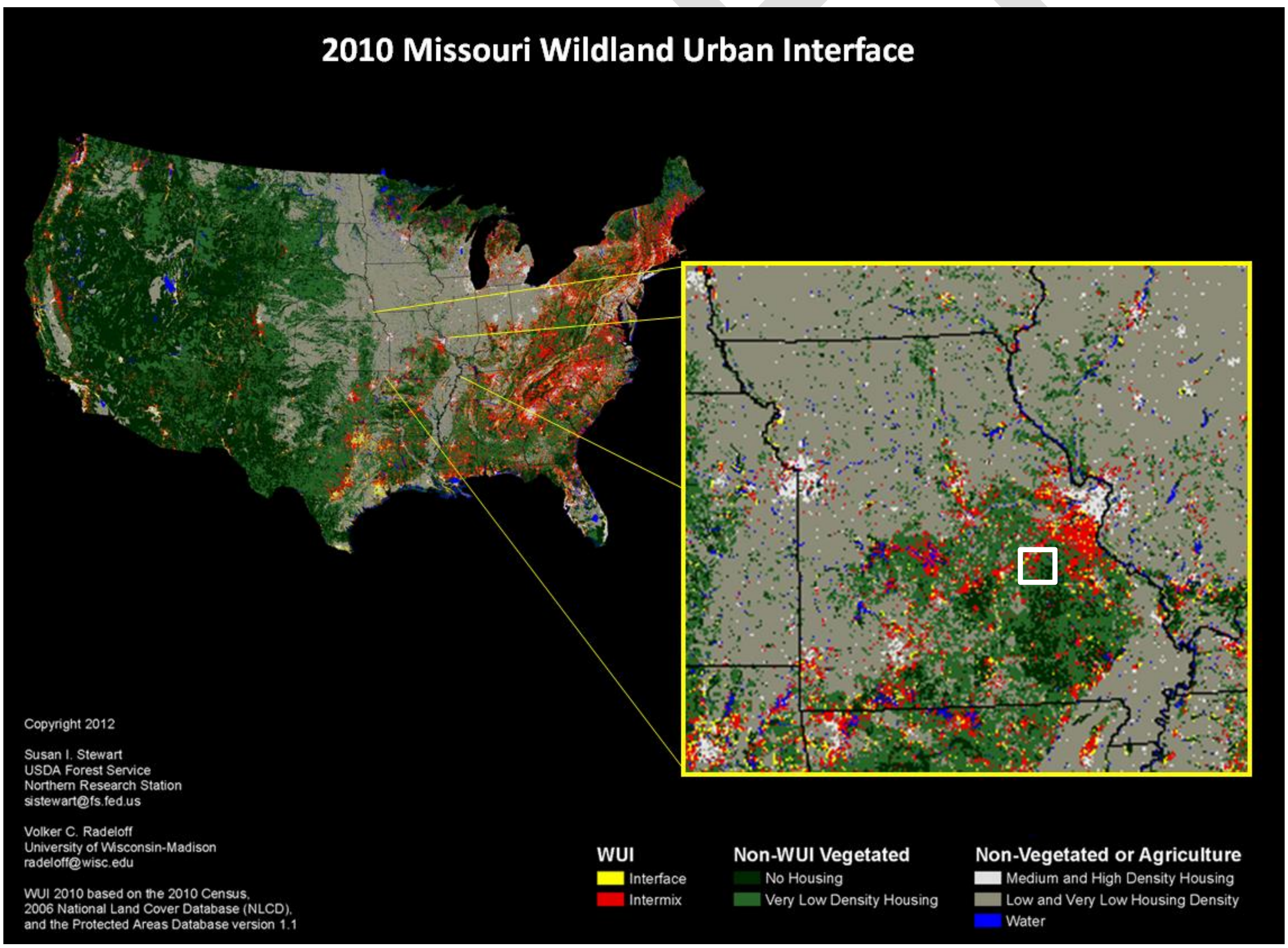
DRAFT

higher fire danger. Drought conditions can also hamper firefighting efforts, as decreasing water supplies may not prove adequate for firefighting. It is common for rural residents to burn their garden spots, brush piles, and other areas in the spring. Some landowners also believe it is necessary to burn their forests in the spring to promote grass growth, kill ticks, and reduce brush. Therefore, 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.

Geographic Location

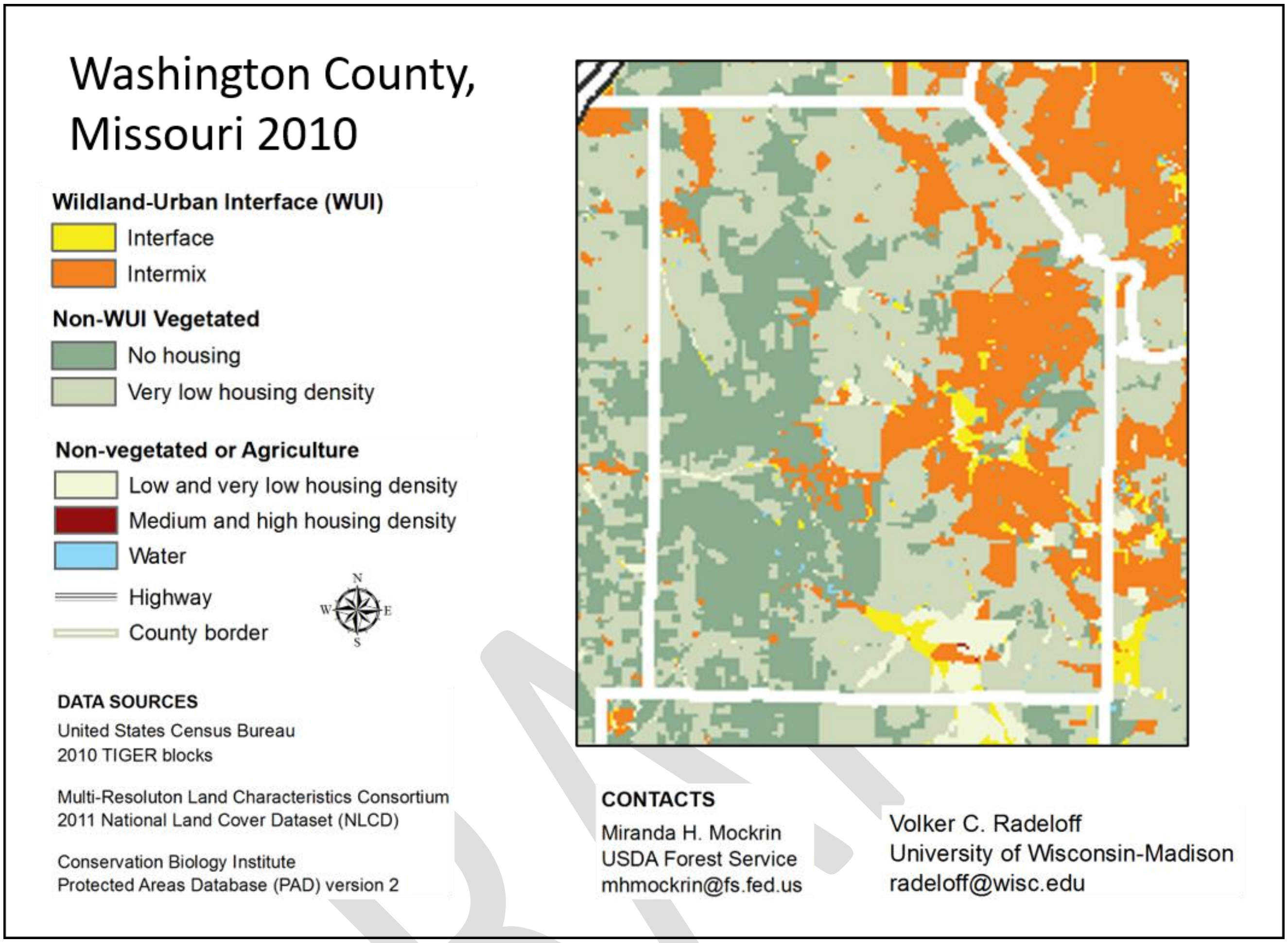
The risk of wildfire does not vary widely across the planning area. However, damages due to wildfires are expected to be higher in communities with more wildland–urban interface (WUI) areas. WUI refers to the zone of transition between unoccupied land and human development and needs to be defined in the plan. Within the WUI, there are two specific areas identified: 1) Interface and 2) Intermix. The interface areas are those areas that abut wildland vegetation and the Intermix areas are those areas that intermingle with wildland areas (**Figure 3.81**). To determine specific WUI areas and variations, data was obtained from ArcGIS, Streets and SILVIS (**Figure 3.82**). According to the WUI area map of Washington County, all cities partially reside in a WUI area.

Figure 3.81. 2010 Missouri Wildland Urban Interface (WUI)



Source: http://silvis.forest.wisc.edu/maps/wui; White square roughly estimates Washington County's location

Figure 3.82. Washington County Wildlife Urban Interface



Source: http://silvis.forest.wisc.edu/GeoData/WUI_cp12/maps/gifs/white/Missouri_WUI_cp12_white_2010.gif

DRAFT

Strength/Magnitude/Extent

Wildfires damage the environment, killing some plants and occasionally animals. Firefighters have been injured or killed, and structures can be damaged or destroyed. The loss of plants can heighten the risk of soil erosion and landslides. Although Missouri wildfires are not the size and intensity of those in the Western United States, they could impact recreation and tourism in and near the fires.

Wildland fires in Missouri have been mostly a result of human activity rather than lightning or some other natural event. Wildfires in Missouri are usually surface fires, burning the dead leaves on the ground or dried grasses. They do sometimes “torch” or “crown” out in certain dense evergreen stands like eastern red cedar and shortleaf pine. However, Missouri does not have the extensive stands of evergreens found in the western US that fuel the large fire storms seen on television news stories.

While very unusual, crown fires can and do occur in Missouri native hardwood forests during prolonged periods of drought combined with extreme heat, low relative humidity, and high wind. Tornadoes, high winds, wet snow and ice storms in recent years have placed a large amount of woody material on the forest floor that causes wildfires to burn hotter and longer. These conditions also make it more difficult for fire fighters suppress fires safely.

The severity of wildfires in Missouri is considered low to moderate, and wildfires in Missouri often go unnoticed by the general public because the sensational fire behavior that captures the attention of television viewers is rare in the state. Yet, from the standpoint of destroying homes and other property, Missouri wildfires can be quite destructive. Large fires have the potential to kill people, livestock, fish, and wildlife as well as destroy crops and pastures. Wildfires can destroy not only natural areas, but homes, businesses, and other facilities. Loss of life due to wildfires is not common in Missouri, but injuries to residents and firefighters can include falls, sprains, abrasions, or heat-related injuries such as dehydration.

Previous Occurrences

Between 2001 and 2020 there were 1,780 wildfires reported in Washington County, according to wildfire reporting to the Missouri Department of Conservation[40]. This is an average of 89 wildfires per year. The size of the fires varied from as small as .01 acre to as large as 10,142.16 acres. **Table 3.86** shows the cause of wildfires, number of wildfires and acres burned for the period 2001-2020. Fires of unknown cause account for the largest number of fires and the greatest number of acres burned.

Table 3.86. 2001-2020 Washington County Wildfires by Cause

Cause	Number	Acres	% Number	% Acres
Arson	34	958.2	1.91%	2.45%
Campfire	9	31.15	0.51%	0.08%
Children	3	3	0.17%	0.01%
Debris	523	5,254	29.38%	13.46%
Equipment	53	490.45	2.98%	1.26%
Fireworks	1	21.55	0.06%	0.06%
Lightning	5	25.1	0.28%	0.06%
Miscellaneous	71	1,858.12	3.99%	4.76%
Not Reported	56	236.93	3.15%	0.61%
Powerline	1	26.68	0.06%	0.07%
Railroad	2	1	0.11%	0.00%
Smoking	21	180.87	1.18%	0.46%
Unknown	1,002	29,942.27	56.29%	76.71%
Totals	**1,780**	**39,031.32**	**100.00%**	**100.00%**

Records for school and special districts are not available at this time.

Probability of Future Occurrence

From the data obtained from the Missouri Department of Conservation[41] (Appendix: F), 1,780 wildfire events occurred in Washington County between 2001 and 2020. This information was utilized to determine the annual average percent probabilities of wildfires. Since multiple occurrences are anticipated per year (1,780 events/20 years), the probability of wildfires per year is 100% with an average of 89 events per year **Table 3.88**.

[40] http://mdc7.mdc.mo.gov/applications/FireReporting/Report.aspx
[41] http://mdc7.mdc.mo.gov/applications/FireReporting/Report.aspx

DRAFT

Table 3.87. Annual Average Percentage Probability of Wildfires in Washington County

Location	Annual Avg. % P	Avg. Number of Events
Washington County	100%	89

*P = probability; see page 3.24 for definition.

Changing Future Conditions Considerations

Higher temperatures and changes in rainfall are unlikely to substantially reduce forest cover in Missouri, although the composition of trees in the forests may change. More droughts would reduce forest productivity and changing future conditions are also likely to increase the damage from insects and diseases. But longer growing seasons and increased carbon dioxide concentrations could offset the losses from those factors. Forests cover about one-third of the state, dominated by oak and hickory trees. As the climate changes, the abundance of pines in Missouri's forests are likely to increase, while the population of hickory trees is likely to decrease.[42]

Higher temperatures will also reduce the number of days prescribed burning can be performed. Reduction of prescribed burning will allow for growth of understory vegetation – providing fuel for destructive wildfires. Drought is also anticipated to increase in frequency and intensity during summer months under projected future scenarios. Drought can lead to dead or dying vegetation and landscaping material close to structures which creates fodder for wildfires.[43]

Vulnerability

Vulnerability Overview

According to the 2018 Missouri State Hazard Mitigation Plan, the Department of Conservation historical wildfire data was the best resource for data on wildfires. The Missouri State Hazard Mitigation Plan used data from 2004-2016 and determined that Washington County should expect to have 114.77 wildfires per year, impacting 1,821 acres **(Table 3.88**).

The state plan also indicates that Washington County is at a high likelihood for building damage from wildfires – likely from the high likelihood of wildfires and the number of structures in WUI interface areas. **Figure 3.83** illustrates the likelihood of wildfire events based on data from 2004-2016. **Figure 3.834** provides a map that illustrates the average annual acreage burned.

Table 3.88. Statistical Data for Wildfire Vulnerability in Washington County

Number of Wildfires 2004-2016	Likelihood of Occurrence (#/year)	Total Acres Burned	Average Annual Acreage Burned
1,492	114.77	23,679.13	1,821

Source: 2018 Missouri State Hazard Mitigation Plan

[42] 2018 Missouri Hazard Mitigation Plan

[43] 2018 Missouri Hazard Mitigation Plan

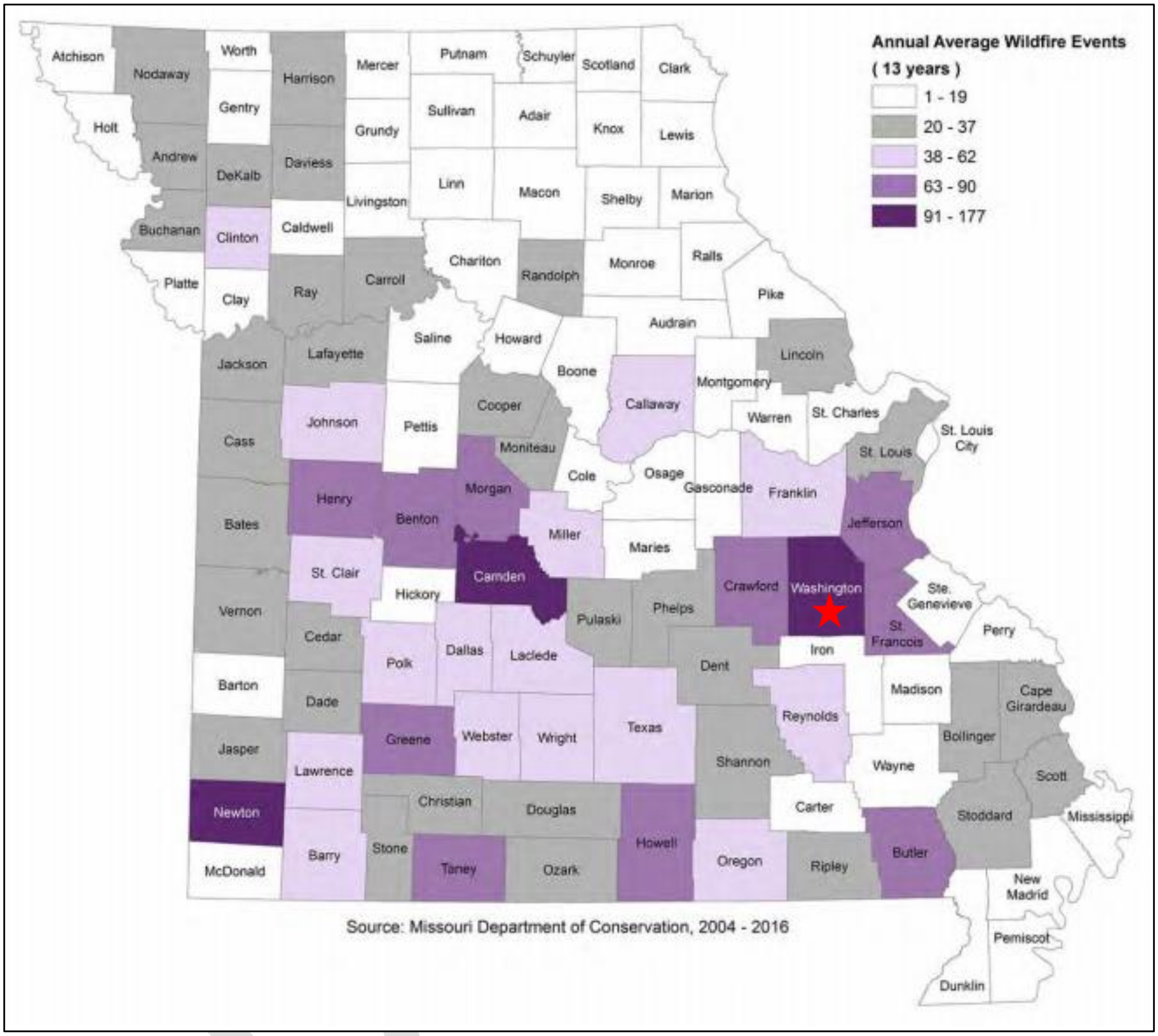
DRAFT

The method used to determine vulnerability to wildfires in the 2018 Missouri Hazard Mitigation plan was a GIS comparative analysis of wildland urban interface and intermix (WUI) areas against building exposure data to determine the types, numbers, and estimated values of buildings at risk to wildfire. This GIS-based analysis utilized data from several sources: the Missouri Spatial Data Inventory Service (MSDIS), HAZUS building exposure value data and wildland urban interface and intermix area data from the University of Wisconsin-Madison SILVIS Lab.

The results of that analysis, including estimated number of structures, value of structures and population are illustrated in **Table 3.89.** The total estimated number of structures vulnerable to wildfires is 9,827. The overall value of structures vulnerable to wildfire in Washington County is estimated at $2,247,109,858. To further illustrate vulnerability in Washington County, maps from the 2018 Missouri Hazard Mitigation plan illustrating these numbers and comparing them statewide are included. The number of structures in the WUI interface and intermix areas statewide are shown in **Figure 3.85**. **Figure 3.86** shows the estimated value of structures in the WUI interface and intermix areas. **Figure 3.87** illustrates the number of people at risk to wildfire in the WUI interface and intermix areas.

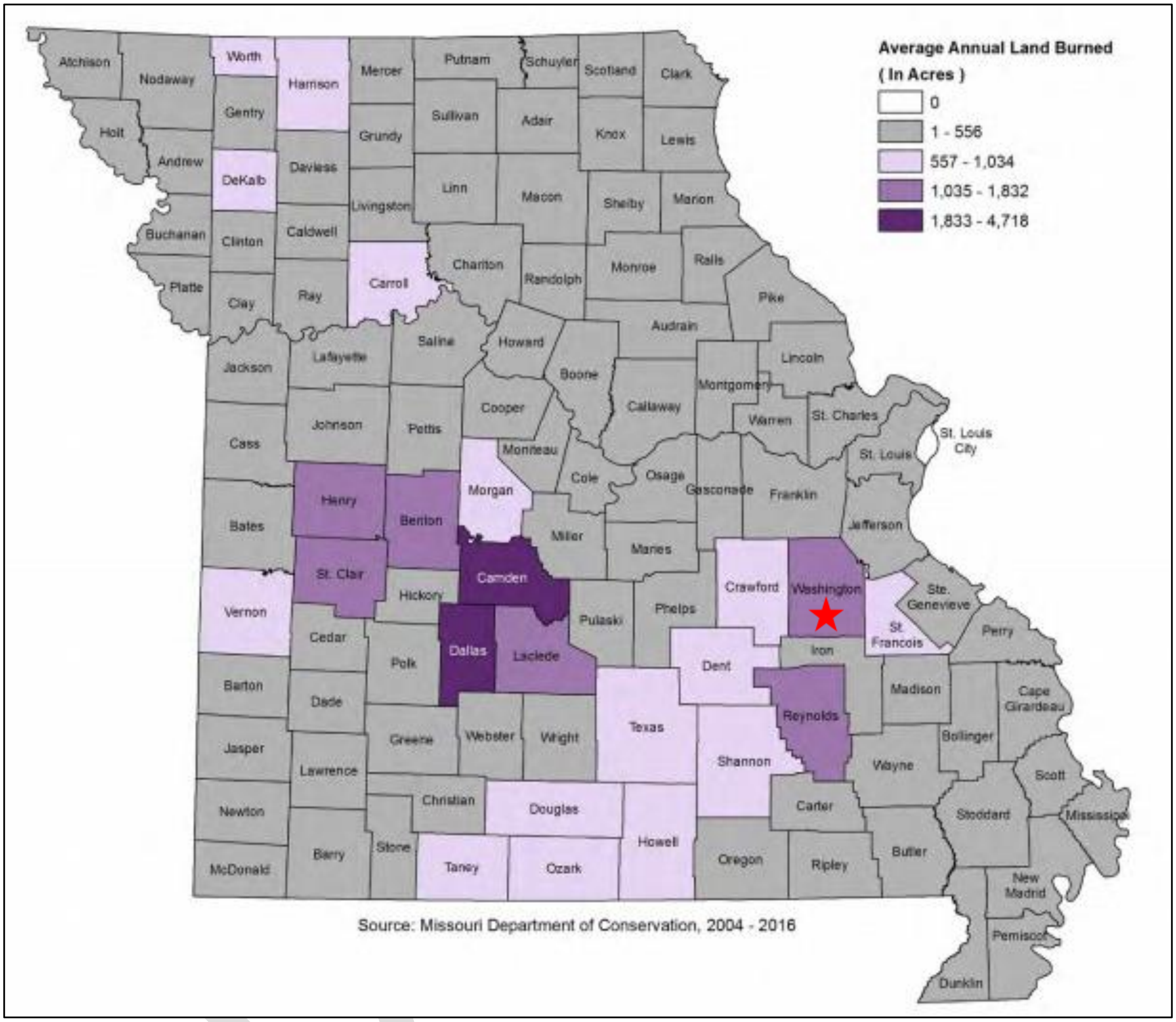
DRAFT

Figure 3.83. Likelihood of Wildfire Events, 2004-2016



*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.84. Average Annual Acreage Burned



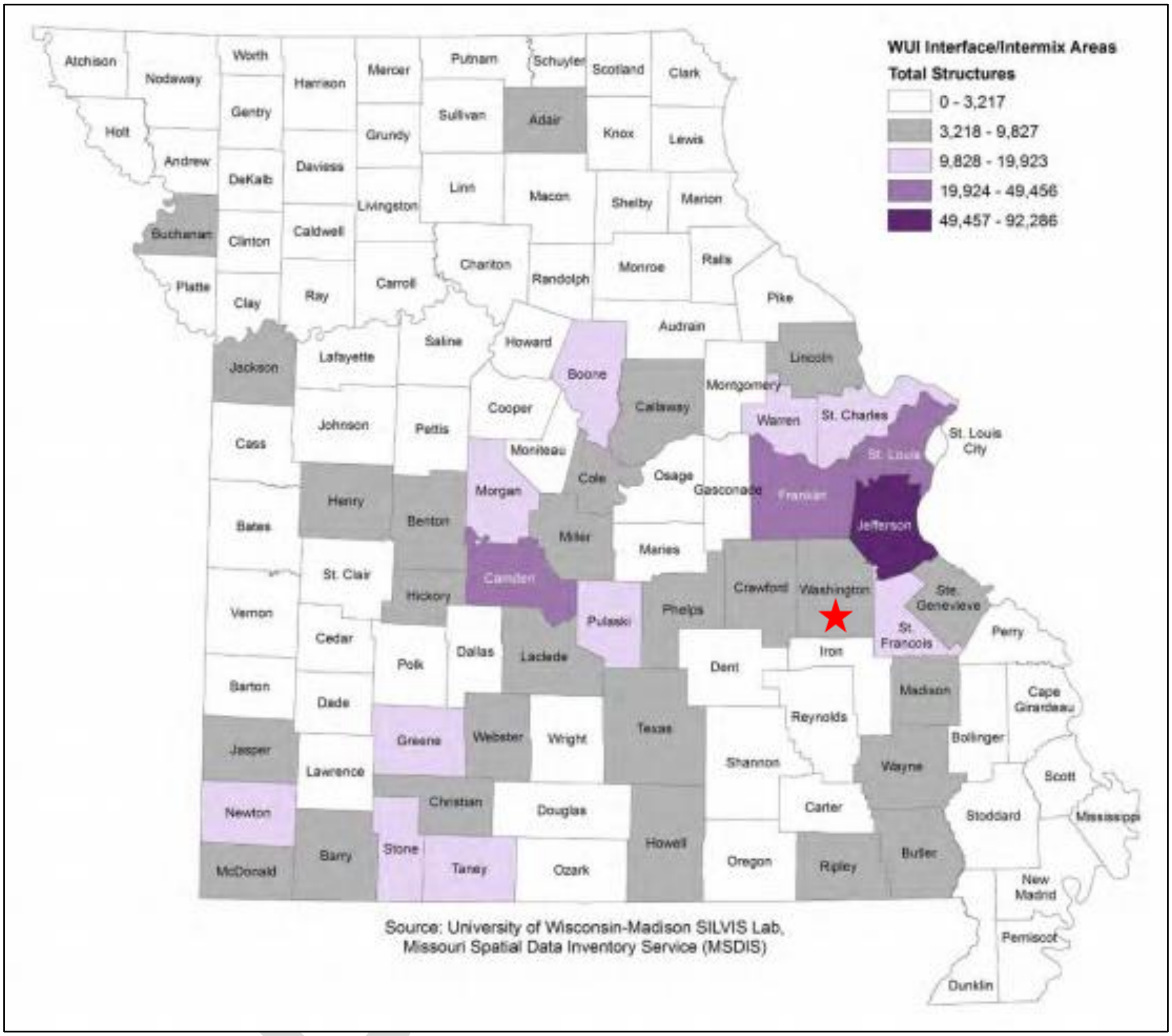
*Source: 2018 Missouri State Hazard Mitigation Plan, *Red star indicates Washington County*

Table 3.89. Estimated Numbers and Values of Structures and Population Vulnerable to Wildfire in Washington County

Washington County	Number of Structures	Value of Structures	Population
Agriculture	2,697	$1,019,466,000	
Commercial	387	$251,030,466	
Education	12	$17,448,000	
Government	19	$14,879,533	
Industrial	29	$18,089,556	
Residential	6,683	$926,196,304	
Totals	**9,827**	**$2,247,109,858**	**17,443**

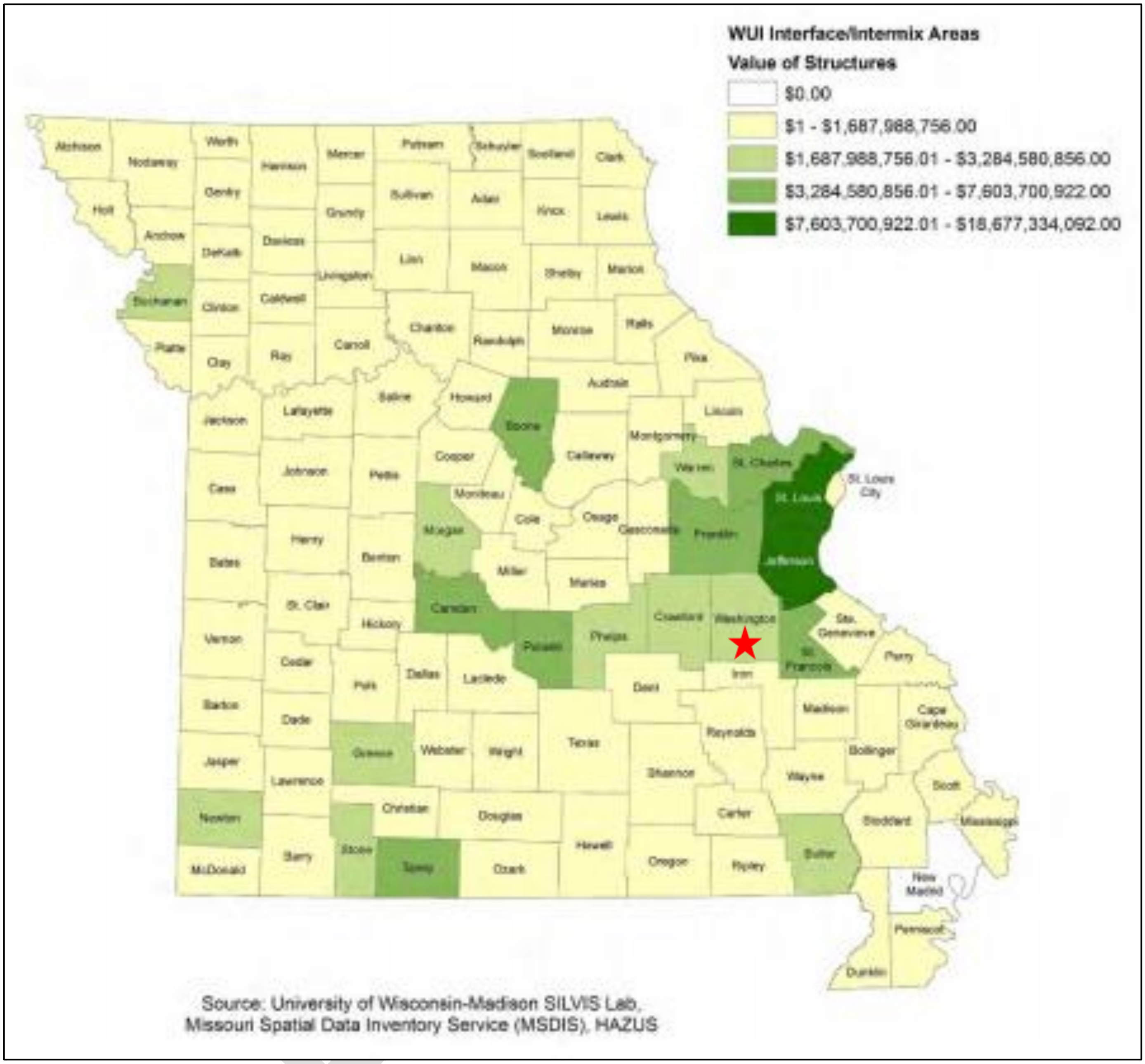
Source: 2018 Missouri State Hazard Mitigation Plan

Figure 3.85. Number of Structures in WUI Interface and Intermix Areas



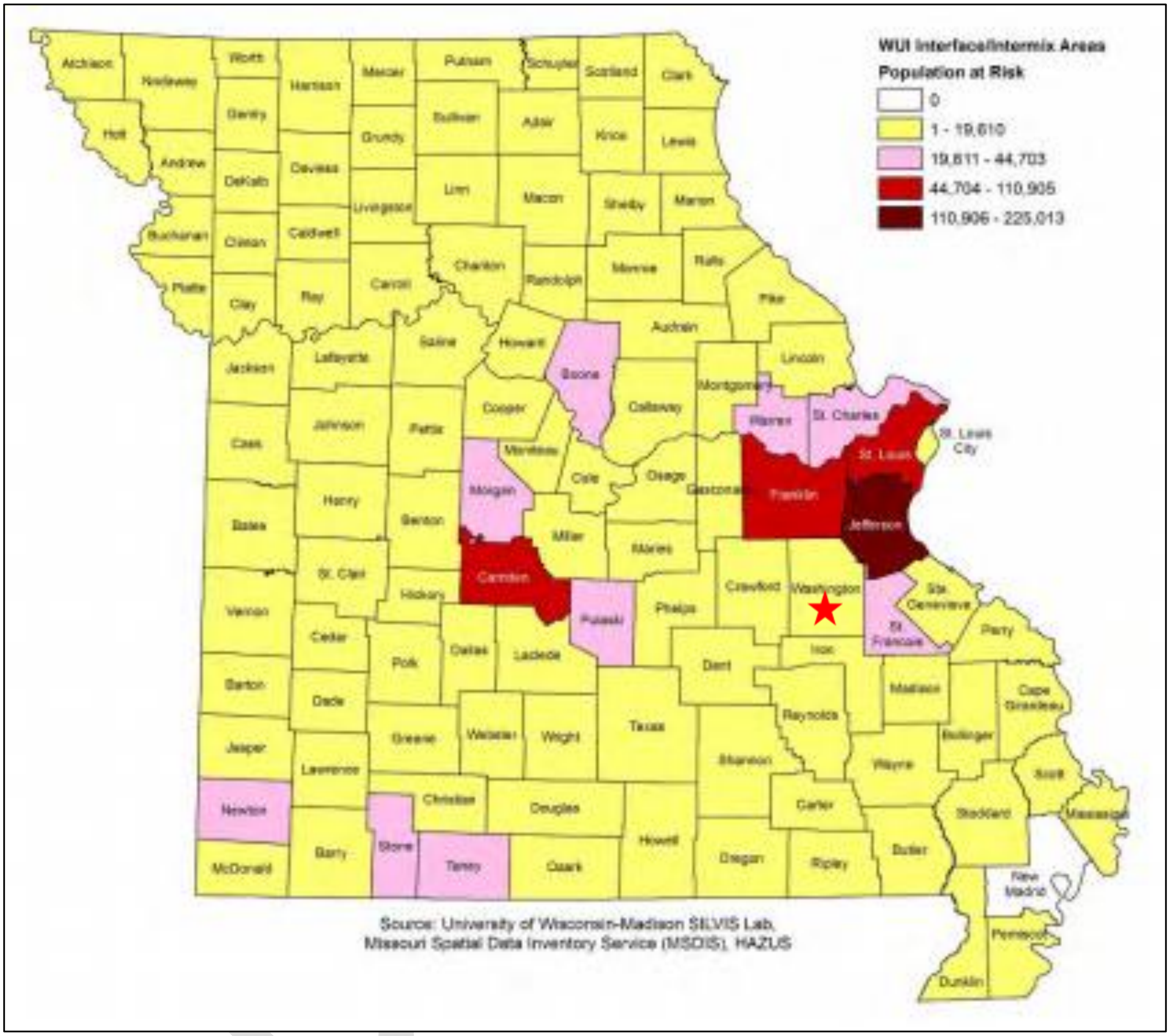
*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Figure 3.86. Value of Structures in the WUI Interface and Intermix Areas



Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County

Figure 3.87. Population at Risk to Wildfire in WUI Interface and Intermix Areas



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Potential Losses to Existing Development

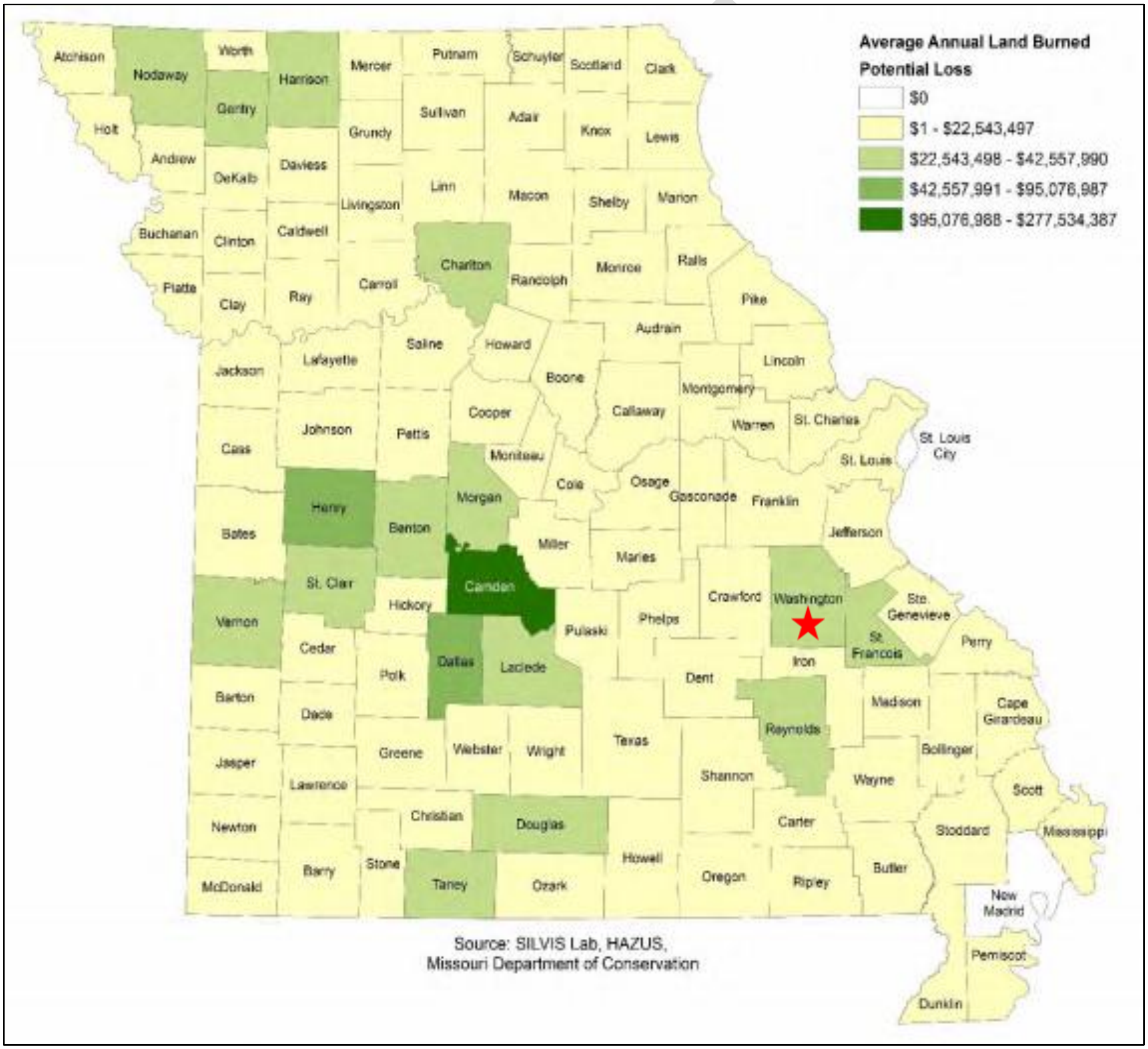
As there was not data available on Washington County specific losses, data was used from the 2018 Missouri State Hazard Mitigation Plan. The factors considered for estimating potential losses due to wildfires were average acreage burned each year per county and the average value of structures per acre in the WU-Interface/Intermix areas. **Table 3.90** and **Figure 3.88** that follows provide the potential loss figures for Washington County based on this methodology.

Table 3.90. **Wildfire Potential Loss Estimates for Washington County**

Total WUI Acreage	Total Structure Value Within WUI	Average Value/Acre within WUI	Average Annual Acreage Burned	Potential Loss
103,621.44	$2,247,109,858	$21,686	1,821	$39,489,771

Source: 2018 Missouri Hazard Mitigation Plan

Figure 3.88. Annualized Wildfire Damages



*Source: 2018 Missouri Hazard Mitigation Plan, *Red star indicates Washington County*

Impact of Future Development

Few future developments are anticipated in WUI areas, however due to lack of data, it is difficult to enumerate. Additionally, as previously mentioned, each jurisdiction within the county resides in a WUI area. This increases the risk of fire hazards for future development.

Hazard Summary by Jurisdiction

As long as drought conditions are not severe, future wildfires in Washington County should have a medium adverse impact on the community, depending on the proximity to population centers. Nonetheless, homes, businesses, and schools located in unincorporated areas are at higher risk from wildfires due to proximity to woodland and more importantly, distance from fire services. All cities and school districts are in WUI areas but are closer to fire services.

Problem Statement

An estimated 9,827 structures and 17,443 people are vulnerable to wildfires in Washington County. Wildfires are expected to occur on an annual basis. To mitigate adverse impacts a comprehensive community awareness and educational campaign on wildfire danger should be designed and implemented. This campaign should include the development of capabilities, systems, and procedures for pre-deploying fire-fighting resources during times of high wildfire hazards; training of local fire departments for wildfire scenarios; encouraging the development and dissemination of maps relating to the fire hazards (WUI areas) to help educate and assist builders and homeowners in being engaged in wildfire mitigation activities; and guidance of emergency services during response. Residents should be educated on the dangers of wildfires and what steps they can take to mitigate their vulnerability. This could include landscaping and water supply.

DRAFT