3 RISK ASSESSMENT

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 risk assessment process identifies and profiles relevant hazards and assesses the exposure of lives, property, and infrastructure to those identified hazards. The goal of the risk assessment process is in the event of a hazard event, to approximate the potential losses in Maries County from hazard events, including loss of life, personal injury, property damage and economic losses. The risk assessment process provides an opportunity for the county and the jurisdictions within the county to better understand their potential risks from natural hazards and to better prepare for those potential events through mitigation planning.

The risk assessment for Maries County and its jurisdictions followed the methodology described in the FEMA publication Local Mitigation Planning Handbook (March 2013). This methodology includes the following steps:

- Describe the hazards
- Identify the community assets
- Analyze risks
- Summarize vulnerability

Multi-Jurisdictional Risk Assessment

For this multi-jurisdictional hazard mitigation plan, the risk assessment looks at each jurisdiction's risks whenever they deviate from the risks facing the entire planning area. Maries County is uniform in terms of climate and topography as well as construction characteristics and development trends. Therefore, hazards and vulnerability do not vary greatly across the planning area for most hazards. Weather-related hazards will impact the entire the county in much the same fashion, as do topographical/geological hazards such as earthquake. Sinkholes are widespread in the county, but more localized in their effects.

The hazards that do vary across the planning area include dam failure and flood. Table 3.2 shows the hazards identified for each participating jurisdiction. In Section 3.2, under each hazard description, the section titled :Likely Location" discusses how some hazards vary between jurisdictions in the planning area. The section titled "Hazard History" provides a narrative, based on the best available data, on where past hazard events have occurred and the approximated losses to specific jurisdictions during those events. Section 3.3 Vulnerability Assessment, includes information on structures and estimates of potential losses by jurisdiction (where data is available) for hazards of moderate and high priority, as determined by the Hazard Mitigation Planning Committee (HMPC).

3.1 Identification of Hazards Affecting Maries County

44 CFR 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.

3.1.1 Methodology

The 2013 State Mitigation Plan provided the following list of potential hazards for consideration in the hazard mitigation planning process:

- Flooding (River and Flash)
- Dam Failure
- Levee Failure
- Drought
- Earthquake
- Extreme Temperatures
- Severe Thunderstorm (Damaging Winds, Hail and Lightening)
- Land Subsidence/Sinkholes
- Severe Winter Weather (Snow and Ice)
- Tornadoes
- Fires (Structural, Urban and Wild)

The following hazard were included in the Maries plan approved on August 22, 2006.

- Tornadoes/Severe Thunderstorms
- Riverine Floods
- Severe Winter Weather
- Drought
- Heat Wave
- Earthquakes
- Dam Failure
- Wildfires

Based on past history and future probability, the HMPC determined that the following potential hazards would be included in the Maries County Hazard Mitigation Plan:

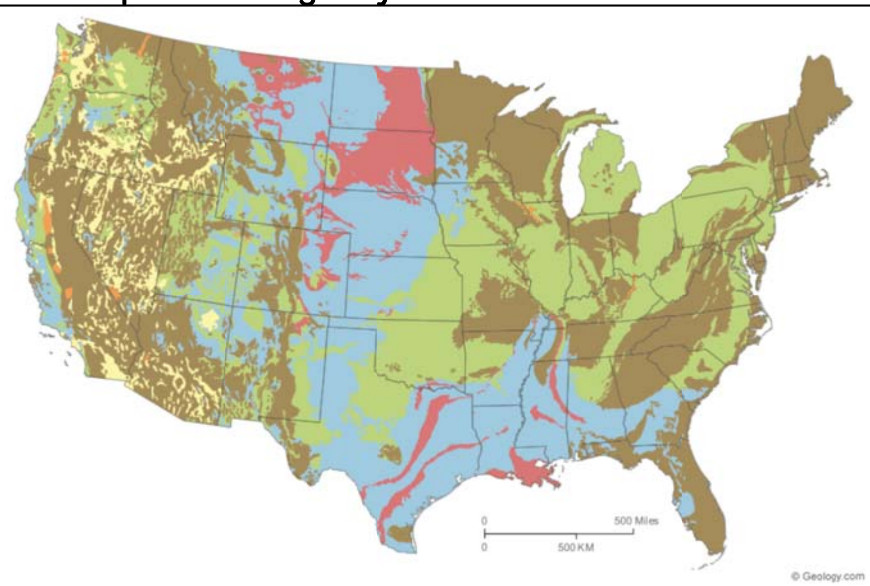
- Dam Failure
- Drought
- Earthquake
- Extreme Heat
- Flood
- Land Subsidence/Sinkholes
- Severe Thunderstorm (Hailstorm/Windstorm)/
- Tornadoes
- Severe Winter Weather
- Wildfire

In determining which hazards to include in the Maries County Plan Update, the HMPC decided to maintain the format of the previously approved plan. This format included extreme cold within the category of Winter Weather, while profiling Extreme Heat separately. Table 3.1 outlines the hazards eliminated from the plan and the reasons for doing so.

Table 3.1 Hazards Not Profiled in the Plan

Hazard	Reason for Omission
Expansive Soils	There are no areas of expansive soils in the planning area. The map in Figure 3-1 demonstrates the lack of swelling clay soil types in the southern half of Missouri. As can be seen in Figure 3-1, maries County is comprised of soils with little to no clays with swelling potential.
Levee Failure	Planning research revealed no Corps of Engineer regulated levees in the planning area. If there are any privately owned levees in Maries Co., they could not be identified. It is likely that levees in maries County are low-head agricultural levees, the breach of which would cause minimal damage. No records indicate that the breaching or overtopping of any levee ever has or would impact property or structures other than the owner of the levee. Damage to residential structures is unlikely.

Figure 3-1 Map of Swelling Clays 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://geology.com/articles/soil/, "Swelling Clays Map of the Conterminous United States" by W. Olive, A. Chleborad, C. Frahme, J. Shlocker, R. Schneider & R. Schuster

Data on hazards was gathered from a variety of sources but primarily from the following:

- 2010 Missouri State Hazard Mitigation Plan
- Spatial Hazard Event and Loss Database (SHELDUS), provided through the University of South Carolina Hazards Research Lab
- National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC)
- Federal Disaster Declarations from the Federal Emergency Management Agency (FEMA)
- Various articles, data sets and publications available via the internet (sources are indicated at the end of each section of the plan document)

The Maries County HMPC identified ten hazards that had the potential to affect the planning area. Those hazards are listed in Table 3.2 and further described in the following section of the plan. It was determined by SEMA that only natural hazards would be addressed in the plan. Technical and man-made hazards are not included in the plan due to limited resources and time limitations and the fact that technical/man-made hazards are addressed in other emergency operations plans.

Table 3.2 Hazards Identified for Maries County Plan and Affected Jurisdictions

Hazard	Maries County	Belle	Vienna	Maries Co. R-I	Maries Co. R-II
Dam Failure	X		X		
Drought	X	X	X	X	X
Earthquake	X	X	X	X	X
Extreme Heat	X	X	X	X	X
Flood	X		X		
Severe Thunderstorms-Hail/Wind	X	X	X	X	X
Tornado	X	X	X	X	X
Severe Winter Weather	X	X	X	X	X
Land Subsidence/ Sinkholes	X				
Wildfire	X	X	X	X	X

3.1.2 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 Maries 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 initiated when the local government's response and recovery capabilities have been exhausted. In this type of situation, the state may declare a disaster and provide resources from the state level. If the disaster is so great that state resources are also overwhelmed, a federal disaster may be declared in order to allow for federal assistance.

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 63 federally declared disasters since 1957. Of those, 33 have occurred between 2000 and 2013. All of these disasters have been weather related – severe wind and rain storms, tornados, flooding, hail, ice storms and winter storms. Table 3.3 lists the federal disaster declarations for Missouri that included Maries County from 2000 through 2013.

Table 3.3 Disaster Declaration History of Maries County 2000-2013

Declaration Number	Declaration Date	Disaster Description	Type of Assistance Received	Counties Included in Disaster Declaration
4144	9/6/2013	Severe Storms, Straight-line Winds and Flooding	Public Assistance	Barry, Camden, Cedar, Dade, Dallas, Laclede, **Maries**, McDonald, Miller, Osage, Ozark, Phelps, Pulaski, Shannon, Taney, Texas, Webster, Wright
4130	7/18/2013	Severe Storms, Straight-line Winds, Tornadoes and Flooding	Public Assistance	Barton, Callaway, Cape Girardeau, Chariton, Clark, Howard, Iron, Knox, Lewis, Lincoln, **Maries**, Marion, Miller, Montgomery, Osage, Perry, Pike, Putnam, Ralls, Saint Charles, Saint Louis, Sainte Genevieve, Scotland, Shelby, Stoddard, Sullivan, Texas, Webster
1961	3/23/2011	Winter Storm	Public Assistance	Adair, Andrew, Audrain, Barton, Bates, Benton, Boone, Caldwell, Callaway, Carroll, Cass, Cedar, Chariton, Clark, Clinton, Cole, Cooper, Dade, Dallas, DeKalb, Grundy, Henry, Hickory, Howard, Johnson, Knox, Laclede, Lafayette, Lewis, Linn, Livingston, Macon, Madison, **Maries**, Marion, McDonald, Miller, Moniteau, Monroe, Montgomery, Morgan, Newton, Osage, Pettis, Platte, Polk, Pulaski, Putnam,

Declaration Number	Declaration Date	Disaster Description	Type of Assistance Received	Counties Included in Disaster Declaration
				Ralls, Randolph, Ray, St. Clair, Saline, Schuyler, Scotland, Shelby, Sullivan, Vernon and Worth
3317	2/3/2011	Severe Winter Storm	Public Assistance	Adair, Andrew, Atchison, Audrain, Barry, Barton, Bates, Benton, Bollinger, Boone, Buchanan, Butler, Caldwell, Callaway, Camden, Cape Girardeau, Carroll, Carter, Cass, Cedar, Chariton, Christian, Clark, Clay, Clinton, Cole, Cooper, Crawford, Dade, Dallas, Daviess, DeKalb, Dent, Douglas, Dunklin, Franklin, Gasconade, Gentry, Greene, Grundy, Harrison, Henry, Hickory, Holt, Howard, Howell, Iron, Jackson, Jasper, Jefferson, Johnson, Knox, Laclede, Lafayette, Lawrence, Lewis, Lincoln, Linn, Livingston, Macon, Madison, Maries, Marion, McDonald, Mercer, Miller, Mississippi, Moniteau, Monroe, Montgomery, Morgan, New Madrid, Newton, Nodaway, Oregon, Osage, Ozark, Pemiscot, Perry, Pettis, Phelps, Pike, Platte, Polk, Pulaski, Putnam, Ralls, Randolph, Ray, Reynolds, Ripley, Saint Charles, Saint Clair, Saint Francois, Saint Louis City, Saint Louis County, Sainte Genevieve, Saline, Schuyler, Scotland, Scott, Shannon, Shelby, Stoddard, Stone, Sullivan, Taney, Texas, Vernon, Warren, Washington, Wayne, Webster, Worth, Wright
1847	6/26/2009	Severe Storms, Tornados and Flooding	Public Assistance	Adair, Barton, Bollinger, Camden, Cape Girardeau, Cedar, Crawford, Dade, Dallas, Dent, Douglas, Greene, Hickory, Howell, Iron, Jasper, Knox, Laclede, Lewis, Madison, Maries, Marion, Miller, Newton, Oregon, Ozark, Perry, Osage, Polk, Pulaski, Ray, Reynolds, Ripley, St. Francois, Ste. Genevieve, Saline, Shannon, Shelby, Stone, Sullivan, Texas, Vernon, Washington, Wayne, Webster, and Wright
3303	1/30/2009	Severe Winter Storm	Public Assistance	All 114 Missouri counties
1809	11/13/2008	Severe Storms, Flooding and a Tornado	Individual and Public Assistance	Adair, Audrain, Barry, Bollinger, Boone, Butler, Callaway, Cape Girardeau, Carter, Chariton, Christian, Clark,

Declaration Number	Declaration Date	Disaster Description	Type of Assistance Received	Counties Included in Disaster Declaration
				Crawford, Dent, Douglas, Dunklin, Howard, Howell, Jefferson, Knox, Lewis, Lincoln, Linn, Madison, Maries, Marion, Miller, Mississippi, Montgomery, New Madrid, Oregon, Osage, Ozark, Perry, Ralls, Randolph, Ray, Reynolds, Ripley, Schuyler, Scotland, Scott, Shannon, Shelby, St. Genevieve, St. Charles, St. Louis, Stoddard, Stone, Sullivan, Taney, Texas, Wayne, Webster and Wright Counties, and the Independent City of St. Louis.
1749	3/19/2008	Severe Storms and Flooding	Individual and Public Assistance	Audrain, Barry, Barton, Boone, Bollinger, Butler, Callaway, Camden, Cape Girardeau, Carter, Cedar, Christian, Cole, Cooper, Crawford, Dade, Dallas, Dent, Douglas, Dunklin, Franklin, Gasconade, Greene, Hickory, Howard, Howell, Iron, Jasper, Jefferson, Laclede, Lawrence, Lincoln, Madison, Maries, McDonald, Miller, Mississippi, Montgomery, Moniteau, Morgan, New Madrid, Newton, Oregon, Osage, Ozark, Pemiscot, Perry, Pike, Polk, Pulaski, Reynolds, Ripley, St. Charles, St. Clair, St. Francois, St. Louis, Ste. Genevieve, Shannon, Scott, Stoddard, Stone, Taney, Texas, Vernon, Warren, Washington, Wayne, Webster, and Wright Counties and the Independent City of St. Louis
1742	2/5/2008	Severe Storms, Tornadoes and Flooding	Public Assistance	Barry, Dallas, Laclede, Maries, McDonald, Newton, Phelps, Stone, Webster
3281	12/12/2007	Severe Winter Storms	Public Assistance	All Missouri counties
1676	1/15/2007	Winter Storms and Flooding	Public Assistance	Barry, Barton, Callaway, Camden , Christian, Cole, Crawford, Dade, Dallas, Dent, Franklin , Gasconade, Greene, Hickory , Jasper, Laclede, Lawrence , Lincoln , Maries, McDonald, Miller, Montgomery , Newton , Osage, Polk, Pulaski, St. Charles , St. Clair, St. Louis, Stone, Warren , Webster, Wright, and the independent City of St. Louis
3232	9/10/2005	Hurricane Katrina	Evacuation Support	All Missouri counties

Source: Missouri State Emergency Management Agency, www.sema.dps.mo.gov

Although the county has been included in 12 federal disaster declarations since 2005, the mitigation goals, objectives and priorities have not changed. The county has always experienced weather related damages and there has been little to no change in growth patterns and development in Maries County since 2006.

3.2 Profile of Hazards Affecting Maries County

44 CFR 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.

3.2.1 Methodology

The HMPC reviewed the format of the previously approved mitigation plan, and determined that some rearrangement was warranted by new FEMA mitigation planning guidance. Each hazard that has been determined to be a potential risk to Maries County is profiled individually in this section of the plan document. The information provided varies dependent upon the amount of data available to use in the profile and risk assessment process. As the plan is updated, and additional data becomes available, this information will be added to provide a more detailed picture of the hazards affecting Maries County. This process will increase the county's ability to assess and prioritize hazards and mitigation strategies.

Each hazard profile includes:

- Description and general characteristics of the hazard
- Hazard history in the planning area, including the frequency and amount of damage in the past. This information will be used as a basis for the probability of events in the future.
- Information on the geographic location of hazards (if applicable)
- Warning time and duration
- Based on past events, discussion of Probable Risk of future occurrences
- Discussion of magnitude/severity of the hazard
- Recommendations for mitigating the damages of the hazard

In order to maintain consistency and incorporate multiple factors into the ranking process, the HMPC prioritized the hazards based on a calculated priority risk index (CPRI). The CPRI evaluates four elements of risk: probability (based on previous events), magnitude/severity, warning time and duration. This process and the formula for weighting each element of risk were described in MitigationPlan.comTM.

The probability of each profiled hazard is classified and quantified in the following manner:

- Highly likely: An event is probable within one year—a near 100 percent probability of occurring. (4)
- Likely: An event is probable within the next three years—a 33 percent probability of occurring. (3)

- Occasional: An event is probable within the next five years—a 20 percent probability of occurring. (2)
- Unlikely: An event is possible within the next 10 years—a 10 percent probability of occurring. (1)

The magnitude of each profiled hazard is classified and quantified in the following manner:

- Catastrophic – More than 50 percent of property severely damaged; shutdown of facilities for more than 30 days; and/or multiple deaths. (4)
- Critical – 25-49 percent of property severely damaged; shutdown of facilities for at least two weeks; and/or injuries and/or illnesses resulting in permanent disability. (3)
- Limited – 10-24 percent of property severely damaged; shutdown of facilities for more than a week; and/or injuries/illnesses do not result in permanent disability. (2)
- Negligible – Less than 10 percent of property severely damaged, shutdown of facilities and services for less than 24 hours; and/or injuries/illnesses treatable with first aid. (1)

The potential speed of onset was classified and quantified in the following manner:

- Less than six hours (4)
- Six to less than 12 hours (3)
- 12-24 hours (2)
- More than 24 hours (1)

The duration of the hazard was classified and quantified in the following manner:

- More than one week (4)
- One week or less (3)
- Less than one day (2)
- Less than six hours (1)

After assigning a score to each of the risk elements listed above, a formula is used to determine the score for each hazard. The formula was developed by MitigationPlan.comTM:

(Probability x .45) + (Magnitude/Severity x .30) + (Warning Time x .15) + (Duration x .10) = CPRI

Based on the CPRI scores, the hazards were then separated into three categories, as done in the Missouri Hazard Mitigation Plan. Based on the data available and the ranking process provided in the 2010 State of Missouri Hazard Mitigation Plan, the hazards adverse impact on the community are ranked based on High, Medium or Low: High (2.5-4.0) Moderate (2.0-2.5) and Low (1.1-1.9).

Data used to determine ranking included the hazard profile, HAZUS data and information gleaned from the State Hazard Mitigation Plan (2010) and Missouri Hazard Analysis (2008).

Table 3.4 summarizes the results of the CPRI exercise for the planning area as a whole.

Table 3.4 Maries County Hazard Profile Summary

Hazard Type	Probability	Magnitude	Warning Time	Duration	CPRI	Planning Priority
Dam Failure	1	1	4	3	1.65	Low
Drought	1	1	1	4	1.3	Low
Earthquake	2	1	4	4	2.05	Moderate
Extreme Heat	4	3	1	3	3.15	High
Flood						
County:	4	1	4	3	3.0	High
Cities & Schools	4	1	4	2	2.9	High
Land Subsidence/ Sinkholes	1	1	4	3	1.45	Low
Severe Thunderstorm (Hail Storm/Wind storm)	4	1	4	1	3	High
Tornado	1	2	4	1	1.75	Low
Severe Winter Weather	4	1	1	3	2.55	High
Wildfire – County:	4	1	4	2	2.9	High
Cities:	3	1	4	2	2.45	Moderate
Schools:	1	1	4	2	1.55	Low

Sources: Maries County hazard mitigation planning committee, Missouri Hazard Mitigation Plan (2007), Missouri Hazard Analysis (2008)

Developing rankings for each hazard helps the county plan for and prioritize risks. Those hazards ranked as High risk should receive the most attention from hazard mitigation planners. Hazard mitigation projects developed by the county should focus first on hazards ranked as High risk. These include extreme heat, flood, severe thunderstorm (hail/wind storm), severe winter storm and for unincorporated areas of the county, wildfire.

3.2.2 Dam Failure

Description

Over the years dam failures have injured or killed thousands of people, and caused billions of dollars of property damage in the United States. Among the most notable were the failures of the Teton Dam in Idaho in 1976, which killed 14 people and caused more than $1 billion in damage, and the Kelly-Barnes Dam in Georgia in 1977 which left 39 dead and $30 million in property damage. In the past few years, there were over 200 documented dam failures nationwide, that caused four deaths and millions in property damage and repair costs.

The problem of unsafe dams in Missouri was underscored by dam failures at Lawrenceton in 1968, Maries 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 widely publicized dam failure in recent years was the failure of the Taum Sauk Hydroelectric Power Plant Reservoir atop Profitt Mountain in Reynolds County, Missouri.

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 600 feet wide and 7,000 feet long that carried a mix of trees, rebar, concrete, boulders and sand downhill and into the park.[i] 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.[ii] 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.

The significance of the damage done by the Taum Sauk Reservoir dam failure 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.[iii]

Overall, many of Missouri's smaller dams are becoming a greater hazard as they continue to age and deteriorate. While many need to be rehabilitated, lack of available funding and often questions of ownership are obstacles difficult to overcome.[iv]

Hazard Characteristics

A dam is defined by the National Dam Safety Act as an artificial barrier which impounds or diverts water and: (1) is more than six feet high and stores 50 acre feet or more, or (2) is 25 feet or more high and stores more than 15 acre feet. Based on this definition, there are over 80,000 dams in the United States. Over 95 percent are non-federal, with most being owned by state governments, municipalities, watershed districts, industries, lake associations, land developers, and private citizens. Dam owners have primary responsibility for the safe design, operation and maintenance of their dams. They also have responsibility for providing early warning of problems at the dam, for developing an effective emergency action plan, and for coordinating that plan with local officials. The State has ultimate responsibility for public safety, and many states regulate construction, modification, maintenance, and operation of dams, and also ensure a dam safety program. Dams can fail for many reasons. The most common are:

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.[v]

Dam construction varies widely throughout the state. A majority of dams are of earthen construction. Missouri's mining industry has produced numerous tailing dams for the surface disposal of mine waste. It is estimated that 50 percent of the dams within Maries County are tailing dams. These dams are constructed of various materials including tailings, cyclone sand tailings, mine waste, earth fill and rock fill. These dams were made to contain mining waste or tailings which are made up of leftover minerals after the milling process and deposited in slurry form within the impoundment. Other types of earthen dams are reinforced with a core of concrete and/or asphalt. The largest dams in the state are built of reinforced concrete and are used for hydroelectric power.[vi]

The Missouri Department of Natural Resources (MDNR), maintains records on 5,243 dams in the state. This includes all regulated and unregulated dams . The 2013 Missouri State Hazard Mitigation Plan states that Missouri has 682 state-regulated dams, of which 460 are considered High Hazard Dams. This is the largest number of manmade dams of any state, due mainly to the topography of the state that allows lakes to be built easily and inexpensively. Of these 5,243, only 682 fall under state regulations, while another 64 dams are under federal control.

Missouri's Department of Natural Resources (MDNR) Water Resources Center maintains a Dam and Reservoir Safety Program. The objective is to ensure that dams are safely constructed, operated and maintained pursuant to Chapter 236 Revised Statutes of Missouri. Under that law, a dam must be 35 feet or higher to be state regulated. These dams are surveyed by state inspectors at least every five years. However, most Missouri dams are less than 35 feet high and so are not regulated. The state encourages dam owners to inspect unregulated dams, but the condition of these dams may be substandard.[vii]

The hazard potential for dam failure is classified by the Interagency Committee on Dam Safety by the following three definitions:

- Low Hazard Potential: Failure or mis-operation results in no probable loss of human life and low economic and/or environmental losses. Losses are principally limited to the owner's property.
- Significant Hazard Potential: Failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities or other impacts. Significant hazard potential classification dams are often located in predominantly rural or agricultural areas but could be located in areas with population and significant infrastructure.
- High Hazard Potential: Failure or mis-operation will probably cause loss of human life.

Hazard Event History

As stated in the Missouri State Hazard Mitigation Plan (MSHMP), according to Stanford University's National Performance of Dams Program, there have been 82 incidents involving dams in Missouri since 1975. Of the 82 incidents listed, 17 (21 percent) were considered dam failures. None of the incidents occurred in Maries County.

Likely Locations

According to the Missouri Spatial Data Information Services (MSDIS), based on information from the MDNR Water Resources Center (WRC), there are a total of 30 dams located in Maries County. The majority are privately owned. Of those 30 dams, a total of six are rated as high hazard risk dams. The National Inventory of Dams, maintained by the U.S. Army Corps of Engineers, shows the same six as high hazard risk.

Of most concern would be those dams that are 35 feet or more in height. There are three dams in the county that are at least 35 feet in height and are regulated by the state. All three of those dams of 35 feet or more in height are rated as high hazard risk dams – Dudenhoeffer Dam, Lake Maxwell Dam, and Rinquelin Trail Dam. In addition, three additional dams that are not regulated by the state that are rated as High Hazard: Bowman Lake Dam, Danube Corporation Lower Dam, and Murphey Lake Dam. The remaining 24 dams are considered low risk. All of the dams registered with the MDNR and their hazard risk are listed in Table 3.5. The non-regulated dams vary in height from 0 to 34 feet.

Figure 3-2 is a map of the dams in Maries County that shows high hazard dams and also categorizes the dams by dam height.

Table 3.5 shows a listing of dams in Maries County, dam height, drainage area, lake area and their hazard risk. Based on the locations of the dams in Maries County, and in particular the high hazard dams, the jurisdictions most vulnerable to dam failure are the cities of Vienna and portions of Maries County. The only affect any dam failures might cause any other jurisdictions, including school districts, would be possible damage to some roads and/or bridges that might result in adjustments made to travel or bus routes. In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county the county would benefit from collecting data on these issues to improve future planning efforts.

Figure 3-2

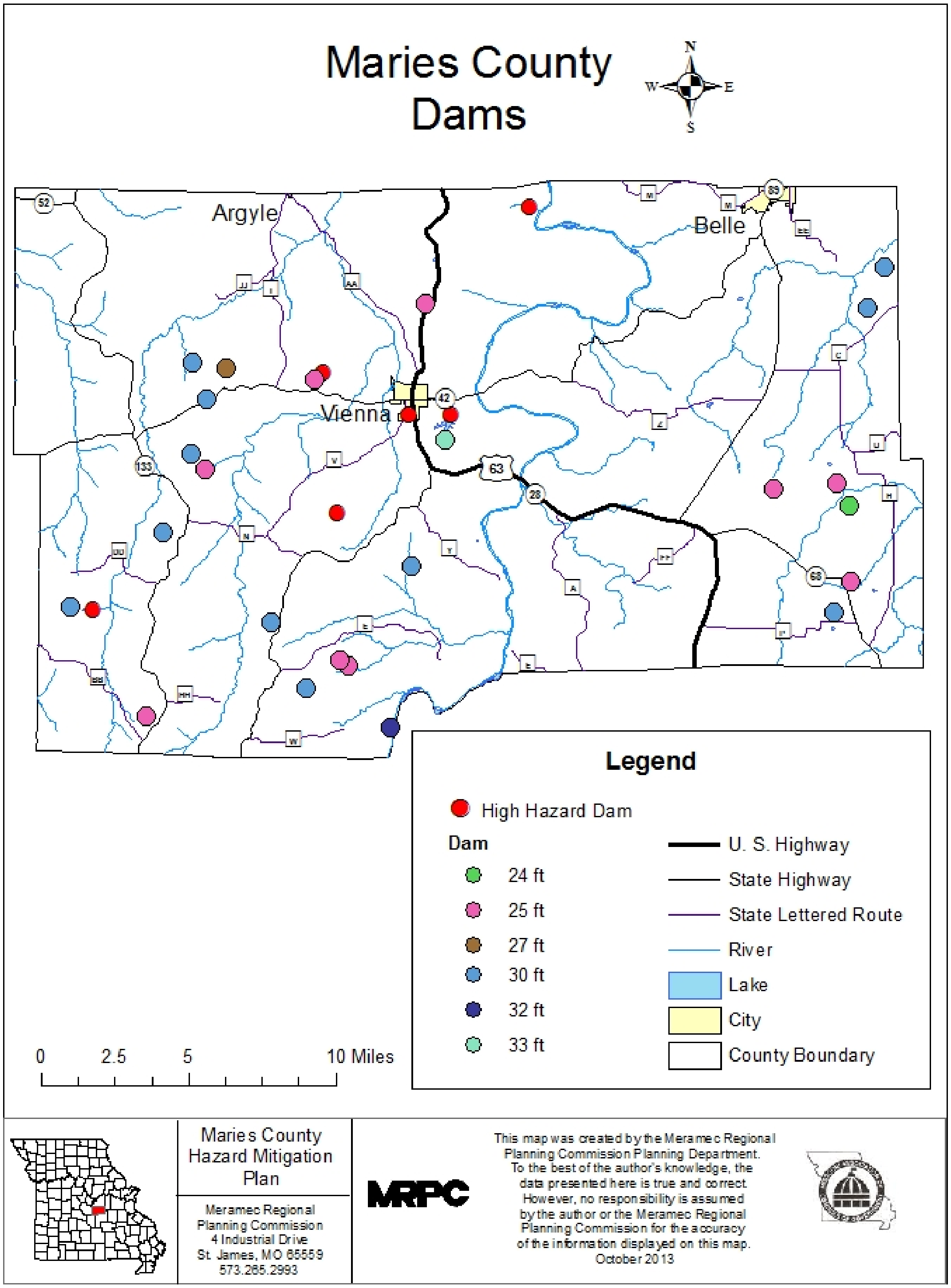

Maries County
Dams
N
W
E
S
Argyle
Belle
Vienna
Legend
High Hazard Dam
Dam
24 ft
25 ft
27 ft
30 ft
32 ft
33 ft
U. S. Highway
State Highway
State Lettered Route
River
Lake
City
County Boundary
0
2.5
5
10 Miles
Maries County
Hazard Mitigation
Plan
Meramec Regional
Planning Commission
4 Industrial Drive
St. James, MO 65559
573.265.2993
MRPC
This map was created by the Meramec Regional
Planning Commission Planning Department.
To the best of the author's knowledge, the
data presented here is true and correct.
However, no responsibility is assumed
by the author or the Meramec Regional
Planning Commission for the accuracy
of the information displayed on this map.
October 2013

Table 3.5 Maries County Dams

Name of Dam	Dam Height (ft)	Drainage Area (ac-ft)	Lake Area (ac)	Hazard Risk
Apex Lake Dam	30	170	4	Low
Blake Lake Dam	30	50	4	Low
Bowman Lake Dam	23	55	9	High
Cowan Lake Dam	25	70	3	Low
Danube Corporation Lower Dam	32	900	37	High
Danube Corporation Upper Dam	25	50	5	Low
Dillon Lake Dam	25	60	12	Low
Dudenhoeffer Dam	55	376	39	High
Hayes Lake Dam	30	130	5	Low
Hidden Lake Dam	25	90	4	Low
Hoban Lake Dam	30	280	9	Low
Kleffner Lake Dam	25	120	5	Low
Koch Lake Dam	32	180	4	Low
Kuhrts Lake Dam	30	40	4	Low
Lake Maxwell Dam	80	978	107	High
Miller Lake Dam	25	120	4	Low
Murphey Lake Dam	27	225	10	High
Nepomuceno Lake Dam	27	125	9	Low
Norbert Sandbothe Pond	33	0	4	Low
Rinquelin Trail Dam	35	580	27	High
Share Lake Dam	30	65	5	Low
Sherrell Lake Dam	25	40	3	Low
Slinkman Lake Dam	30	55	6	Low
Swarthout Lake Dam	25	28	4	Low
Veasmann Lake Dam	30	40	3	Low
Vogt Dam	30	130	6	Low
Wensler Lake Dam	24	200	8	Low
Whippoorwill Lake Dam	30	65	9	Low
Wilson Lake Dam	30	70	5	Low
Wilson Lake Dam	25	160	3	Low

Source: Missouri Department of Natural Resources – website: http://www.dnr.mo.gov/env/wrc/damsft[viii]

An insufficiency exists in the data for dams in Maries County. MDNR is in the process of helping dam owners develop emergency action plans (EAP) for all state regulated, high-hazard potential dams in the state, but to date, there are only two that have inundation maps on file – Lake Maxwell Dam and Dudenhoeffer Lake Dam. Those inundation maps are included in Figures 3-4 through 3-7 Although there are topographical and aerial photography maps available, no information on failed dam inundation areas exists for the other high hazard dams in the county. Topographic and aerial photographic maps were studied and compared to try to illustrate the likely areas that would be affected. However, until better data can be developed and confirmed, the information illustrated in Figures 3-3 and 3-8 should be considered a representation of potential impact areas. The county will continue to strive to improve the data on dam inundation.

Six of the dams are classified by MDNR as high hazard risk dams. Many of these high hazard dams have structures or infrastructure located below the dam. The aerial maps included in Figures 3-3 through 3-8 better illustrate the impact areas should any of these dams fail and show the high hazard risk dams and the probable impact area should the dam fail. This impact area has been drawn in, based on analysis of topographic maps and aerial photos.

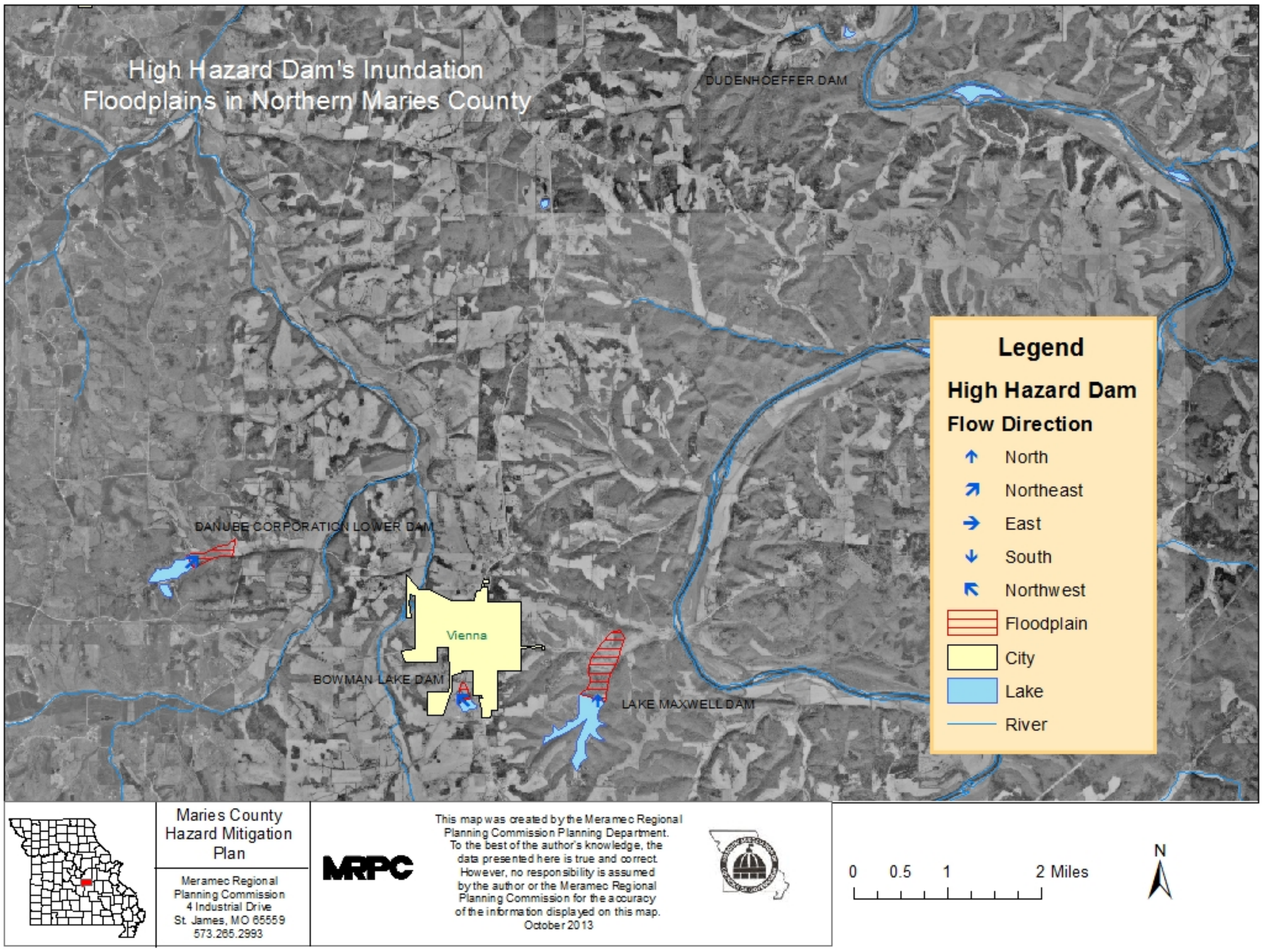
There are three high hazard risk dams located in the central part of the county around Vienna. Danube Corporate Lower Dam is located approximately 3 miles west of Vienna, north of Highway 42. There are two farms with homes and outbuildings located in the probable inundation area below the dam. The first is located approximately 350 yards below the dam and well within the hazard zone if a catastrophic failure were to occur. The second farm is located approximately 1,490 yards from the dam and along Maries County Road 213, which could also suffer damage. The land below the dam is currently in pasture, forest and cropland.

Bowman Lake Dam is located adjacent to the city limits of Vienna on the south side of the community. It lies on the west side of Highway 63. The estimated inundation area runs north- into an open, undeveloped area for over 600 yards before reaching some utility buildings and Maries County Road 640. 230 yards beyond CR 640, the inundation zone intersects with another pair of utility buildings before reaching Highway 42. It is doubtful that damage would extend beyond this area.

Lake Maxwell Dam is located southeast of Vienna, approximately one mile from the city limits. According to the maps developed by MDNR, the inundation zone would flow north-northeast .6 miles to Highway 42 and then flow along 42 for .6 miles to the Gasconade River. This would impact Highway 42, Maries County Road 336, a private road on the south side of 42 and possible Maries County Road 335 on the east side of the Gasconade River. There might be one or more residences near the river that would also be impacted. Figures 3-4 through 3-5 are the inundation maps developed and provided by MDNR. Figure 3-4 shows a more extensive map of the inundation area including approximate times of impact following a catastrophic failure. Figure 3-5 shows the area immediately below the dam in greater detail.

Dudenhoeffer Dam is located in the north central part of the county, approximately 2.5 miles due east of Highway 63 and one mile north of Maries County Road 302. Based on the maps provided by MDNR, should a catastrophic failure occur, few, if any structures would be affected. There would be damage to one or more private roads as well as pasture land. The outflow from the lake would eventually end up in the Gasconade River, approximately 1.6 miles from the dam site. [GIS data available did not have Dudenhoeffer Dam, so this dam is not included in Figure 3-3, but more detailed information can be found in Figures 3-6 and 3-7.]

Figure 3-3



The two remaining high hazard dams are located in southwest and south central Maries County. The inundation zones for these two dams are approximated in Figure 3-8. Rinquelin Trail Dam is located approximately two miles west of Highway 133 and approximately two due north of Highway BB. The dam lies .2 of a mile south of Maries County Road 630. Should a catastrophic failure occur, there is one home located approximately .3 of a mile west of the dam that might be affected. Maries County Road 630 is approximately one half mile from the dam and would likely be damaged. Just east of the county road is a small tributary of the Osage River and the flood water would be carried down it. Approximately 1.5 miles downstream, State Highway DD crosses this tributary. Depending on the volume and power of the water, there is potential for this bridge to be impacted. There are no other structures within several miles of the inundation area that would likely be affected.

Murphey Lake Dam is located approximately four miles southwest of Vienna, between Maries County Roads 616 and 617. Two smaller lakes lie immediately below Murphey Lake Dam.

There is a power line right of way located .3 of a mile below the dam that would likely be impacted if the dam were to fail. In addition, there is a farm house located with .5 a mile of the dam that may also be impacted by a catastrophic failure. Other than these two features, the land below the dam is made up of forest and pasture for more than three miles.

Figure 3-4

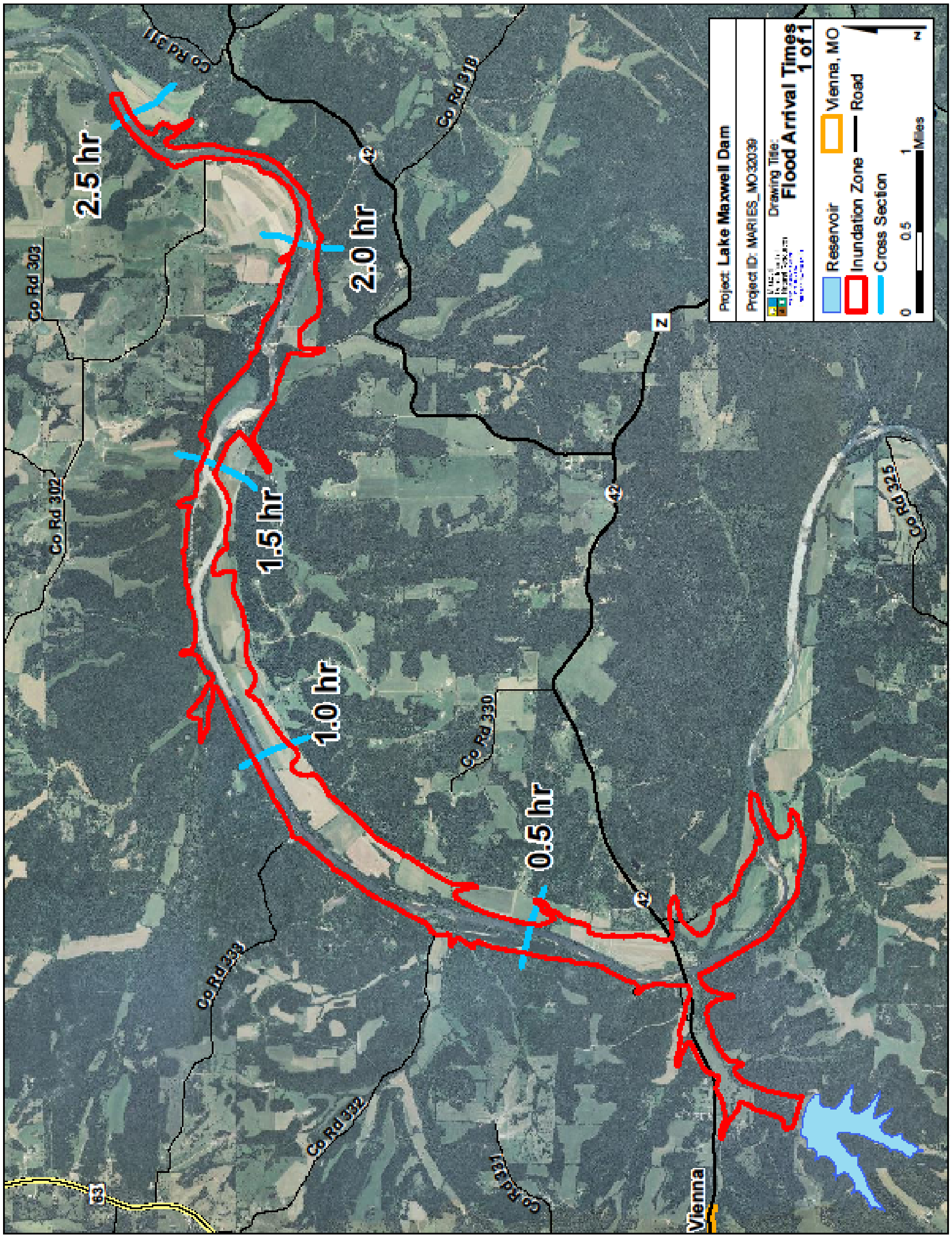


Figure 3-5

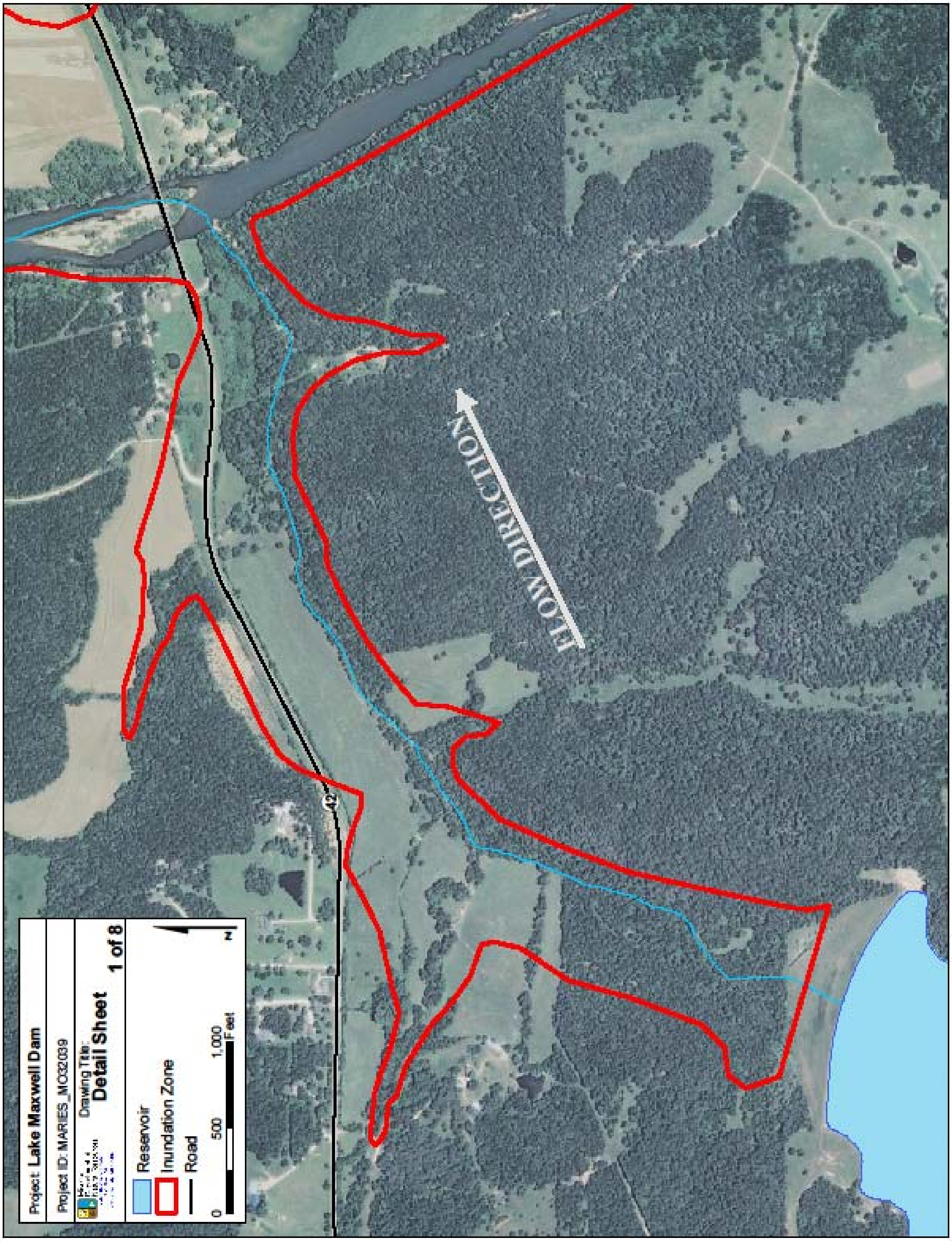
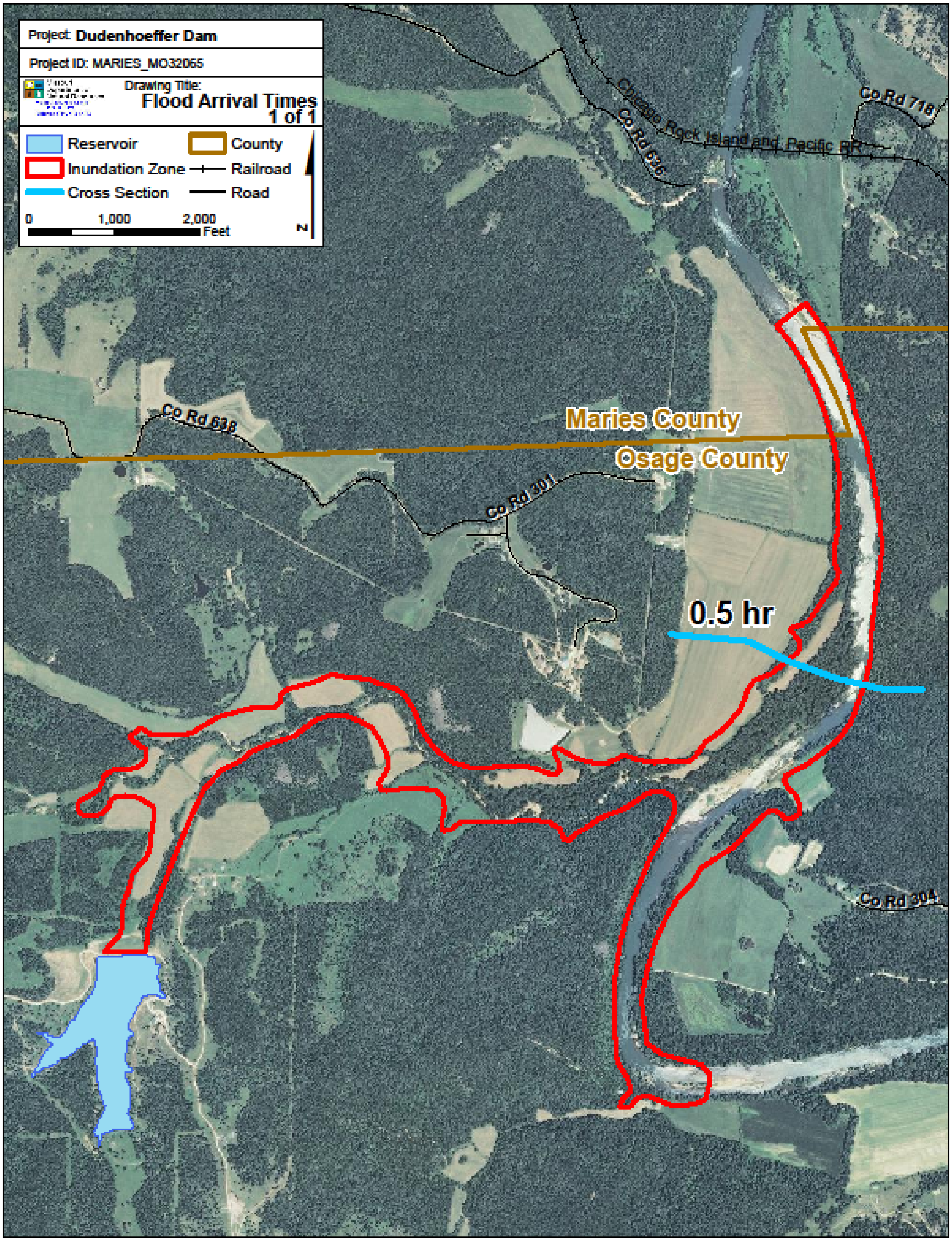

FLOW DIRECTION
42
Project: Lake Maxwell Dam
Project ID: MARIES_MO32039
Drawing Title:
Detail Sheet
1 of 8
Reservoir
Inundation Zone
Road
0
500
1,000
Feet
N

Figure 3-6



Project: Dudenhoeffer Dam
Project ID: MARIES_MO32065
Drawing Title:
Flood Arrival Times
1 of 1
Reservoir
County
Inundation Zone
Railroad
Cross Section
Road
0
1,000
2,000
Feet
N
Chicago Rock Island and Pacific RR
Co Rd 718
Co Rd 636
Co Rd 638
Maries County
Osage County
Co Rd 301
0.5 hr
Co Rd 304

Figure 3-7

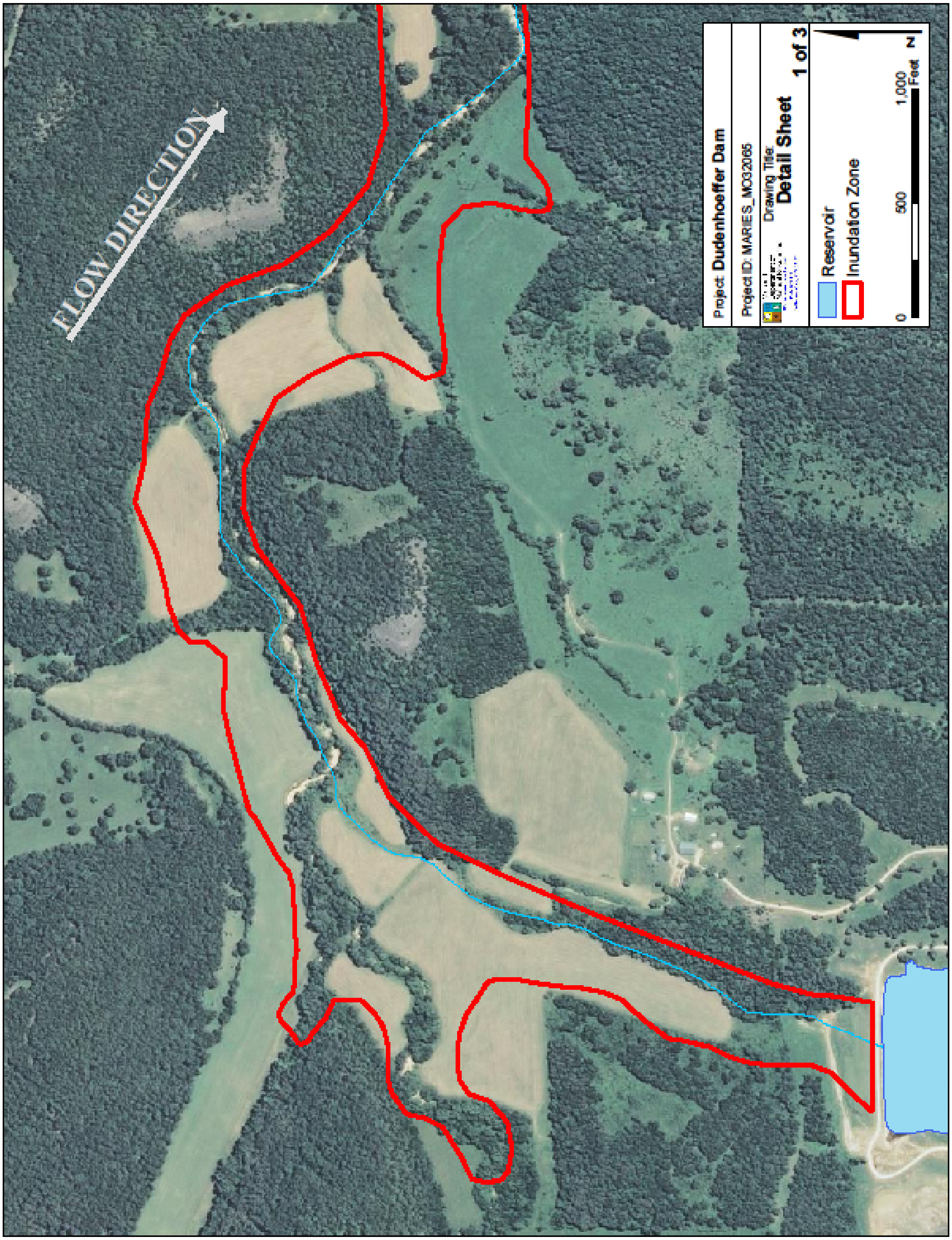
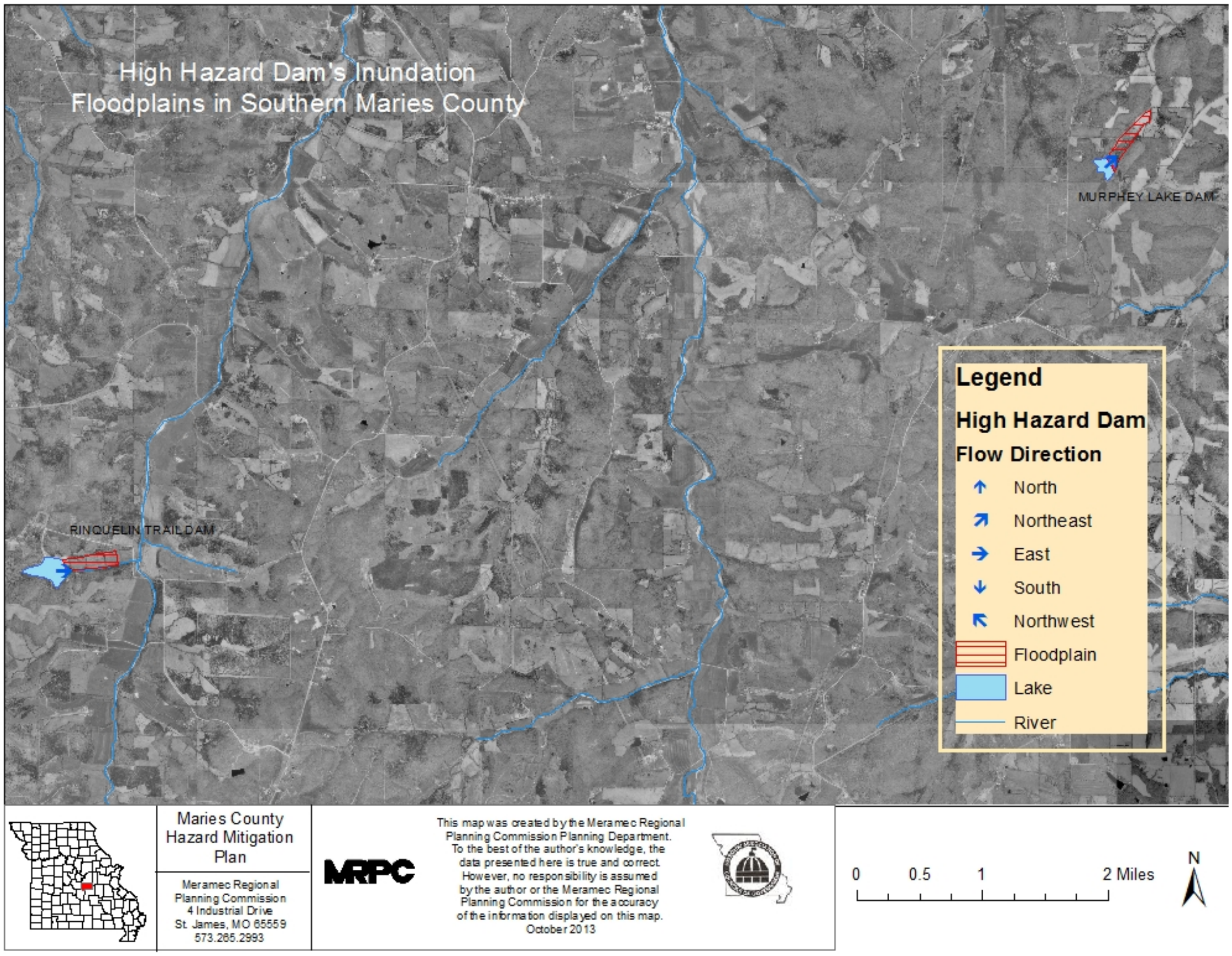

FLOW DIRECTION
Project: Dudenhoeffer Dam
Project ID: MARIES_MO32065
Drawing Title:
Detail Sheet
1 of 3
Reservoir
Inundation Zone
0
500
1,000
Feet
N

Figure 3-8



Dam failure leads to the cascading emergency of flash flooding. When a dam fails, the pent-up water can be suddenly unleashed and have catastrophic effects on life and property downstream. Homes, bridges and roads can be demolished in minutes. There have been at least 27 recorded dam failures in 20 Missouri counties in the last 100 years. Fortunately, only one drowning has been associated with a dam failure in the state[ix], and until the Taum Sauk Reservoir dam failure, there had previously been little consequence to property. The Taum Sauk Reservoir breach destroyed a state park and cost millions of dollars to remediate.

Warning Time and Duration

The speed with which a dam may fail depends mainly upon the cause of the failure. A dam may fail in a matter of a few minutes or the process may takes days, weeks or months. Because of this warning time can vary radically from incident to incident. If there is a catastrophic failure of a large dam, there could be very little or no warning for people living in the impact area. Based on history, warning time is typically less than six hours. The duration of the actual breach and subsequent flooding will be less than one week, although the remediation will tak significantly longer. For this reason the CPRI rating assigned was Probable (3), with a warning time of six hours or less (4) and a duration of less than a week (3).

Severity/Magnitude

Discussion of the possible severity of dam failure, as well as the severity of dam failures that have occurred in Missouri, are in previous sections. In addition, previous sections discuss property that could be damaged should dam failure occur. A dam failure in Maries County would likely have little impact on the daily operations of the community. Families living near the dam may experience washed out roadways or possibly even a demolished home. Damage to highways and bridges could result in transportation problems that might take weeks or months to repair. Although the Taum Sauk Reservoir incident had a great impact on the local economy of that area, there are no dams in Maries County that are economically significant enough to have a similarly adverse economic impact. Based on this, all jurisdictions in Maries County were assigned a CPRI rating of Negligible (1) – Less than 10 percent of property severely damaged, shutdown of facilities and services for less than 24 hours; and/or injuries/illnesses treatable with first aid. Although the city of Vienna and portions of Maries County have more proximity to high hazard dams, the number of roads, homes and businesses that might be affected is restricted to less than 10 percent of the properties in both of these jurisdictions.

Statement of Probable Likeliness of Future Occurrence

Unlikely (1) – Event is possible within the next 10 years; event has up to one in 10 years chance of occurring; history of events is less than or equal to 10 percent likely per year. As there has not been a dam incident in the county, the probability of a future occurrence is not likely.

Probability

Based on previous events of dam failure in the planning area, a failure causing significant damages was assigned the CPRI rating of Unlikely (1) – Event is possible within the next 10 years; event has up to one in 10 years chance of occurring; history of events is less than or equal to 10 percent likely per year. As there has not been a dam incident in the county, the probability of a future occurrence is not likely.

Recommendations

- Encourage land use management practices to decrease the potential for damage from a dam collapse, including discouragement of development in areas with the potential for sustaining damage from a dam failure.
- Install public education programs to inform the public of dam safety measures and preparedness activities.
- Offer training programs for dam owners to encourage them to inspect their dams and so that they may learn how to develop and exercise emergency action plans.
- Encourage jurisdictions to review plans and perform exercises in preparation for dam failures.
- Encourage and support the development of emergency action plans for all high hazard dams in the county.

Hazard Summary – Dam Failure – All Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
1.65	Low

3.2.3 Drought

Description

Drought is a normal, recurrent feature of climate, although many erroneously consider it a rare and random event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration; it differs from aridity, which is restricted to low rainfall regions and is a permanent feature of climate.

Drought is an insidious hazard of nature. Although it has scores of definitions, it originates from a deficiency of precipitation over an extended period of time, usually a season or more. This deficiency results in a water shortage for some activity, group, or environmental sector. Drought should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration (i.e., evaporation + transpiration) in a particular area, a condition often perceived as “normal”. It is also related to the timing (i.e., principal season of occurrence, delays in the start of the rainy season, occurrence of rains in relation to principal crop growth stages) and the effectiveness (i.e., rainfall intensity, number of rainfall events) of the rains. Other climatic factors such as high temperature, high wind, and low relative humidity are often associated with it in many regions of the world and can significantly aggravate its severity.

Drought should not be viewed as merely a physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event (less precipitation than expected resulting from natural climatic variability) and the demand people place on water supply. Human beings often exacerbate the impact of drought. Recent droughts in both developing and developed countries and the resulting economic and environmental impacts and personal hardships have underscored the vulnerability of all societies to this “natural” hazard.[x]

Hazard Characteristics

Drought is not a hazard that affects just farmers, 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 and a big city’s tourism. On average, drought costs the U.S. economy about $7 billion to $9 billion a year, according to the National Drought Mitigation Center. The dictionary definition of drought is a period of prolonged dryness. Current drought literature commonly distinguishes between four “categories” of drought, all of which define drought in simplified terms:

1. **Agricultural Drought**, defined by soil moisture deficiencies.
2. **Hydrological Drought**, defined by declining surface and groundwater supplies, and
3. **Meteorological Drought**, defined by precipitation deficiencies.

4. **Socioeconomic Drought**, defined as drought that impacts supply and demand of some economic commodity

Each of these definitions relates the occurrence of drought to water shortfall in some component of the hydrological cycle. Each affects patterns of water and land use, and each refers to a repetitive climatic condition. In urban areas, drought can affect those communities dependent on reservoirs for their water, as decreased water levels due to insufficient rain can lead to the restriction of water use. In agricultural areas, drought during the planting and growing season can have a significant impact on yield. To take the definition of drought even further, the U.S. Government definition of an agricultural drought incorporates specific parameters based upon historical records. Agricultural drought is "a combination of temperature and precipitation over a period of several months leading to a substantial reduction in yield (bushels per acre) of one or more of the three major food grains (wheat, soybean, corn). A substantial reduction is defined as a yield (bushels per acre) less than 90 percent of the yield expected with temperature/ precipitation equal to long term average values."

Regardless of the specific definition, droughts are difficult to predict or forecast both as to when they will occur, and how long they will last. According to Dr. Grant Darkow, Department of Atmospheric Science, University of Missouri-Columbia, there is a recognizable "upper air flow pattern and simultaneous surface pattern associated with abnormal dryness over Missouri." When the upper airflow pattern is typified by air flowing in a broad arc over the central plains with higher speeds in southern Canada than over the U.S., then the air over the southern plains will be "characterized by a weak clockwise circulation." "Storm systems coming off the Pacific Ocean" will cross the extreme northwestern states and southern Canada, thus bypassing the Midwestern states. When this flow pattern persists, the result can be a prolonged period of drought.[xi]

Hazard History

Missouri's average annual rainfall ranges from about 34 inches in the northwest to about 48 inches in the southeast. Even the driest areas of Missouri have enviable rainfall, compared to most western states. But lack of rainfall impacts certain parts of the state more than others because of alternate sources and usage patterns. Most of the southern portions of Missouri are less susceptible to problems caused by prolonged periods of non-rain, since there are abundant groundwater resources. Even with decreased stream flow or lowered reservoir levels, groundwater is still a viable resource in southern Missouri. Row-crop farming is not extensive and therefore agricultural needs aren't as great as in other parts of the state. The only exception is in the southwestern and southeastern areas where irrigation is used.[xii]

According to the National Climatic Data Center (NCDC) and the Missouri Department of Natural Resources (MDNR), since 1900, there have been 14 drought events reported for the Southeast Climate Region of which Maries County is included. Those events have varied in length from 9 to 38 months. The most severe droughts occurred between 1930 and 1936 (three different events) and again in 1956 when the greatest rainfall deficit ever recorded for the region occurred. In recent memory, the area suffered from drought in 1999, 2000, 2006, 2007 and most recently 2012-13.

Drought of 1999-2000. Most of Missouri was in a drought condition during the last half of 1999, along with other states in the Midwest and the nation. The dryness did not begin to evolve until July 1999, but rapidly developed into a widespread drought by September. At that time, Missouri was placed under a Phase I Drought Advisory level by the Department of Natural Resources (DNR), and Governor Carnahan declared an Agricultural Emergency for the entire State. Agricultural reporting showed a 50 percent crop loss from the drought in 50 counties, with severe damage to pastures for livestock, corn crops, and Missouri's top cash crop—soybean. On Oct. 13, 1999, U.S. Agriculture Secretary Dan Glickman declared all Missouri counties agricultural disaster areas, making low-interest loans available to farmers in Missouri and contiguous states. The drought intensity increased through autumn and peaked at the end of November 1999. In fact, the five-month span between July and November became the second driest July-November period in Missouri since 1895, averaging only 9.38 inches of rain.

A wetter than normal winter diminished dry conditions in central and southern Missouri, but long-term moisture deficits continued to exist. At the same time, the remainder of the state (roughly north of the Missouri River) continued under drought conditions. Overall dry conditions returned through much of the state in March 2000, and costly wildfires and brush fires (70) erupted in many counties. By May, the entire state was under a Phase II Drought Alert level, and on May 23, 2000, then Gov. Mel Carnahan announced activation of the Missouri Drought Assessment Committee (DAC), made up of state and federal agencies and chaired by the director of the Missouri Department of Natural Resources. At a May 25th meeting, the DAC selected a subcommittee (guided by the Missouri Drought Response Plan) to determine the drought status of each county. Based on observations across the state and projections of future rainfall, the committee in June upgraded the drought status for 27 northern Missouri counties to Phase III, Conservation. This was based on concerns for water supplies and agricultural impacts. The City of Milan in Sullivan County was among the most severely affected for water supplies. In June, a total of 80 Missouri counties remained under the Phase II alert level, while seven counties in Southeast Missouri (Butler, Dunklin, Mississippi, New Madrid, Pemiscot, Scott and Stoddard) remained under Phase I advisory conditions.

By mid-July 2000, some areas of northern Missouri benefited from additional rainfall, while drier conditions prevailed in other areas. At its July 12, 2000 meeting, the DAC revised its assessment, placing 30 counties under Phase III Conservation, including Maries County and nine other counties in the south central area. The remaining 84 counties in the state were all under Phase II, Drought Alert. This included seven counties in northern Missouri downgraded from Phase III Conservation, and seven counties in Southeast Missouri previously assessed as Phase I, Advisory. To ease the agricultural impact of the drought during the summer months, Gov. Carnahan gained release of over 1 million acres from the Conservation Reserve Program (CRP) to allow farmers and ranchers in 21 counties an additional source to cut hay for livestock feed. Also, livestock producers in 16 counties were released from CRP contracts to allow cattle grazing on certain idle lands.[xiii] Total crop damages from the 1999-2000 drought were estimated at $660,000 for the entire state.[xiv]

The event of 2006-2007 was far milder, with a drought alert being issued during February 2006 and again in October 2007, but no significant damage occurred. The drought that struck Maries County in 2012 was part of a much larger climate event that affected much of the United States and is still on-going in some areas of the country. It is estimated that this widespread drought could result in $75 to $150 billion in damages and economic losses nationwide. Fortunately, drought conditions reversed for Maries County in 2013.

Drought can be caused by both lack of rain during the spring, summer and fall and lack of snow during the winter months because both are necessary for the recharging of groundwater sources. The driest months are typically January and February.

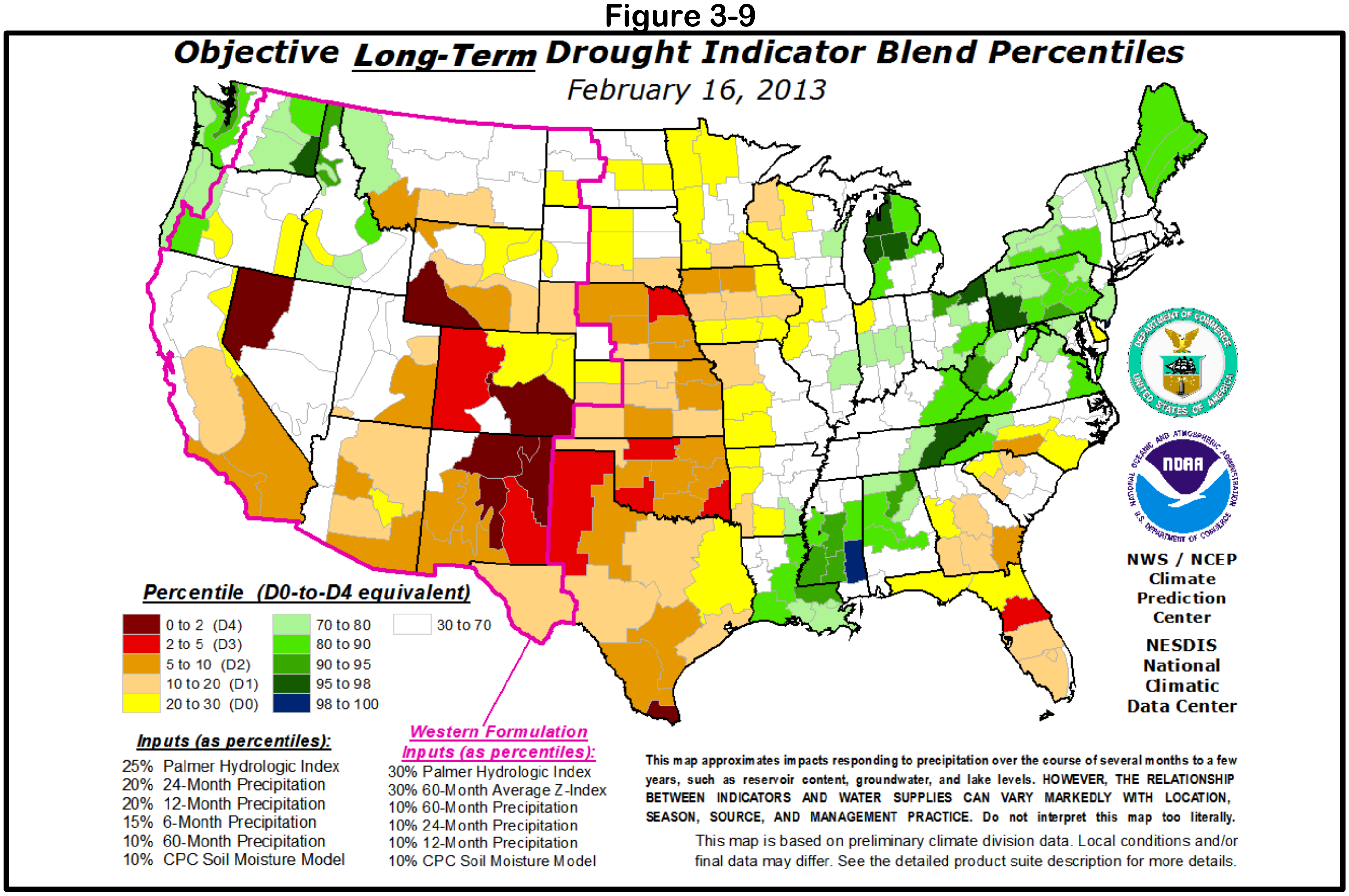
Likely Locations

Maries County is located in the southern half of Missouri where abundant groundwater resources can serve to offset the severity of drought that may limit surface water resources. Furthermore, row crop farming and the use of irrigation is very limited or non-existent in the county, so the demand for water for agricultural purposes is not as great as in other parts of the state.

All areas of Maries County are susceptible to drought, but particularly cities where concentrated numbers 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. However, rural residences with individual wells will likely also be affected.

Figure 3-9 shows the areas of the United States that are most susceptible to long-term drought conditions and the percentage of precipitation related to drought conditions.

Figure 3-9



Speed of Onset and Existing Warning Systems

Drought is a hazard that evolves slowly and may not cause danger for months or years. Warning systems are important to drought conditions as city and county officials must inform residents of water conservation efforts or provide other information about the drought emergency. The State of Missouri uses the Drought Response System to rate, monitor and inform the public of drought conditions and is divided into four phases:

- **Phase I: Advisory Phase** – requires a drought monitoring and assessment system to provide enough lead time for state and local planners to take appropriate action
- **Phase II: Drought Alert** - when the PDSI reads -1.0 to -2.0, and stream flows, reservoir levels, and groundwater levels are below normal over a several month period, or when the Drought Assessment Committee (DAC) determines that Phase II conditions exist based on other drought determination methods
- **Phase III: Conservation Phase** – when the PDSI reads -2.0 o -4.0, and stream flows, reservoir levels and groundwater levels continue to decline, along with forecasts indicating an extended period of below-normal precipitation, or when the DAC determines that Phase III conditions exist based on other drought determination models
- **Phase IV: Drought Emergency** – when the PDSI is lower than -4.0, or when the DAC determines that Phase IV conditions exist based on other drought determination methods (Hays, 1995)[xv]

Warning Time and Duration

A drought evolves slowly and can last for months or even years. Based on this information, the assigned CPRI rating is (1), or a Probable warning time of more than 24 hours (1). The assigned CPRI for duration is a (4), or more than one week.

Probability

Based on the history of previous events in the planning area, the CPRI rating for drought is Unlikely (1) – Event is possible within the next 10 years; event has up to one in 10 years chance of occurring; history of events is less than or equal to 10 percent likely per year. In the past decade, Missouri has experienced drought conditions that have affected a large portion of the state. Future occurrence of mild drought in Maries County is likely but severe drought is very unlikely.

Severity/Magnitude

Drought produces a complex web of impacts that spans many sectors of the economy and reaches well beyond the area experiencing physical drought. This complexity exists because water is integral to our ability to produce goods and provide services.

Impacts are commonly referred to as direct or indirect. Reduced crop, rangeland and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat are a few examples of direct impacts. The consequences of these impacts illustrate indirect impacts. For example, a reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced tax revenues because of reduced expenditures, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs. Direct or primary impacts are usually biophysical. Conceptually speaking, the more removed the impact from the cause, the more complex the link to the cause. In fact, the web of impacts becomes so diffuse that it is very difficult to come up with financial estimates of damages. The impacts of drought can be categorized as economic, environmental, or social.

Not all impacts of drought are negative. Some agricultural producers outside the drought area or with surpluses benefit from higher prices, as do businesses that provide water-related services or alternatives to water-dependent services; these types of businesses were among the “winners” in the 1987–89 U.S. drought.

Many economic impacts occur in agriculture and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and subsurface water supplies. In addition to obvious loss of yield 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 diseases to forests and reduce growth. The incidence of forest and range fires increases substantially during extended droughts, which in turn places 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. Reduced income for farmers has a ripple effect. Retailers and others who provide goods and services to farmers face reduced business. This leads to unemployment, increased credit risk for financial institutions, capital shortfalls, and loss of tax revenue for local, state, and federal government. Less discretionary income affects the recreation and tourism industries. Prices for food, energy, and other products increase as supplies are reduced. In some cases, local shortages of certain goods result in the need to import these goods from outside the stricken region. Reduced water supply impairs the navigability of rivers and results in increased transportation costs because products must be transported by rail or truck.

Environmental losses are the result of damages to plant and animal species, wildlife habitat, and air and water quality; forest and range fires; degradation of landscape quality; loss of biodiversity; and soil erosion. Some of the effects are short-term and conditions quickly return to normal following the end of the drought. Other environmental effects linger for some time or may even become permanent. Wildlife habitat, for example, may be degraded through the loss of wetlands, lakes, and vegetation. However, many species will eventually recover from this temporary aberration. The degradation of landscape quality, including increased soil erosion, may lead to a more permanent loss of biological productivity of the landscape. Although environmental losses are difficult to quantify, growing public awareness and concern for environmental quality has forced public officials to focus greater attention and resources on these effects.

Social impacts mainly involve public safety, health, conflicts between water users, reduced quality of life, and inequities in the distribution of impacts and disaster relief. Many of the impacts specified as economic and environmental have social components as well. Population out-migration is a significant problem in many countries, often stimulated by greater availability of food and water elsewhere. Migration is usually to urban areas within the stressed area or to regions outside the drought area; migration may even be to adjacent countries, creating refugee problems. However, when the drought has abated, these persons seldom return home, depriving rural areas of valuable human resources necessary for economic development. For the urban area to which they have immigrated, they place ever-increasing pressure on the social infrastructure, possibly leading to greater poverty and social unrest.[xvi]

The next drought to affect Maries County will likely have no or little impact on the daily activities of Maries County residents and businesses. If a major drought should occur, farmers may suffer low crop yields and/or have difficulty finding adequate pasture and watering sources for livestock.

The CPRI rating assigned is Negligible (1) – Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged. Because of its geographical location and characteristic weather patterns, Missouri is vulnerable to drought conditions. According to the Missouri State Hazard Mitigation Plan, in regards to drought susceptibility, Maries County is located in a region of the state which is considered moderately susceptible to drought. Groundwater resources are adequate to meet domestic and municipal water needs and the topography is generally unsuitable for row-crop irrigation. Based on historical information, future drought events in Maries County will most likely have a negligible effect on residents.

Recommendations

- All cities and the county commission should adopt water conservation ordinances that limit the amount of water that residents may use during a period of drought. T
- The county and its sectors should develop water monitoring plans as an early warning system. Each sector should inventory and review their reservoir 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 its jurisdictions should continually look for and fund water system improvements, new systems and new wells.

Hazard Summary – Drought – All Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
1.3	Low

3.2.4 Earthquake

Description

Earthquakes can be defined as shifts in the earth's crust causing the surface to become unstable. This instability can manifest itself in intensity from slight tremors to large shocks. The duration can be from a few seconds up to five minutes. The period of tremors (and shocks) can last up to several months. The larger shocks can cause ground failure, landslides, liquefaction, uplifts and sand blows.

The earth's crust is made up of gigantic plates, commonly referred to as tectonic plates. These plates form what is known as lithosphere and vary in thickness from 6 1/2 miles (beneath oceans) to 40 miles (beneath mountain ranges) with an average thickness of 20 miles. These plates "float" over a partly melted layer of crust called the asthenosphere. The plates are in motion and where a plate joins another, they form boundaries. Where the plates are moving toward each other is called convergent plate boundary and when they are moving away from each other is called a divergent plate boundary. The San Andreas Fault in California is a horizontal motion boundary, where the Pacific plate is moving north while the North American plate is moving west. These movements release built up energy in the form of earthquakes, tremors and volcanism (volcanoes). Fault lines such as the San Andreas come all the way to the surface and can be readily seen and identified. There are fault lines that do not come all the way to the surface, yet they can store and release energy when they adjust. Many of the faults in the Central United States can be characterized this way.

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

There are eight earthquake source zones in the Central United States, two of which are located within the state of Missouri—the New Madrid Fault and the Nemaha Uplift. Other 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.

The Nemaha Uplift is of concern to Missourians because it runs parallel to the Missouri/Kansas border from Lincoln, NE to Oklahoma City, OK. Its earthquakes are not as severe as the historic New Madrid fault zone, but there have been several earthquakes that have affected the Missouri side of the line.[xvii]

Hazard Characteristics

Ground shaking from earthquakes can collapse buildings and bridges; disrupt gas, electric, and phone service; and sometimes trigger landslides, avalanches, flash floods, fires, and huge, destructive ocean waves (tsunamis). Buildings with foundations resting on unconsolidated landfill and other unstable soil, and trailers and homes not tied to their foundations are at risk because they can be shaken off their mountings during an earthquake. When an earthquake occurs in a populated area, it may cause deaths and injuries and extensive property damage.[xviii]

The effect of an earthquake on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally - total destruction. Although numerous intensity scales have been developed over the last several hundred years to evaluate the effects of earthquakes, the one currently used in the United States is the Modified Mercalli (MM) Intensity Scale. It was developed in 1931 by the American seismologists Harry Wood and Frank Neumann. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals. It does not have a mathematical basis; instead it is an arbitrary ranking based on observed effects.

The Modified Mercalli Intensity value assigned to a specific site after an earthquake has a more meaningful measure of severity to the nonscientist than the magnitude because intensity refers to the effects actually experienced at that place. After the occurrence of widely-felt earthquakes, the Geological Survey mails questionnaires to postmasters in the disturbed area requesting the information so that intensity values can be assigned. The results of this postal canvass and information furnished by other sources are used to assign an intensity within the felt area. The maximum observed intensity generally occurs near the epicenter.

The lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above. The following Table 3.6 is an abbreviated description of the Modified Mercalli Scale.

Table 3.6 Modified Mercalli Intensity (MMI) Scale

MMI	Felt Intensity
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

MMI	Felt Intensity
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.[xix]

Large earthquakes in Missouri could trigger additional hazards such as soil liquefaction, lateral spreading, landslides and sinkhole collapse – specifically in the karst topography present in much of southeast Missouri. Liquefaction is a site soil response to strong earthquake ground motion. Strong earthquake waves cause water pressure to increase within sandy soils, forcing sand grains apart, and the material will behave as a dense liquid. Sand blows form in the areas where liquefied sand is overlain by heavier clay rich silts, causing a geyser-like eruption of sand onto the land surface. Liquefaction causes land to lose its load-bearing capacity, which can lead to differential settlement and associated building foundation failures. Lateral spreading can occur on even gentle slopes and seriously damage buried utilities and road networks. Landslides could be triggered in steep slopes and road cuts through unstable geologic materials, potentially damaging and closing roads and railroads. Earthquakes could exacerbate existing problems and cause landslides where none have occurred before.[xx]

Figure 3-10 shows projected earthquake intensities for Missouri and the surrounding states that are affected by the New Madrid Fault.

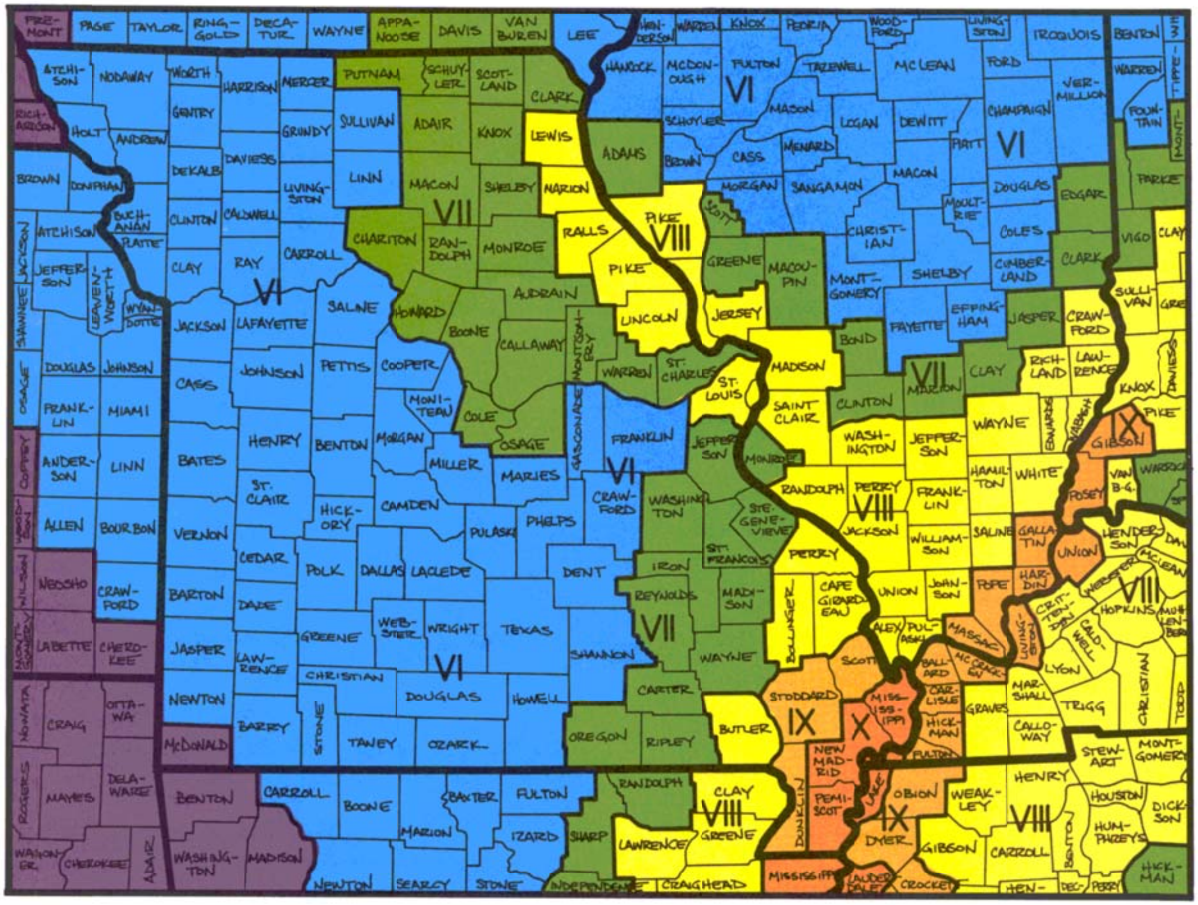
Hazard Event History

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.

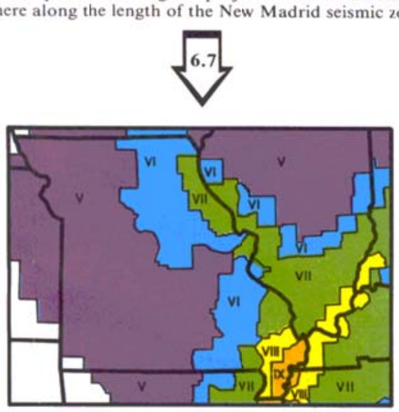
Whatever the seismic history of the region may have been before the first Europeans arrived, after Dec. 16, 1811, there could be no doubt about the area's potential to generate severe earthquakes. On that date, shortly after 2 AM, the first tremor of the most violent series of earthquakes in the United 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 river banks caved in, sand bars gave way, and entire islands disappeared. The violence of the

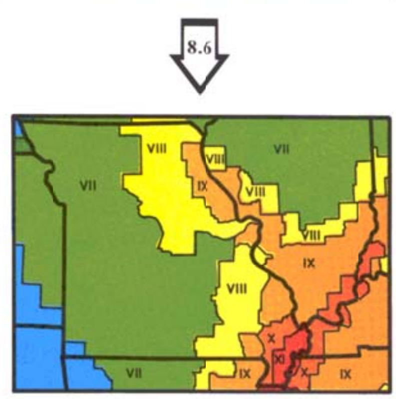
Figure 3-10

PROJECTED EARTHQUAKE INTENSITIES



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.





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: Missouri State Emergency Management Agency website: http://sema.dps.mo.gov 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 was 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 Maries, 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.[xxi]

Several area residents observed a small seismic occurrence during the early morning hours of July 8, 2003, near Cuba in nearby Crawford County. According to information from the USGS, a micro-earthquake happened about 5 miles northwest of Cuba and measured 2.9 on the Richter scale. The earthquake originated at a depth of about 3.1 miles beneath the earth's surface. In southern parts of Missouri, earthquakes of this magnitude happen frequently, but are an unusual event in Maries County.

Small earthquakes continue to occur frequently in Missouri. An average 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.[xxii]

Large amounts of damage caused by an earthquake can lead to cascading natural disasters. Dam structures could be weakened and even potentially destroyed by massive shaking of the earth. The potential failure of the dam could cause the structure to release its contents and cause a flash flooding emergency as well. The earthquake may also cause electrical lines to break, which could potentially start fires that spread into wildfires.

Maries County is located in east central Missouri, less than 160 miles from the southeast corner of the state that has the potential for catastrophic damage should a significant earthquake occur. According to the Earthquake Intensity Map provided through state agencies, in the event of a severe quake in southeast Missouri, Maries County, with a Mercalli rating of VI, the quake would be felt by all, with some heavy furniture moved and broken plaster. However, damage from the event would be slight.

The HAZUS scenario for Maries County however, showed a somewhat different outcome should a major earthquake occur in southeast Missouri. The HAZUS scenario was run based on a 7.7 magnitude earthquake. The results indicated that as many as 920 buildings would be at least moderately damaged with an estimated 38 buildings damaged beyond repair. These numbers are moderated somewhat when comparing the total building stock value to estimated structural damage costs. The county has an estimated building stock value of $851 million and the HAZUS report indicated that there would be as much as $8.8 million in structural damage (one percent of the total building stock value). In addition, the HAZUS report estimates that three of the 64 bridges in the county would sustain some damage. Utility systems would remain functional, although there could be breaks or leaks in water, wastewater and natural gas lines. An estimated 22 households might be displaced and as many as 13 people might seek temporary shelter in the county. More details on the HAZUS earthquake report is included in Section 3.3 Vulnerability

Assessment. It should be noted that this HAZUS report is in striking contrast to HAZUS reports generated for surrounding counties and so there may be a problem with the data.

Additional impacts would be the result of damage to transportation and communications systems. In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Warning Time and Duration

Earthquakes may occur at any time and are very difficult to predict, making timely warnings nearly impossible. For this reason, the CPRI rating assigned was probable warning time of less than six hours (4). Duration of more than one week (4).

Severity/Magnitude

Discussions of the possible severity of an earthquake and the severity and magnitude of previous earthquakes that have occurred in Missouri, are in previous sections. In addition, previous sections discuss the level of damage that might occur based on the Mercalli Scale. Since Maries County is not in the New Madrid shock zone, it will most likely endure some damage from the earthquake to poorly constructed or designed buildings, utility disruption, environmental impacts and economic disruptions/losses. If a major earthquake should occur, Maries County could also be impacted by the number of refugees traveling through the area seeking safety and assistance and the staging of state and federal relief/response. It should be noted that scenarios run with HAZUS for Maries County are somewhat in conflict with the Earthquake Intensity Map, showing more structural damage to buildings as well as infrastructure. However, after further analysis, the severity of the damage still falls within the category of negligible. HAZUS reports show structural damage costs to buildings at approximately one percent and utilities being shut down for 24 hours or less. Based on this, all jurisdictions in Maries County were assigned a CPRI rating of Negligible (1) – Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged.

Probability

In much the same way as meteorologists forecast rain, earth scientists present forecasts of earthquakes as the chance or “probability” of an earthquake occurring in a specific time interval. It is generally accepted that earthquakes can be expected in the future as frequently as in the recent past. The USGS and the Center for Earthquake Research and Information of the University of Memphis now estimate that for a 50-year time period: the probability of a repeat of the 1811-1812 earthquakes is between seven and 10 percent. The probability of an earthquake with magnitude 6.0 or larger is between 25 and 40 percent.[xxiii] Based on this data, a CPRI rating assigned was Occasional (2): An event is probable within the next five years—a 20 percent probability of occurring.

Recommendations

- Encourage purchase of earthquake hazard insurance.
- Establish structurally sound emergency shelters in several parts of the county.

Hazard Summary – Earthquake – All Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
2.05	Moderate

3.2.5 Extreme Heat

Description

The National Weather Service defines a heat wave as three consecutive days of 90° F plus temperatures. These high temperatures generally occur from June through September, but are most prevalent in the months of July and August. Missouri experiences about 40 days per year above 90 degrees, based on a 30-year average compiled by the NWS from 1961-1990. July leads this statewide mean with 15 days above 90 degrees, followed by August with an average of 12 days over 90. June and September average six days and four days respectively for temperatures above 90 during the same 30-year period. This is based on local climatological data from NWS stations at Kansas City, Columbia, Springfield, and St. Louis. As these regional reports indicate, all of Missouri is subject to heat wave during the summer months. Ambient temperature however, is not the only factor to consider when assessing the likely effect of heat. Relative humidity must also be considered, along with exposure, wind, and activity.[xxiv]

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.

Heat can kill by pushing the human body beyond its limits. Under normal conditions, the body's internal thermostat produces perspiration that evaporates and cools the body. However, in extreme heat and high humidity, evaporation is slowed and the body must work extra hard to maintain a normal temperature. Elderly people, young children, and those who are sick or overweight are more likely to become victims of extreme heat. Because men sweat more than women, they are more susceptible to heat illness because they become more quickly dehydrated. The duration of excessive heat plays an important role in how people are affected by a heat wave. Studies have shown that a significant rise in heat-related illnesses happens when excessive heat lasts more than two days. Spending at least two hours per day in air conditioning significantly cuts down on the number of heat-related illnesses.[xxv]

Heat disorders generally have to do with a reduction or collapse of the body's ability to shed heat by circulatory changes and sweating, or a chemical (salt) imbalance caused by too much sweating. When heat gain exceeds the level the body can remove, or when the body cannot compensate for fluids and salt lost through perspiration, the temperature of the body's inner core begins to rise and heat-related illness may develop. Ranging in severity, heat disorders share one common feature: the individual has overexposed or over-exercised for his/her age and physical condition in the existing thermal environment. Sunburn, with its ultraviolet radiation burns, can significantly retard the skin's ability to shed excess heat.[xxvi]

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

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

Figure 3-11

Heat Index

Extreme danger | Danger | Extreme caution | Caution

Apparent temperature *is how hot the heat-humidity combination makes it feel.*

AIR TEMPERATURE (DEGREES FAHRENHEIT) / RELATIVE HUMIDITY (PERCENT)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
140	125																				
135	120	128																			
130	117	122	131																		
125	111	116	123	131	141																
120	107	111	116	123	130	139	148														
115	103	107	111	115	120	127	135	143	151												
110	99	102	105	108	112	117	123	130	137	143	150										
105	95	97	100	102	105	109	113	118	123	129	135	142	149								
100	91	93	95	97	99	101	104	107	110	115	120	126	132	138	144						
95	87	88	90	91	93	94	96	98	101	104	107	110	114	119	124	130	136				
90	83	84	85	86	87	88	90	91	93	95	96	98	100	102	106	109	113	117	122		
85	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	95	97	99	102	105	108
80	73	74	75	76	77	77	78	79	79	80	81	81	82	83	85	86	86	87	88	89	91
75	69	69	70	71	72	72	73	73	74	74	75	75	76	76	77	77	78	78	79	79	80
70	64	64	65	65	66	66	67	67	68	68	69	69	70	70	70	71	71	71	71	71	72

In addition to the effects of a heat wave on humans, heat can also affect animals. Livestock often respond to heat by reducing their food intake. This in turn affects milk production, reproduction and muscle (meat) building. All of these things can have a negative impact on agriculture.[xxvii]

Heat waves can also be a major contributing factor to power outages (brownouts, etc.), as the high temperatures result in exceptionally high demand for electricity for cooling purposes. Power outages for prolonged periods increase the risk of heat stroke and subsequent fatalities due to the loss of air conditioning or fans and proper ventilation.[xxviii]

In addition to human losses, a heat wave has the possibility of cascading into other natural disasters. Severe heat can lead to drought conditions if no rain is present for a lengthy period of time. This lack of rain and presence of hot temperatures can also encourage the spreading of wildfires. As mentioned earlier, another serious cascading emergency is power disruptions as demand exceeds the power grids ability to supply electricity. Specific property or crop damage estimates are unknown, though it may be presumed that periods of high heat were detrimental to crop yields.

Hazard Event History

According to the Missouri State Hazard Mitigation Plan, the summer of 1980 was the deadliest year for heat-related deaths in the state. 295 people died of heat related illnesses during the heat wave that gripped the state that summer. More recently, in 1999, 42 Missouri residents died of hyperthermia. Nine instances of excessive heat were recorded in Maries County between 1996 and 2013. Numerous people were treated for heat-related illnesses and heat related deaths were reported throughout Missouri for most of those events. Statewide, heat wave deaths most often occur in urban areas and people age 65 and older are most susceptible. The summer of 2012 was notable for the duration of excessive heat. There were three separate incidents where temperatures were near or above 100 degrees for multiple days in a row in June, July and August. The heat wave accompanied the worst drought that the area had seen in several years.

Temperatures in Maries County have been recorded at reaching 103 degrees Fahrenheit and heat indices have ranged between 115 and 120 during instances of extreme heat.

Excessive heat is most common in the summer months of June through August. Education is the most preventive warning system available in Maries County. The Maries/Phelps County Health Department provides information to residents about preparing for heat waves. The National Weather Service (NWS) is able to predict periods of high heat with good accuracy and this information is disseminated to the population through various forms of media.

Warning Time and Duration

Due to improvements in meteorology, the heat waves can be predicted several days in advance of onset. Table 3.7 shows the three response levels developed by the NWS, based on the Heat Index, to alert the public to the potential heat hazards:

Table 3.7 National Weather Service Heat Index Response Levels

Heat Index	Response Level
130 degrees F or higher	Warning
105 degrees F to 129 degrees F	Watch
90 degrees F to 104 degrees F	Advisory

Source: Missouri State Hazard Mitigation Plan May 2007

The Missouri Department of Health and Senior Services will announce a statewide hot weather health alert (Table 3.8) when conditions are as follows:

Table 3.8 MO Dept. of Health & Senior Services Hot Weather Alerts

Type of Alert	Conditions of Alert
Hot Weather Health Alert	Heat indices of 105 degrees F in a large portion of the state are first reached (or predicted).
Hot Weather Health Warning	Heat indices have been 105 degrees F or more for two days in a large portion of the state, or weather forecasts call for continued heat stress conditions for at least 24 to 48 hours over a large portion of the state.
Hot Weather Health Emergency	When extensive areas of the state meet the following criteria: (1) high sustained level of heat stress (HI 105 degrees F for three days) (2) increased numbers of heat-related illnesses and deaths statewide and (3) the NWS predicts hot, humid temperatures for the next several days for a large portion of the state.

Source: Missouri Department of Health and Senior Services.

For these reasons, the CPRI rating assigned was Probable warning time of 24 hours or more (1), Duration of less than one week (3).

Severity/Magnitude

When extreme heat next strikes Maries County the impact will probably have a low impact on the community as a whole. However, due to the fact that the poor and elderly are at higher risk of injury and death from heat waves, the County needs to take steps to provide cooling shelters and similar mitigation actions to protect this segment of the population. Some agricultural producers may see a crop loss and water suppliers may see an increase amount of water consumption. Mental and physical stress may be caused by the extreme heat. Heat waves place stress on the power grid as well and may result in power outages or brownouts.

Extreme heat has the potential for and has caused death in Maries County – and so could be classified as catastrophic. Historically, heat-related deaths have seldom occurred in Maries County. However, the possibility is one to be considered when heat indices are above 100 degrees Fahrenheit. Because Maries County has had heat related deaths in the past, has a high level of poverty, which increases vulnerability to this hazard, extreme heat is assigned a CPRI rating of Critical – 25 -50 percent of property severely damaged; shutdown of facilities for at least two weeks; and/or injuries resulting in permanent disability (3).

Probability

Based on historical evidence, the occurrence of extreme heat is a yearly phenomenon in Maries County. It can be assumed with reasonable security that high temperatures will be seen in the county on an annual or biannual basis. Information from the Department of Health and Senior Services and the NWS for the state of Missouri rates the probability of a heat wave as moderate and severity as moderate, but the probability could be upgraded to severe.[xxix] For these reasons, the CPRI rating assigned is Highly Likely (4) – event is probable within one year—a near 100 percent probability of occurring.

Recommendations

- Working with the Maries County Health Department and EMD, local governments should encourage residents to reduce the level of physical activity, wear lightweight clothing, eat fewer protein-rich foods, drink plenty of water, minimize their exposure to the sun and spend more time in air-conditioned places.
- 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.
- Charitable organizations and the health department should work together to provide fans to at-risk residents during times of critical heat and if necessary set up cooling shelters.

Hazard Summary – Extreme Heat – All Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
3.15	High

3.2.6 Flood (Riverine and Flash)

Description

Floods are the number one weather-related killer in the United States. Between 1993 and 1999, Missouri recorded more than 75 deaths attributed to flooding. 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, which is characterized by rapid accumulation or runoff of surface waters from any source. This type of flooding impacts smaller rivers, creeks and streams, and can also occur as a result of dams being breached or overtopped. Because flash floods can develop in just a matter of hours, most flood related deaths result from this type of flooding event.

The areas adjacent to rivers and stream banks that serve to carry excess flood water during rapid runoff are called floodplains. A floodplain is defined as the lowland and relatively flat areas adjoining rivers and streams. The term base flood, or 100-year flood is the area in the floodplain that is subject to a one percent or greater chance of flooding in any given year, based upon historical records. Floodplains are a vital part of a larger entity called a basin—defined as all the land drained by a river and its branches.

The land that forms the state of Missouri is contained within either the Mississippi, Missouri, Arkansas or White River basins. The Mississippi River Basin drains the eastern part of the state; the Missouri River Basin drains most of the northern and central part of the state; the White River Basin drains the south central part of the state; while, the Arkansas River Basin drains the southwest part of the state. The Missouri River Basin drains over half the state, as the river moves west to east across the state. When the Missouri River joins the Mississippi at St. Louis, it becomes part of the Mississippi River Basin—the largest basin in terms of volume of water drained on the North American continent.

The fact that most of the land that comprises the state of Missouri is part of the Mississippi-Missouri River drainage basin means that a significant portion of the land area of the state lies in flood-plains. For example, some 43 percent of the land in St. Charles County is in floodplains. In terms of agricultural land in Missouri, 34 percent of Missouri's cropland lies in a floodplain. This leaves much of the Missouri population and economic resources extremely vulnerable to flooding.[xxx]

In some cases, flooding may not be directly attributable to a river, stream or lake overflowing its banks. 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 is called sheet flooding and is becoming increasingly more common as development outstrips the ability of the drainage infrastructure to properly carry and disburse the water flow.

Flooding can also occur outside the floodplain when combined storm and sanitary sewers cannot handle the extremely heavy flow of water that often accompanies storm events. The result of this problem is flooded basements.

Flash floods occur within six hours of a rain event, or after a dam or levee failure, or following a sudden release of water held by an ice or debris jam, and flash floods can catch people unprepared. Residents usually have little or no notice of these sudden and dangerous flood events.

As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force.

Because flooding along rivers is generally characterized as a slow moving disaster, communities downstream often have sufficient time to take protective measures, such as sandbagging and evacuations. Nevertheless, these flood disasters extract a heavy toll in terms of human suffering and extensive losses to public and private property. By contrast, flash flood events, which are characterized by a rapid water rise with little warning time, have caused a higher number of deaths and major property damage in many areas of Missouri in recent years.[xxxi]

Flooding in Maries County is typically mild and affects small areas of the county. However, flash flooding has been known to cause inconveniences in some areas. While the flooding mainly affects low water bridges on county-maintained roads, it has been known to flood some city streets and state highways. Drivers who travel on the county maintained roads have dealt with closed roads numerous times due to flash flooding. Flash flooding and riverine flooding have both closed some state highways – the most major being Highway 63 at the Gasconade River.

Typical damages caused by Maries County floods can range from destroyed crops to floating cars and damaged homes and businesses. Propane gas tanks and chain-link fences have also been lifted from their anchored positions and carried downstream. Some roads have experienced severe erosion caused by flash floods.

Hazard Event History

Maries County has several rivers and small tributaries in unincorporated areas that are susceptible to flooding. There is an area in the vicinity of Nagagomi spring where a cluster of weekend cabins and homes are located and a few additional cabins scattered along the Gasconade River that are prone to riverine flooding. Since 1994, the county has experienced 16 separate incidents of riverine flooding resulting in $644,000 in property damage. The most significant flooding events were in July of 1998 and April of 2011.

The city of Belle does not have any designated floodplain zones within the city limit. The city of Vienna has only a small undeveloped area within the city limits designated as flood zone where the wastewater treatment facility is located.

Flash flooding occurs much more frequently than riverine flooding, with 47 separate flash flooding events occurring since 1994 and damages of $571,000. The county, on average, experiences at least two to three flash flooding events nearly every year, however most of these events cause little or no property or crop damages, nor loss of life. One exception was a flash flood that occurred in August 2013 that resulted in $500,000 in damages in Maries County, with some damage done to the Vienna wastewater treatment plant and at least one evacuation required. Over 20 inches of rain fell in some areas of the Ozarks, with other neighboring counties suffering much greater damage and loss of life. Several roads and bridges in the county were damaged from this flash flooding event.

A total of 61 floods and flash floods have affected the county since April 1994. Of the 63 reported events, 12 events caused property damage ranging from $1,000 per event to $500 thousand in August 2013. The remaining 51 flood events caused no property damage or injuries. Table 3.9 illustrates flood events in the county from April 1994 to August 2013.

There are some major roads in the county that have been affected by flooding. Highway 63 between Vichy and Vienna has been closed due to flooding along the Gasconade River several times – most recently in August of 2013. The other state highway that has been affected include Highway 42 east of Vienna where it crosses the Gasconade River. When these highways are shut down due to flooding, detours can take travelers far out of their way to get around the flooding.

Table 3.9 Maries County Flood Events and Locations (1994-2013)

Location or County	Date	Type	Property Damage	Crop Damage
Brinktown	4/10/1994	Flash Flood	0	0
Belle	7/6/1994	Flash Flood	0	0
Maries County	5/17/1995	Flash Flood	0	0
Vienna	5/7/1996	Flash Flood	$15,000	$5,000
Belle	6/6/1996	Flash Flood	$5,000	0
Vienna	6/17/1997	Flash Flood	0	0
Belle	6/22/1997	Flash Flood	0	0
Vienna	6/25/1997	Flash Flood	0	0
Vienna	8/19/1997	Flash Flood	0	0
Brinktown	3/17/1998	Flash Flood	0	0
Maries County	3/19/1998	Flash Flood	0	0
Maries County	6/4/1998	Flash Flood	0	0
Maries County	6/8/1998	Flash Flood	0	0
Maries County	7/26/1998	Flood	$419,000	0
Maries County	1/31/2002-2/1/2002	Flood	0	0
Maries County	4/19/2002	Flash Flood	0	0
Maries County	4/19/2002	Flood	0	0
Maries County	5/8/2002	Flood	$10,000	0
Vichy	5/9/2002	Flash Flood	0	0
Brinktown	5/12/2002	Flash Flood	0	0
Maries County	5/12/2002	Flood	0	0
Maries County	5/17/2002	Flood	0	0
Maries County	7/10/2002	Flash Flood	$20,000	0
Maries County	7/18/2002	Flash Flood	0	0
Vienna	7/18/2003	Flash Flood	0	0
Belle	7/30/2004	Flash Flood	0	0
Maries County	1/5/2005	Flash Flood	0	0
Maries County	1/5/2005	Flood	0	0
Brinktown	4/2/2005	Flash Flood	0	0
Brinktown	6/10/2005	Flash Flood	0	0
Vienna	8/27/2006	Flash Flood	0	0
Vienna	5/10/2007	Flash Flood	0	0
Brinktown	9/25/2007	Flash Flood	0	0
Belle	1/7/2008	Flash Flood	0	0
Belle	2/17/2008	Flash Flood	0	0
Van Cleve	3/18/2008	Flash Flood	$1,000	0
Belle	3/19/2008	Flood	0	0
Belle	4/3/2008	Flash Flood	0	0
Van Cleve	4/10/2008	Flash Flood	0	0
Vichy	8/5/2008	Flash Flood	0	0
Hayden	9/3/2008	Flood	0	0
Van Cleve	9/14/2008	Flash Flood	0	0
Brinktown	5/8/2009	Flash Flood	$25,000	0

Location or County	Date	Type	Property Damage	Crop Damage
Vichy	5/27/2009	Flash Flood	0	0
Yarna	6/10/2009	Flash Flood	0	0
Vichy	10/29/2009	Flood	0	0
Belle	1/24/2010	Flood	0	0
Shantytown	5/20/2010	Flood	$15,000	0
Vienna	3/14/2011	Flood	0	0
Veto	4/25/2011	Flood	$100,000	0
Vienna	4/25/2011	Flood	$100,000	0
Shantytown	5/12/2011	Flash Flood	0	0
Shantytown	7/12/2011	Flash Flood	0	0
Yarna	3/15/2012	Flash Flood	0	0
Vichy	3/17/2012	Flash Flood	$5,000	0
Shantytown	4/14/2012	Flash Flood	0	0
Belle	5/31/2013	Flash Flood	0	0
Vienna	6/1/2013	Flood	0	0
Safe	6/16/2013	Flash Flood	0	0
Shantytown	8/2/2013	Flash Flood	0	0
Vienna	8/7/2913	Flash Flood	0	0
Brinktown	8/7/2013	Flash Flood	0	0
Vienna	8/7/2013	Flash Flood	$500,000	0

Source: National Climactic Data Center

Of the three local government jurisdictions participating in this plan, two are currently participating in the National Flood Insurance Program (NFIP): Maries County and the city of Vienna. The city of Belle does not participate in the NFIP. According to repetitive loss data provided by SEMA, there are 15 repetitive loss properties in Maries County. One property has been mitigated. There were 40 losses attributed to 14 of the properties and the one mitigated property has had two losses. There is one severe repetitive loss (SRL) property with four losses and another SRL property with two losses that is currently pending.

Likely Locations

Of the three participating governmental jurisdictions in the Maries County Hazard Mitigation Plan, two are members of the National Flood Insurance Program (NFIP). Those are Maries County and the city of Vienna. The city of Belle is not currently a member of the NFIP. According to FEMA, there are Flood Insurance Rate Maps (FIRMs) for the unincorporated areas of Maries County but not for the city of Vienna. Digitized FIRM data is currently not available for the county.

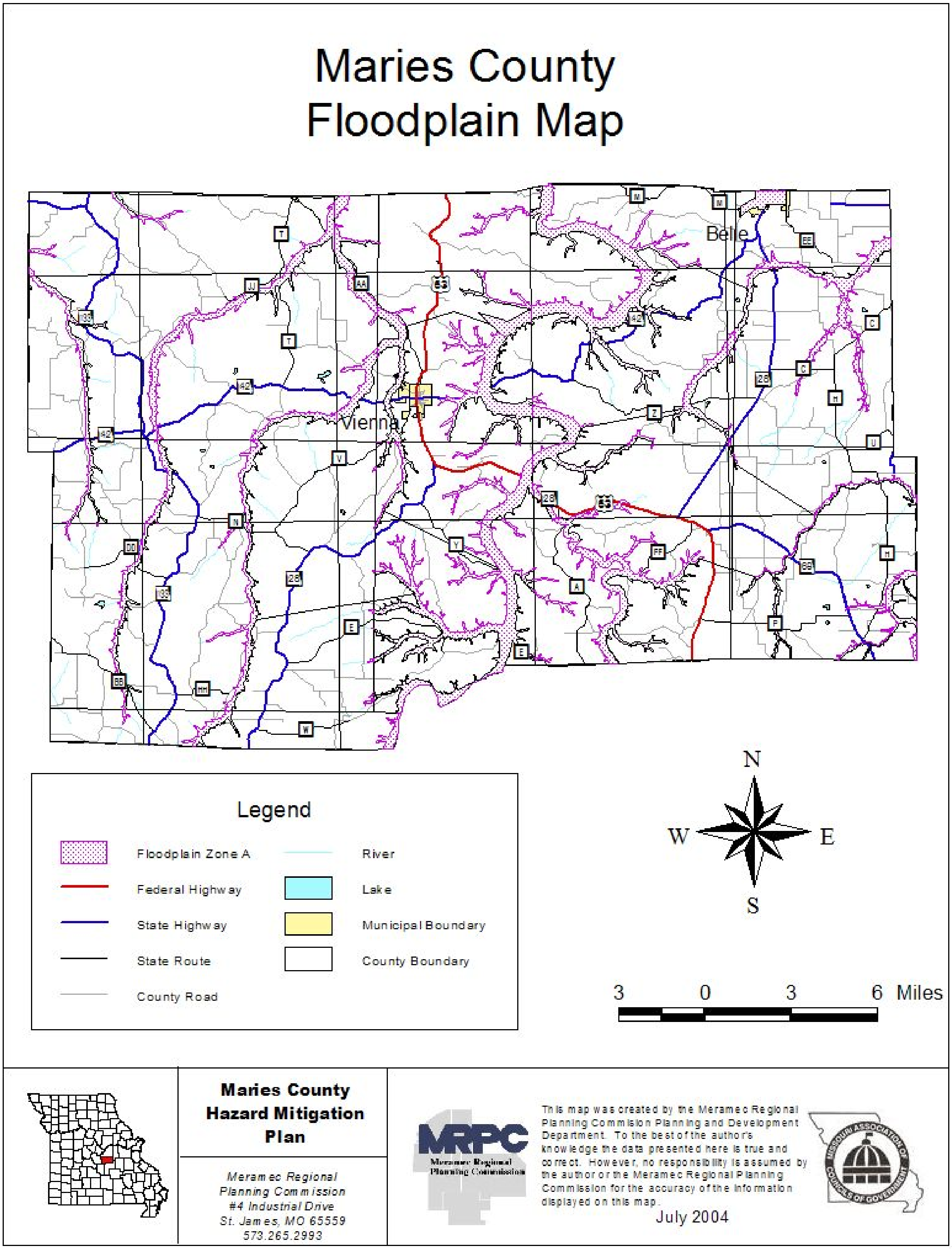
The Maries County Hazard Mitigation Plan contains maps created with FEMA's Hazards U.S. Multi-Hazard (HAZUS-MH) database. This software program is a nationally applicable standardized methodology for estimating potential losses from earthquakes, hurricane winds and floods. HAZUS-MH uses Geographic Information Systems (GIS) software to map and display hazard data and the results of damage and economic loss estimates for buildings and infrastructure, as well as allowing users to estimate the impacts of specific types of hazards. This software is based on current scientific and engineering knowledge. There are uncertainties inherent in any loss estimation technique. Therefore, there may be significant differences between the modeled results contained in this plan and the actual social and economic losses following a specific flood.

HAZUS-MH was used in section 3.3 to estimate potential losses from a 100 year flood in the planning area. As DFIRM was not available to generate maps for flood planning purposes, all of the maps included here have been generated with HAZUS-MH and/or GIS information provided by the Missouri Spatial Data Information System (MSDIS). All maps are for planning purposes only.

There are three watersheds located in Maries County: the Osage River watershed, the Gasconade River watershed and the Bourbeuse River watershed. The river with the potential to cause the most flood damage in the county is the Gasconade River. The river drains 2,806 square miles and flows northward for 271 miles until it reaches the Missouri River. The Osage River watershed covers a significant portion of Maries County, but the river itself lies outside the county boundaries and so does not have a great impact. The Maries River is an Osage River tributary that floods from time to time. A large portion of the eastern part of the county is covered by the Bourbeuse River watershed. Like the Osage River watershed, the river itself lies outside of the county boundary. Various floodplain maps are included at the end of this section for each jurisdiction. Figure 3-12 is a floodplain map for the county.

In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Figure 3-12



Maries County
Floodplain Map
Belle
Vienna
Legend
Floodplain Zone A
Federal Highway
State Highway
State Route
County Road
River
Lake
Municipal Boundary
County Boundary
N
W
E
S
3 0 3 6 Miles
Maries County Hazard Mitigation Plan
Meramec Regional Planning Commission
#4 Industrial Drive
St. James, MO 65559
573.265.2993
MRPC
This map was created by the Meramec Regional Planning Commision Planning and Development Department. To the best of the author's knowledge the data presented here is true and correct. However, no responsibility is assumed by the author or the Meramec Regional Planning Commission for the accuracy of the information displayed on this map.
July 2004

Warning Time and Duration

While floods are known to grow slowly and allow adequate time for warning, the flash flooding that is often associated with Maries County can rapidly develop into an emergency for which residents are unprepared. While it may seem prudent to estimate that most residents can predict probable flooding by witnessing large amounts of rain, many residents are still swept downstream in their cars while trying to cross bridges and low water crossings inundated by water. Radio and television stations in the area can provide warnings to residents based on missives from the National Weather Service. If adequate warning is available, county or city enforcement officials can help residents evacuate from potentially dangerous flooding areas. According to the Missouri State Hazard Mitigation Plan, in recent years, flash flooding rather than riverine flooding has actually caused more deaths and property damage in many parts of the state. The county is vulnerable to flooding primarily from the Gasconade River, but also from tributaries of the Osage and Bourbeuse rivers. The rest of the jurisdictions – the cities of Belle and Vienna and both school districts are vulnerable to flash flooding, but not to riverine flooding. Riverine floods generally have several days of warning, but for the purposes of this assessment, all jurisdictions will be scored based on flash flooding for warning time and both types of flooding for duration.

Based on historical data discussed in earlier sections, the CPRI rating assigned for Maries County is <u>Probable warning time of less than six hours for most common flash flooding (4). Duration of less than one week (3).</u>

For the cities of Belle and Vienna and the Maries County R-I and R-II school districts a CPRI rating is assigned as <u>Probable warning time of less than six hours for most common flash flooding (4). Duration of less than one day (2).</u>

Severity/Magnitude

The Missouri State Hazard Mitigation Plan states that in terms of overall damage, Missouri's most severe single hazard is flooding. Flooding has resulted in more federal disaster declarations in Missouri than any other hazard in the past three decades. However, much of this flood damage has occurred in the two major river basins – the Missouri River and the Mississippi River. Of the 58 flood events reported, four resulted in significant damage in Maries County. In July 1998, there was $419,000 in damages reported for Maries County. In April 2005, a multiple jurisdictional flood event resulted in $200,000 in property damage. In August 2013, in a region-wide flooding event there was $500,000 in damages in Maries County. There are 15 properties listed by the NFIP that have had repetitive losses with the most recent losses in August 2013.

The flooding issue that would have the broadest impact on residents and travelers would be the shutdown of state highways 42 and especially 63. Highway 63 is the main north south route through the region. Detours around the Gasconade River bridge on Highway 63 can be time consuming. Shutdowns typically last two or three days and can have a significant impact on travel in and through the area. Some school bus routes may be affected by flooding for short periods of time and adjustments made to the routes driven by busses, but these would be short-lived and not considered a significant problem.

The next flash flood in Maries County will most likely have limited impact on the day-to-day activities of the county overall. Although several have been mitigated in the last few years, many county roads still have low water crossings or can be damaged by flooding. Highway 63 is the most significant state highway in the county and it has been shut down due to flooding on the Gasconade River in the past. There is not a great deal of development along the rivers in the county, with the exception of the Nagogami area and a few other scattered cabins. Temporary road closures will affect some of the jurisdictions.

Based on historical information of flood events and flood damages in Maries County, the CPRI rating for severity of a future flood would be Limited (2) - Injuries and/or illnesses do not result in permanent disability; shutdown of facilities for more than a week; 10-24 percent of property severely damaged. While some county residents may be delayed in their traveling, damages are usually limited to areas along the Gasconade and/or Maries rivers. Loss of life and injuries are also typically limited. Historically, the most impacted areas have been in unincorporated areas of the county.

Probability

Riverine flooding has historically occurred most frequently in the spring when a combination of wet weather and spring thaw have resulted in flood conditions in the large river basins of the Missouri and Mississippi. However, flash floods can occur at any time of the year and are generally caused by severe thunderstorms with heavy rainfall. Since January 1996 through August 2013, flood events have occurred in Maries County in every month of the year with the exceptions of November and December.

All past information regarding flooding in Maries County leads to the assessment that flooding will occur in the Gasconade River, Bourbeuse River and the Osage River basins and flash flooding will happen again in the county. It can be safely assumed that this type of flooding will happen at least once every year, depending on weather conditions and precipitation. For these reasons the CPRI rating for probability of future flooding is Highly Likely (4) – Event is probable within one year—a near 100 percent probability of occurring.

Recommendations

- The county has adopted a floodplain management ordinance concerning construction in the floodplain and should rigorously enforce the ordinance in order to reduce flood damages in the future.
- The county and communities should consider doing buyouts of properties that are flood prone and have had repetitive losses to mitigate future disasters.
- Local governments should make a strong effort to further improve warning systems to insure 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.

Hazard Summary – Flood – Maries County

Calculated Priority Risk Index	Planning Priority
3.0	High

Hazard Summary – Flood – Cities of Belle and Vienna, Maries County R-I and R-II School Districts

Calculated Priority Risk Index	Planning Priority
2.9	High

3.2.8 Land Subsidence/Sinkholes

Description

According to the US Geological Survey, land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; dissolution of limestone aquifers (sinkholes); collapse of underground mines; drainage of organic soils; and initial wetting of dry soils (hydrocompaction). Land subsidence occurs in nearly every state of the United States.[xxxii]

Land subsidence occurs when large amounts of ground water have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock collapses in on itself. Land subsidence typically occurs over large areas rather than in a localized area as a sinkhole does. One of the largest problems associated with land subsidence is the resulting permanent reduction in the total storage capacity of the affected aquifer system. Figure 3-14 shows areas of the country where excessive pumping of groundwater has resulted in land subsidence and possible permanent damage to the local aquifer.[xxxiii]

Historically, land subsidence, which is generally attributed to human activities, does not impact the central Ozarks region. The related hazard of sinkholes is the more evident hazard for this part of the state.

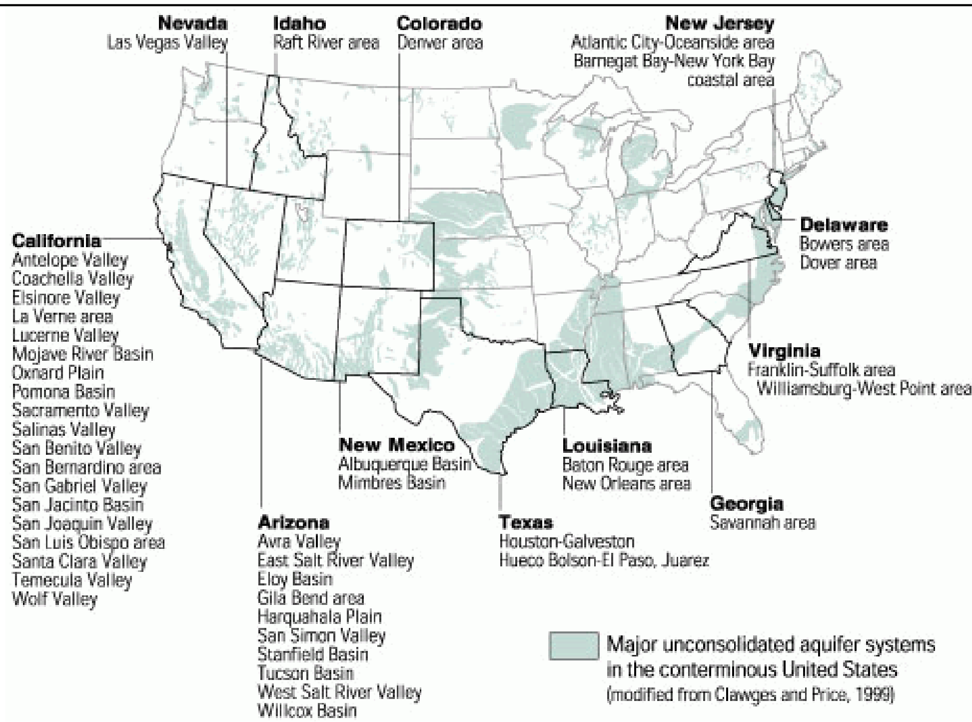
A sinkhole is a surface area usually formed when bedrock slowly dissolves, creating voids below ground that can cause depressions on the surface or even result in openings in the ground when the ceiling of an underlying cave collapses. Typically sinkholes appear as conical depressions in the ground. These geologic features can be very shallow and nondescript or may cover acres of ground and be hundreds of feet deep. Sinkholes are places where water drains into underground fissures and can be direct conduits to an area's groundwater. Springs are typically recharged from sinkholes and losing streams. The illustration in Figure 3-15 shows how sinkholes typically form in the Ozarks region.[xxxiv]

Although there have not been any reported incidents of sinkholes collapsing and causing personal injury or damage to property in Maries County, it is not an uncommon occurrence in Missouri. "Sinkhole collapses are a common geologic hazard in areas such as the Ozarks," said Mimi Garstang, former Geological Survey and Resource Assessment (GSRA) division director and state geologist. "Fortunately, most occur in areas away from development and typically don't cause serious damage."[xxxv]

Most sinkholes are formed by natural processes: the movement of water through soluble rock causing erosion and the formation of voids, but human activity can speed up the process and cause sinkholes to form. Examples include drilling, leaking water and sewer lines, drainage modifications, and leaking lagoons and lakes. In 1948 an incident occurred in St. Francis County where a drilling rig caused numerous sinkholes to form.

Figure 3-14

Areas of United States Affected by Subsidence Caused by Groundwater Pumpage

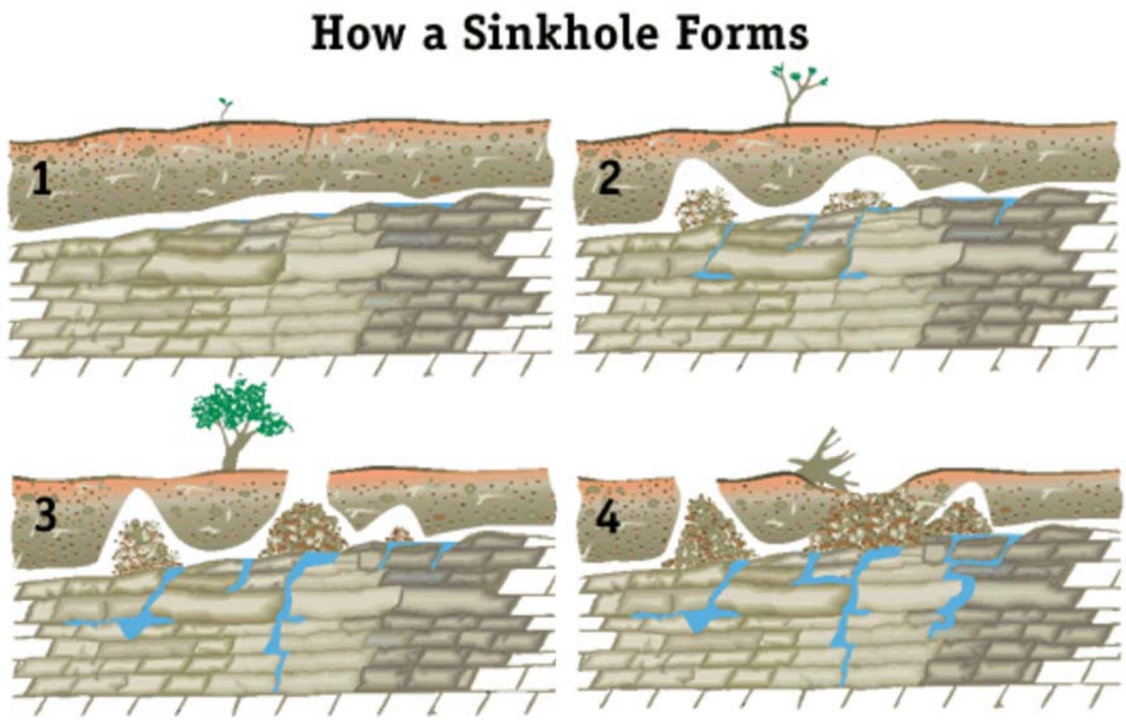


Source: US Geological Survey- http://ga.water.usgs.gov/edu/earthgwlandsubside.html

The event was documented by J. Harlen Bretz in the book "Caves of Missouri." Sinkholes began developing around the drilling rig when it encountered voids in the bedrock. By the time the drilling was completed there were an estimated 20 sinkholes in the area around the drill hole. Some were up to 90 feet long and 20 feet wide. It was conjectured that the drilling caused water that was in voids closer to the surface to drain into voids encountered at deeper levels. This resulted in the collapse of the voids closer to the surface as loss of buoyancy and removal of sediments caused the surface collapses.[xxxvi]

There have been a number of incidents in Missouri where sinkholes have formed and drained lakes. In the 1960s, a lake was built in northern Howell County near the Eleven Point River. A sinkhole formed in the lake bed and drained it. Although attempts were made to repair the hole, the lake has never held water for more than short periods of time. A well-publicized sinkhole collapse in the St. Louis region occurred in 2004 when Lake Chesterfield, the centerpiece of an upscale subdivision in St. Charles County, drained in a matter of days due to a sinkhole collapse. Some $650,000 was spent to repair the lake, but it continues to leak.[xxxvii]

Figure 3-15



Sinkholes can form in a variety of ways, but all require collapse into voids that have developed in the subsurface. The movement of slightly acidic shallow groundwater dissolves the bedrock along fractures and other openings. The dissolved materials, along with some of the insoluble clays and rock fragments found above the bedrock, are removed through subsurface openings (fig. 1). Over time, the voids enlarge as groundwater movement carries away material (fig.2). A sinkhole commonly forms when the material above the void can no longer support its own weight and collapses (fig.3). Eventually, the sides of the sinkhole erode, leaving a bowl-shaped depression (fig.4).

Source: "Missouri Resources" magazine, Spring/Summer 2003 – Volume 20 – Number 1, "That Sinking Feeling – a Void, a Collapse" by Jim Van Dyke.

Several sewage lagoons in southern Missouri have also been adversely affected by sinkholes, including an incident in West Plains that completely drained the lagoon. In most cases, the communities are forced to abandon the original lagoon site and rebuild elsewhere or use alternate methods of sewage treatment.[xxxviii]

There have been incidents of damage to homes and property in other parts of the state, such as Springfield and Farmington, when sinkholes formed near or under existing buildings. In some cases the sinkhole was stabilized and the damage to property repaired. However, due to the instability of sinkhole areas, the damage and process are often not reversible and losses can be substantial, as illustrated by the incident involving Lake Chesterfield.

Hazard Event History

Although there are sinkholes and sinkhole areas in Maries County, and incidents have occurred in other counties in southern Missouri, there have been no recorded incidents of property damage or injuries due to sinkholes in Maries County. Based on the map of sinkholes in Maries County, the incorporated communities appear to lie outside the zone of sinkhole occurrences in the county.

Likely Locations

Sinkholes are a characteristic of karst which is defined as "a landscape characterized by the presence of caves, springs, sinkholes and losing streams, created as groundwater dissolves soluble rock such as limestone or dolomite."[xxxix] As illustrated by Figure 3-16, much of the southern half of Missouri has karst topography and has areas conducive to the development of caves and potential sinkholes.

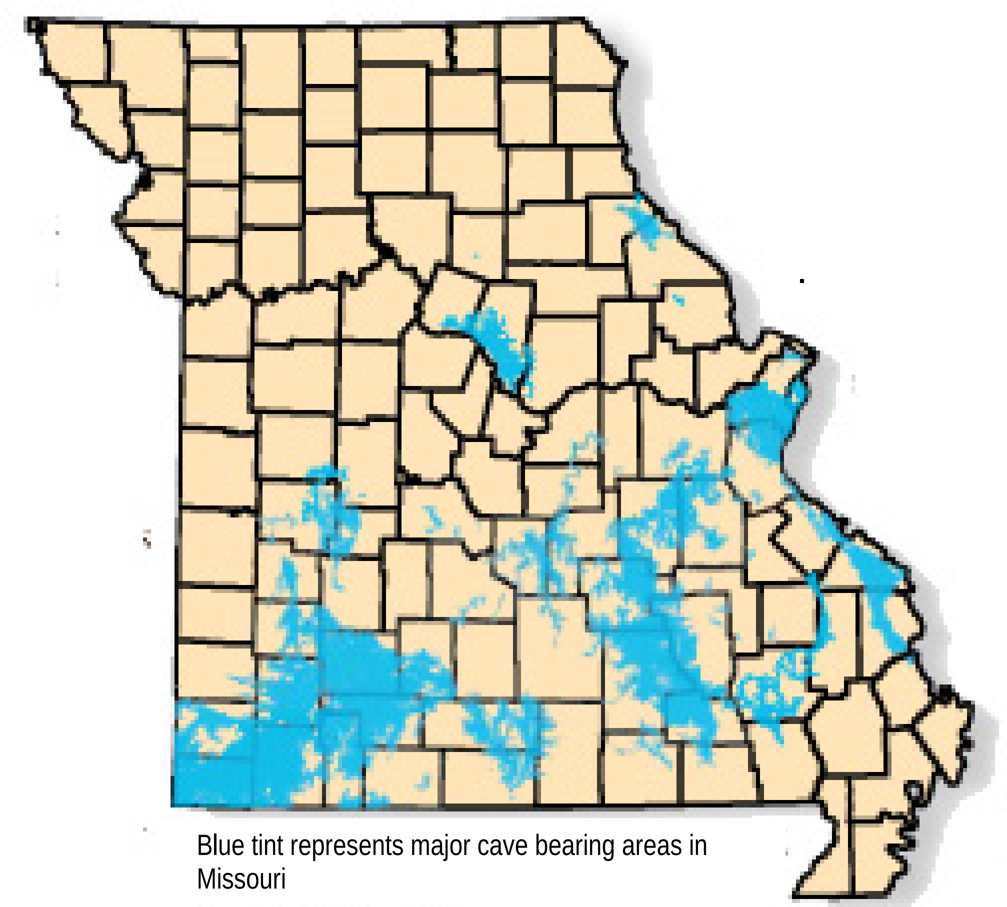
Figure 3-17 is a map of Maries County water resources, including springs, lakes, rivers, streams, watersheds, and marked in red—sinkholes. As is evidenced by this map, there are several sinkholes in Maries County – 15 known sinkholes. Fortunately, none of the sinkholes are located near communities or highly developed areas of the county.

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.[xl] In the event of a sudden collapse, an open sinkhole can form in a matter of minutes and swallow lawn, 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 Maries County.

There have also been deaths and injuries attributed to the sudden formation of sinkholes, fortunately neither has ever occurred in Maries County or in the region.

In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

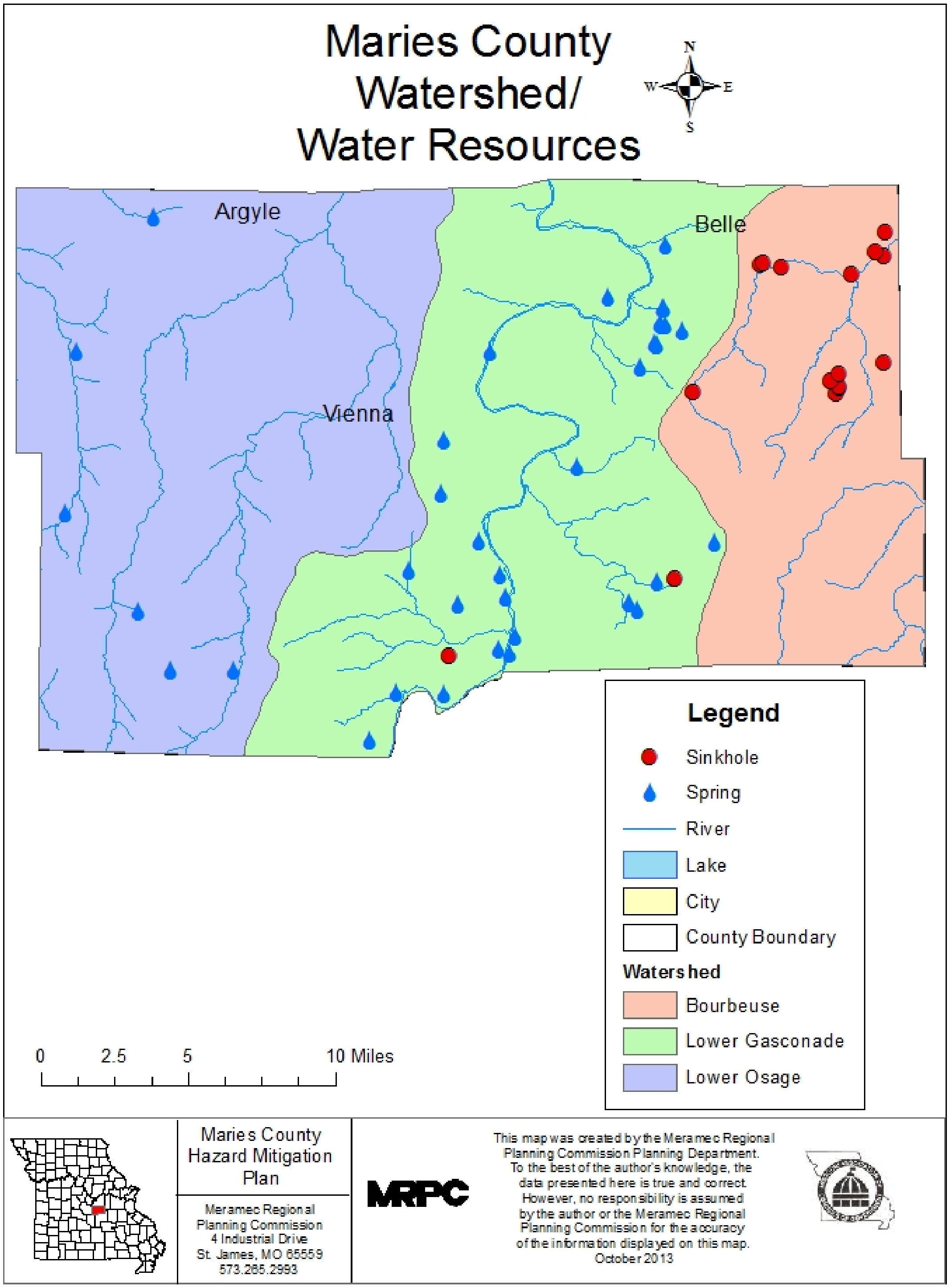
Figure 3-16
Cave Bearing Areas of Missouri



Blue tint represents major cave bearing areas in Missouri

Source: "Geologic Column of Missouri" Volume 2 Issue 2 – publication of the Missouri Department of Natural Resources.

Figure 3-17


Maries County
Watershed/
Water Resources
N
W
E
S
Argyle
Belle
Vienna
Legend
Sinkhole
Spring
River
Lake
City
County Boundary
Watershed
Bourbeuse
Lower Gasconade
Lower Osage
0
2.5
5
10 Miles
Maries County
Hazard Mitigation
Plan
Meramec Regional
Planning Commission
4 Industrial Drive
St. James, MO 65559
573.265.2993
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This map was created by the Meramec Regional
Planning Commission Planning Department.
To the best of the author's knowledge, the
data presented here is true and correct.
However, no responsibility is assumed
by the author or the Meramec Regional
Planning Commission for the accuracy
of the information displayed on this map.
October 2013

Warning Time and Duration

Sinkhole collapses have historically been sudden and dramatic. In some cases, as in a sinkhole forming under a structure, there are warning signs such as cracks in foundations and obvious shifts in the structure itself. But most sinkhole collapses in Missouri have been characterized as abrupt and with little or no warning. The initial collapse may be immediate, but the area will often remain unstable for more than a few days. Based on the historic data available a CPRI rating of Probable warning time of less than six hours for sink hole collapse (4). Duration of less than one week (3).

Severity/Magnitude

If a sinkhole collapse should occur in a developed area of Maries County, the incident itself would be localized and would affect a relatively small area. If it occurs in a residential neighborhood, one or two homeowners could be affected. If the collapse should occur under public infrastructure, such as a road or sewer treatment facility, the impact could be far greater. The sewer treatment facilities in West Plains and Republic, Missouri were eventually abandoned and new facilities had to be built with public funds, which affected all of the residents of those communities.[xli] Even in a situation where the collapse would affect a residential area, costs could be considerable. The draining of Lake Chesterfield had a significant negative impact on the value of the homes in that area. Residents spent $650,000 in an effort to repair the lake, but in the end were not successful in stopping the lake from leaking.[xlii]

This hazard does not appear to have varying magnitude for the jurisdictions. Maries County's risk would be considered negligible due to lower population density and the lack of public facilities that might be vulnerable – such as waste water treatment facilities. The risk to the communities and school district would also be negligible as there are no sinkholes located within or on the borders of these jurisdictions or their facilities. For these reasons this hazard has been assigned a CPRI rating of Negligible (1) - Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged.

Probability

There is certainly the possibility of damage occurring in the future from this hazard because sinkholes are a feature in parts of Maries County. However, as there have been no incidents to date, development typically avoids areas with sinkholes, and the incident would be localized, the severity of a sinkhole collapse would likely not be great. The exception would be if a sinkhole damaged a critical public facility such as a water treatment plant or sewage lagoon. In this type of situation, the entire population served by that public facility would be dramatically affected and would likely have to cover the cost of repairing or replacing the facility. From a historical point of view, Maries County has not had problems with sinkholes and the likeliness of a future occurrence would be considered Unlikely (1) – Event is possible within the next 10 years; event has up to one in 10 years chance of occurring; history of events is less than or equal to 10 percent likely per year.

Recommendations

Sinkholes and sinkhole 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.
- 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 advised to avoid placing themselves and their property in danger by building in sinkhole areas.
- Communities with building codes should include prohibitions on building in known sinkhole areas.

Hazard Summary – Sinkhole – All Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
1.45	Low

3.2.9 Severe Storms (Hail Storm/Wind Storm)/Tornado

Description

Despite their small size, all thunderstorms are dangerous. Every thunderstorm produces lightning, which kills more people each year than tornados. Heavy rain from thunderstorms can lead to flash flooding. Strong winds, hail, and tornados are also dangers associated with some thunderstorms. Thunderstorms affect relatively small areas when compared with hurricanes and winter storms. The typical thunderstorm is 15 miles in diameter and lasts an average of 20 to 30 minutes. Of the estimated 100,000 thunderstorms that occur each year in the United States, only about 10 percent are classified as severe.

Tornados are cyclical windstorms often associated with the Midwestern areas of the United States. According to the National Weather Service, Missouri ranks 8th in the nation for frequency of tornados.[xliii] Weather conditions which are conducive to tornados often produce a wide range of other dangerous storm activities, including severe thunderstorms, downbursts, straight line winds, lightning, hail, and heavy rains.

Essentially, tornados are a vortex storm with two components of winds. The first is the rotational winds that can measure up to 500 miles an hour, and the second is an uplifting current of great strength. The dynamic strength of both these currents can cause vacuums that can overpressure structures from the inside. Although tornados have been documented in every state, most of them occur in the central United States. The unique geography of the central United States allows for the development of the thunderstorms that spawn tornados. The jet stream, which is a high velocity stream of air, determines which area of the central United States will be prone to tornado development. The jet stream normally separates the cold of the north from the warm of the south. During the winter, the jet stream flows west to east over Texas to the Carolina coast.

As the sun "moves" north, so does the jet stream, which at summer solstice flows from Canada across Lake Superior to Maine. During its move north in the spring and its recession south during the fall, it crosses Missouri causing the large thunderstorms that breed tornados.

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

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

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 tornados have been known to move in any direction. Tornados are most likely to occur between 3 p.m. and 9 p.m. in the afternoon and evening, but have been known to occur at all hours of the day or night.[xliv]

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

Tornados are the most concentrated and violent storms produced by the earth’s atmosphere. They are created by a vortex of rotating winds and strong vertical motion, which possess remarkable strength and cause widespread damage. Wind speeds in excess of 300 mph have been observed within tornados, and it is suspected that some tornado winds exceed 400 mph. The low pressure at the center of a tornado can destroy buildings and other structures it passes over. Most are caused by intense local thunderstorms. Most tornados are just a few dozen yards wide and only briefly touch down, but highly destructive violent tornados may carve out paths over a mile wide and more than 50 miles long.[xlvi]

In Missouri, tornados occur most frequently between April and June, with April and May usually producing the most tornados. However, tornados can occur at any time of the year. While tornados can occur at any time of the day or night, they are most likely to occur between 3 p.m. and 9 p.m. Between 1996 and 2013 there were 234 days where tornado events, sometimes multiple tornadoes, occurred in Missouri. During that timeframe there were 233 deaths and 2,032 injuries attributed to tornadic events, with the most devastating occurring in Jasper County on May 22, 2011. Total property damages for that same period were $3,844,480,000, with $22.231 million in crop damages. Missourians have a high probability that tornados will continue to affect their lives.

Every tornado is a potential killer and many are capable of great destruction. Tornados can topple buildings, roll 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 a tornado's winds. Tornados do their destructive work through the combined action of their strong rotary winds and the impact of windblown debris. In the simplest cases, the force of the tornado's winds pushes the windward wall of a building inward. The roof is lifted up and the other walls fall outward. Until recently, this damage pattern led to the incorrect belief that the structure had exploded as a result of the atmospheric pressure drop associated with the tornado.[xlvii]

A system of measurement has been developed to define the severity of a tornado based on wind speed and damage. This is known as the Fujita Scale, first proposed by Dr. Theodore Fujita in 1971. This scale is used by meteorologists to estimate the speed of winds after a tornado by studying the damage caused by the tornado to structures, not the appearance of the tornado. Different points on the scale are measured using the definitions in Table 3.10.

In February 2007, an enhanced version of the Fujita Scale was adopted by meteorologists in the U.S. Table 3.11 shows both the Fujita Scale and the Enhanced Fujita Scale.

Storm winds can damage buildings, power lines and other property and infrastructure due to falling trees and branches. Severe thunderstorms can result in collapsed or damaged buildings, damaged or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others. Roads blocked by fallen trees during a windstorm may have severe consequences to people who need access to emergency services. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric service and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from severe thunderstorms related to both physical damages and interrupted services.

Falling trees are a major cause of power outages. Strong winds can cause flying debris and downed utility lines. For example, tree limbs breaking in winds of only 45 mph can be thrown over 75 feet. As such, overhead power lines can be damaged even in relatively minor windstorm events. Utility lines brought down by summer thunderstorms have also been known to cause fires, which start in dry roadside vegetation. Falling trees can bring electric power lines down to the pavement, creating the possibility of lethal electric shock. Rising population growth and new infrastructure in the county creates a higher probability for damage to occur from severe thunderstorms as more life and property are exposed to risk.

Table 3.10
The Fujita Scale of Tornado Definitions

Status	Definition
F0	(Light Damage) 40-72 mph. Chimneys are damaged, tree branches are broken, shallow-rooted trees are toppled.
F1	(Moderate Damage) 73-112 mph. Roof surfaces are peeled off, windows are broken, some tree trunks are snapped, unanchored manufactured homes are over-turned, attached garages may be destroyed.
F2	(Considerable Damage) 113-157 mph. Roof structures are damaged, manufactured homes are destroyed, debris becomes airborne (missiles are generated), large trees are snapped or uprooted.
F3	(Severe Damage) 158-260 mph. Roofs and some walls are torn from structures, some small buildings are destroyed, non-reinforced masonry buildings are destroyed, most trees in forest are uprooted.
F4	(Devastating Damage) 207-260 mph. Well-constructed houses are destroyed, some structures are lifted from foundations and blown some distance, cars and large objects are blown some distance.
F5	(Incredible Damage) 261-318 mph. Strong frame houses are lifted from foundations, reinforced concrete structures are damaged, automobile-sized debris becomes airborne, trees are completely debarked.

Source: http://www.disastercenter.com/tornado/fujita.htm

Table 3.11

Enhanced F Scale for Tornado Damage

An update to the original F-scale by a team of meteorologists and wind engineers, implemented in the U.S. on 1 February 2007.

FUJITA SCALE			DERIVED EF SCALE		OPERATIONAL EF SCALE	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	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

IMPORTANT NOTE ABOUT ENHANCED F-SCALE WINDS: The Enhanced F-scale still is a set of wind estimates (not measurements) based on damage. Its uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to the 28 indicators listed below. These estimates vary with height and exposure. **Important**: The three second gust is not the same wind as in standard surface observations. Standard measurements are taken by weather stations in open exposures, using a directly measured, "one minute mile" speed.

Source: National Oceanic and Atmospheric Administration - http://www.spc.noaa.gov/efscale/ef-scale.html

Hail is another hazard associated with thunderstorms. A hailstorm forms when updrafts carry raindrops into extremely cold portions of the atmosphere where the drops condense and freeze. Hail falls when it becomes heavy enough to overcome the strength of the updraft and gravity takes over. The onset of hailstorms is generally very rapid and difficult to predict. The following table illustrates the different sizes and intensities of hail as well as the type of damage associated with each category.

Table 3.12 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.

Intensity Category	Diameter (mm)	Diameter (inches)	Size Description	Typical Damage Impacts
Severe	21-30	0.8 – 1.2	Walnut	Severe damage to fruit and crops, damage to glass and 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 tiles roofs, significant risk of injuries.
Destructive	51-60	2.0 – 2.4	Hen's egg	Bodywork of grounded aircraft dented, brick walls pitted.
Destructive	61-70	2.4 – 3.0	Tennis ball > cricket ball	Severe roof damage, risk of serious injuries.
Destructive	71-80	3.0 – 3.5	Large orange > softball	Severe damage to aircraft bodywork.
Super Hailstorm	81-90	3.6 – 3.9	Grapefruit	Extensive structural damage. Risk of severe or even fatal injuries to persons caught in the open.
Super Hailstorm	> 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.

In regards to unique construction characteristics or other conditions which may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Hazard Event History

Maries County lies along the eastern edge of tornado alley and from 1996 to 2013 the county recorded six tornados from F0 to F2 in strength. One tornado event caused damage of $5 million. Recorded tornados in Maries County since 1957 are shown in Table 3.13. Since 1957, one person has been injured in Maries County due to tornados and there have been no deaths.

Table 3.13 Tornado History – Maries County[xlviii]

Date	Location	Magnitude	Number injured/killed	Property Damage
7/29/1957	Maries County	F1	0 injured, 0 killed	$2,500
11/15/1960*	Maries County	F2	0 injured, 0 killed	$25,000
11/15/1960*	Maries County	F2	0 injured, 0 killed	$25,000
6/1/1999	Brinktown	F1	0 injured, 0 killed	$75,000
5/4/2003	Vienna	F0	0 injured, 0 killed	$0
1/7/2008	Veto	EF0	1 injured, 0 killed	$5,000,000
TOTALS			1 injured, 0 killed	$5,127,500

Source: National Oceanic and Atmospheric Administration - http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
**Separate storm events.*

Historical data furnished by the National Climatic Data Center show tornados have touched down in unincorporated parts of the county as well as Vienna. The January 7, 2008 tornado was the most damaging in the last 57 years, costing an estimated $5 million. The tornado struck the Rolla Regional Airport near Vichy and destroyed several buildings as well as airplanes.

Thunderstorm winds, while not as powerful as tornados, are still a cause for concern in Maries County. 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.[xlix]

The National Oceanic and Atmospheric Administration reports 61 incidences of thunderstorms with high winds and high wind events in Maries County since 1955, typically occurring two to three times per year. These thunderstorm winds often result in the uprooting of trees, which may cause damage to nearby power lines, buildings or homes. Twelve incidents resulted in reported property damage ranging from $1,000 to $35,000. Since 1955, the county has suffered $122,000 in property damage due to strong winds and thunderstorms.

Another hazard associated with thunderstorms is lightning. Lightning kills 75 to 100 people in the United States each year. According to the National Oceanic and Atmospheric Administration's National Climatic Data Center, no deaths in Maries County have been attributed to lightening.

Hail is a fairly common weather activity in Maries County, having occurred 72 times in the last 57 years. As hail is a hazard typically covered by individual insurance, damage data is not well documented for hail storms. Large hail can reach the size of grapefruit. Hail causes several hundred millions of dollars in damage annually to property and crops across the nation. The size of hailstones in Maries County has been recorded as large as 4.5 inches in diameter in 2004, but typically hail stones are much smaller. While hail can be damaging, it has typically been mild in Maries County and only caused $5,000 in property damages since 1957.[l]

Table 3.14 lists those thunderstorm and high wind events that occurred in Maries County, as well as all hail events recorded for Maries County.

Table 3.14 List of All Hail Storms and Thunderstorms/High Winds Resulting in Property Damage or Injuries in Maries County 1950-2009

Location	Date	Type	Magnitude	Property Damage
County	7/10/1955	Thunderstorm Wind	65 kts.	0
County	4/17/1957	Thunderstorm Wind	53 kts.	0
County	4/17/1957	Hail	Unknown	0
County	6/10/1958	Thunderstorm Wind	71 kts.	0
County	6/10/1958	Hail	Unknown	0

Location	Date	Type	Magnitude	Property Damage
County	3/29/1960	Hail	Unknown	0
County	7/18/1961	Thunderstorm Wind	70 kts.	0
County	9/24/1961	Hail	Unknown	0
County	8/18/1965	Thunderstorm Wind	65 kts.	0
County	5/21/1969	Thunderstorm Wind	52 kts.	0
County	5/21/1969	Hail	Unknown	0
County	4/12/1970	Hail	Unknown	0
County	5/4/1974	Thunderstorm Wind	50 kts.	0
County	6/9/1974	Thunderstorm Wind	Unknown	0
County	8/31/1974	Thunderstorm Wind	Unknown	0
County	5/11/1975	Hail	Unknown	0
County	5/20/1975	Thunderstorm Wind	Unknown	0
County	6/21/1977	Thunderstorm Wind	Unknown	0
County	7/14/1978	Thunderstorm Wind	50 kts.	0
County	7/2/1980	Thunderstorm Wind	50 kts.	0
County	4/16/1982	Hail	Unknown	0
County	5/28/1982	Thunderstorm Wind	Unknown	0
County	5/28/1982	Hail	Unknown	0
County	5/25/1984	Hail	Unknown	0
County	6/2/1985	Hail	Unknown	0
County	6/3/1985	Hail	Unknown	0
County	5/18/1986	Thunderstorm Wind	Unknown	0
County	5/8/1988	Thunderstorm Wind	55 kts.	0
County	6/23/1988	Thunderstorm Wind	50 kts.	0
County	6/17/1992	Hail	Unknown	0
Vienna	4/19/1993	Hail	Unknown	0
Dixon Area	6/8/1994	Hail	Unknown	0
Hayden	5/12/1995	Hail	Unknown	0
Vienna	5/18/1995	Hail	Unknown	0
Vienna	10/10/1995	Hail	Unknown	0
Vichy	2/26/1996	Hail	.88 in.	0
Hayden	2/26/1996	Thunderstorm Wind	52 kts.	0
Brinktown	9/23/1996	Hail	.75 in.	0
Belle	10/17/1996	Hail	.75 in.	0
Vichy	5/2/1997	Hail	.75 in.	0
Vienna	5/17/1997	Hail	.75 in.	0
Vichy	3/27/1998	Thunderstorm Wind		$30,000
Belle	4/15/1998	Hail	1.00 in.	$5,000
Vichy	4/15/1998	Thunderstorm Wind		$1,000
Brinktown	6/18/1998	Hail	.88 in.	0
Belle	4/21/1999	Hail	.75 in.	0
Vichy	6/27/1999	Thunderstorm Wind	50 kts.	0
Brinktown	8/7/1999	Thunderstorm Wind		0
Vienna	4/19/2000	Thunderstorm Wind		0
Vichy	4/20/2000	Thunderstorm Wind	57 kts.	0
County	2/25/2001	High Wind		$100,000
Vienna	4/3/2001	Hail	.75 in.	0

Location	Date	Type	Magnitude	Property Damage
Vienna	4/9/2001	Hail	1.00 in.	0
County	4/11/2001	High Wind	50 kts.	0
Belle	8/29/2001	Hail	1.00 in.	0
Vienna	10/23/2001	Hail	1.00 in.	0
County	5/7/2002	Thunderstorm Wind	55 kts.	0
Brinktown	5/12/2002	Thunderstorm Wind	52 kts.	0
Belle	6/11/2002	Thunderstorm Wind	62 kts.	$5,000
Belle	7/10/2002	Thunderstorm Wind	52 kts.	$10,000
Vichy	7/18/2002	Hail	.75	0
Hayden	12/17/2002	Hail	.75	0
Brinktown	3/12/2003	Hail	1.00 in.	0
Brinktown	3/25/2003	Hail	.75 in.	0
Brinktown	5/4/2003	Hail	1.00 in.	0
Vichy	6/10/2003	Hail	.75 in.	0
Brinktown	6/10/2003	Thunderstorm Wind	65 kts.	0
Vienna	6/10/2003	Thunderstorm Wind	65 kts.	0
Brinktown	7/11/2003	Thunderstorm Wind	65 kts.	0
High Gate	8/19/2003	Hail	.75 in.	0
Belle	8/21/2003	Hail	1.00 in.	0
Belle	8/21/2003	Thunderstorm Wind	65 kts.	0
Belle	8/28/2003	Thunderstorm Wind	65 kts.	0
Brinktown	5/25/2004	Hail	.75 in.	0
Vienna	5/25/2004	Hail	.75in.	0
Brinktown	5/26/2004	Hail	.75 in.	0
Vichy	5/26/2004	Hail	.75 in.	0
Belle	5/30/2004	Hail	4.50 in.	0
Vichy	5/30/2004	Hail	1.75 in.	0
Hayden	7/5/2004	Thunderstorm Wind	55 kts.	0
Brinktown	7/5/2004	Thunderstorm Wind	50 kts.	0
Brinktown	4/20/2005	Hail	.88 in.	0
Hayden	4/20/2005	Hail	1.00 in.	0
Vienna	4/21/2005	Hail	1.00 in.	0
Vichy Airport	4/21/2005	Hail	1.25 in.	0
Vichy	6/9/2005	Thunderstorm Wind	60 kts.	$2,000
Brinktown	6/9/2005	Thunderstorm Wind	55 kts.	0
Vichy Airport	6/13/2005	Hail	.88 in.	0
Belle	6/13/2005	Thunderstorm Wind	50 kts.	0
Vichy	8/13/2005	Thunderstorm Wind	50 kts.	0
Brinktown	9/13/2005	Thunderstorm Wind	50 kts.	0
Vienna	3/30/2006	Hail	.88 in.	0
Vienna	4/2/2006	Hail	1.00 in.	0
Belle	4/2/2006	Thunderstorm Wind	50 kts.	0
Belle	4/18/2006	Hail	1.00 in.	0
Vichy	9/22/2006	Hail	.88 in.	0
Vichy	4/3/2007	Hail	.75 in.	0
Vienna	6/22/2007	Thunderstorm Wind	50 kts.	$20,000
Vichy Airport	10/17/2007	Thunderstorm Wind	54 kts.	0

Location	Date	Type	Magnitude	Property Damage
Vienna	3/26/2008	Hail	1.50 in.	0
Belle	3/26/2008	Hail	.75 in.	0
Veto	3/27/2008	Hail	1.00 in.	0
Safe	3/27/2008	Hail	1.75 in.	0
Brinktown	3/27/2008	Thunderstorm Wind	55 kts.	$4,000
Vienna	7/8/2008	Thunderstorm Wind	50 kts.	0
Veto	8/5/2008	Thunderstorm Wind	50 kts.	0
Belle	6/2/2009	Thunderstorm Wind	50 kts.	$2,000
Brinktown	7/11/1009	Thunderstorm Wind	50 kts.	$10,000
Vichy	6/27/2010	Thunderstorm Wind	61 kts.	$35,000
Vichy Airport	10/26/2010	Thunderstorm Wind	59 kts.	0
Vichy	4/10/2011	Thunderstorm Wind	52 kts.	$2,000
Vienna	4/19/2011	Hail	.88 in.	0
Vichy	4/19/2011	Hail	1.00 in.	0
Lane’s Prairie	4/19/2011	Thunderstorm Wind	50 kts.	$1,000
Vienna	4/22/2011	Hail	1.00 in.	0
Vienna	5/25/2011	Hail	1.25 in.	0
Veto	7/22/2011	Thunderstorm Wind	52 kts.	0
Brinktown	8/20/2011	Thunderstorm Wind	52 kts.	0
Lanes Prairie	1/17/2012	Hail	1.00 in.	0
Vienna	3/2/3012	Hail	1.75 in.	0
Belle	3/15/2012	Hail	1.50 in.	0
Yarna	3/15/2012	Hail	1.00 in.	0
Vichy	3/17/2012	Hail	1.75 in.	0
Vichy	7/2/2012	Thunderstorm Wind	50 kts.	0
Vienna	8/4/2012	Hail	.88 in.	0
Vienna	8/4/2012	Thunderstorm Wind	52 kts.	0
Vienna	8/8/2012	Hail	.88 in.	0
Yarna	8/8/2012	Hail	0.88 in.	0
Van Cleve	1/29/2013	Thunderstorm Wind	52 kts.	0
Vienna	5/20/2013	Hail	1.50 in.	0
Belle	5/20/2013	Hail	1.75 in.	0
Vienna	6/23/2013	Hail	1.00 in.	0
Vienna	7/5/2013	Hail	1.00 in.	0
Veto	9/1/2013	Thunderstorm Wind	52 kts.	0

Source: National Oceanic and Atmospheric Agency, National Climatic Data Center, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

Thunderstorms, high winds, hail and tornados are typically associated with spring and summer weather patterns. However, these types of storms can occur at any time during the year provided the conditions are right, as evidenced in the table above.

Warning Time and Duration

Significant advances have occurred over the past decade in predicting and tracking severe storms and tornados. Severe thunderstorms can develop and change direction quickly, making it difficult to adequately inform both heavily populated and sparsely populated areas. While a thunderstorm may be predicted, its severity and the chance of tornado development are less predictable. Tornado warning sirens exist in Vienna and Belle. Several radio stations and television stations in the region provide updates when severe weather threatens Maries County. Weather radios also provide an early warning. Based on the technology available and nature of this hazard, it has been assigned a CPRI rating of Probable warning time of less than six hours (4). Duration of less than six hours (1).

Severity/Magnitude

It is likely that the next disaster's impact on Maries County will be limited based on data for previous severe thunderstorms and tornados. While there is a possibility of strong winds, there has been little damage done to commercial or residential structures in the past, with the exception of the 2008 tornado that struck the Rolla Regional Airport in Vichy and caused $5 million in damages. The county has had a total of $5,075,000 in damages from six tornados. No lives have been lost in the past 57 years from tornados or severe storms. Mitigation activities may provide a more secure prediction that loss of life will be negligible in the future.

Because the severity or magnitude is different for severe storms and tornados, each of these hazards has been rated on the CPRI separately to provide a more complete hazard analysis.

Tornados. Each class of tornado will cause different degrees of damages and will only strike certain parts of the county. For example, a lower strength tornado may cause limited damage in a larger portion of the county while a high strength tornado may cause significant damage in a smaller area of the county. Based on past history (since 1957) available through the National Climatic Data Center, there has been one injury and no deaths in Maries County due to tornados. Out of six tornados, one was rated as an F1, one was rated as F0 and one was rated as EF0. Data is not available for the other three tornados which occurred prior to 1961. Since 1957, the county has experienced $5.1275 million in damages from tornados, with $5 million of that figure attributed to one EF0 tornado that struck the airport. With a history of $5.1275 million dollars in losses over 57 years, the average damages are estimated at $89,956.14 per year. As can be evidenced by tornados like the one that struck Joplin, Mo., tornados have the potential to exact catastrophic damage and this knowledge should be factored into the assessment. Based on historical data and the potential magnitude of damage that tornados can inflict, the CPRI rating is Limited (2) - Injuries and/or illnesses do not result in permanent disability; complete shutdown of critical facilities for more than one week; 10-24 percent of property is severely damaged.

Severe Storms. Despite the frequency of severe thunderstorms in Maries County, storms causing damage in regards to high winds and hail have been relatively few. Since 1955 the county has sustained a total of $505,000 in property damage from thunder and hail storms. For these reasons, severe storms are assigned a CPRI rating of Negligible (1) - Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged.

Probability

Because the probability of future occurrence is different for severe storms and tornados, each of these two hazards has been rated on the CPRI separately to provide a more complete hazard analysis.

Tornados. Historical data is discussed in earlier sections of this document. The probability of tornados is low, with tornados occurring in the county on an average of every nine to ten years. Based on the available data, tornados have been assigned a CPRI rating of Unlikely (1) – Event is probable within the next ten years; a 10 percent probability of occurring per year.

Severe Storms. Severe thunderstorms are virtually guaranteed to occur in the future in Maries County. On average several severe storms occur each year. Based on historic information, it is highly likely that a severe storm, possibly including high winds and hail will occur at least once each year and affect a majority of the county. However, the strength of these thunderstorms is generally low with little or no damage. For these reasons, severe storms have been assigned a CPRI rating of Highly Likely (4) – event is probable within one year—a near 100 percent probability of occurring.

Recommendations

- Early warnings and tornado safe rooms are possibly the best hope for residents when severe weather strikes. While more than two hours warning is not possible for tornados, citizens must immediately be aware when a city will be facing a severe weather incident. Cities that do not already possess adequate warning systems should plan to purchase a system or upgrade an existing system.
- Storm shelters/tornado safe rooms are another important means of mitigating the effects of tornados and 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.
- Efforts should be made to find ways of funding tornado safe rooms in schools and high population facilities such as large employers.

Hazard Summary – Tornado for all Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
1.75	Low

Hazard Summary – Thunderstorm/High Wind/Hail for all Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
3.0	High

3.2.10 Severe Winter Weather

Description

Severe winter weather, including snowstorms, ice storms and extreme cold, can affect any area of Missouri. Severe winter weather can cause injuries, deaths and property damage in a variety of ways.[li] The greatest threat is likely to occur in the area north of the Missouri River, as was the case with the devastating Kansas City area ice storm on January 31, 2002, which stretched into central Missouri and led to a Presidential Disaster Declaration. However, there have been several ice storms in the past ten years that have affected the Ozarks. The most significant being a historic winter storm that occurred on January 31 through February 2 in 2011. This storm affected the nation's midsection from the southern Plains through the middle and upper Mississippi Valley into the Great Lakes. Portions of Interstate 70 and 44 were closed across Missouri. The storm included freezing rain, sleet and heavy snow and high winds produced blizzard like conditions with near zero visibility at times. Snow accumulations in mid-Missouri ranged from 14 to 22 inches.[lii]

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

Winter storms can be defined differently in various parts of the country. Heavy snow in the south can be a dusting in the mountains. Sleet is raindrops that freeze into ice pellets before reaching the ground. Sleet usually bounces when hitting a surface and does not stick to objects; however, it can accumulate like snow and cause a hazard to motorists. Freezing rain is 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 glaze of ice. Even small accumulations of ice can cause a significant hazard. An ice storm occurs when freezing rain falls and freezes immediately on impact; communications and power can be disrupted for days or weeks, and even small accumulations of ice may cause extreme hazards to motorists and pedestrians.

Winter storms are considered deceptive killers. This is because most deaths are indirectly related to the storm. Causes of death range from traffic accidents due to adverse driving conditions such as icy roads, to heart attacks caused by overexertion while shoveling snow and other related activities. Hypothermia or frostbite may be considered the most direct cause of death and injuries, which can be attributed to winter storms and/or severe cold. Economic costs are also difficult to measure. Heavy accumulations of ice can bring down trees, electric power lines and poles, telephone lines and communications towers. Such power outages create an increased risk of fire, as home occupants seek use of alternative fuel sources (wood, kerosene, etc. for heat, and fuel burning lanterns or candles for emergency lighting). Crops, trees and livestock can be killed or injured due to deep snow, ice or severe cold. Buildings and automobiles may be damaged from falling tree limbs, power lines and poles. Local governments, home and business owners and power companies can be faced with spending millions of dollars for restoration of services, debris removal and landfill hauling.[liii] In regards to unique construction characteristics or other conditions which may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Winter weather warnings are set up in stages of severity by the National Weather Service. These stages are as follows:

- <u>Winter Weather Advisory</u>: Winter weather conditions are expected to cause significant inconveniences and may be hazardous. If caution is exercised, these situations should not become life threatening. The greatest hazard is often to motorists.
- <u>Winter Storm Watch</u>: Severe winter conditions have begun or are about to begin.
- <u>Blizzard Warning</u>: Snow and strong winds will combine to produce a blinding snow (near zero visibility), deep drifts, and life-threatening wind chill.
- <u>Frost/Freeze Warning</u>: Below freezing temperatures are expected and may cause significant damage to plants, crops, or fruit trees. In areas unaccustomed to freezing temperatures, people who have homes without heat need to take added precautions.

In addition to snow, the effects of temperature and wind chill increase the severity of a winter storm. Wind blowing across exposed skin drives down the skin temperature and eventually the internal body temperature. The faster the wind blows, the faster the heat is carried away, the greater the heat loss and the colder it feels. Exposure to low wind chills can be life threatening to humans and animals.

A new Wind Chill Temperature Index took effect on November 1, 2001, replacing the original wind chill index that was devised in 1945. To find the Wind Chill Temperature Index from the table that follows, find the air temperature along the top of the table and the wind speed along the left side. The point where the two intersect is the wind chill temperature.

Figure 3-18

Wind Chill Chart

Wind (mph) \ Temperature (°F)	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: National Oceanic and Atmospheric Administration

Hazard Event History

Severe winter weather typically strikes Missouri more than once every year. Maries County receives the gamut of winter weather events from heavy snows to freezing rain. Major snowstorms happen at least once each year causing multiple school closings and suspended business and government activity. Anywhere from one to fifteen inches of snow is possible and one to three inches of ice. Storms can last from less than an hour to several days. Damages are usually minimal and no deaths are attributed to severe weather in Maries County. However, icy conditions often make roads hazardous and automobile accidents are frequent occurrences. Since 1996, more than $3.905 million in property damage has been reported from winter storms and extreme cold weather that affected Maries County.

A major winter storm on November 30, 2006, caused a combination of freezing rain, sleet, and heavy snow to fall over sections of southwest and central Missouri. The frozen precipitation began on the 30th and fell as freezing rain and sleet, with ice accumulations up to four inches in some areas. The second wave of precipitation occurred overnight causing large amounts of snow to accumulate over the ice. Maries County was one of several counties affected. Downed power lines resulted in widespread power outages. Many residents went without power for several days. A few weeks later, starting on January 12, 2007, an ice storm swept through the state and caused $3.3 million in damages from downed trees, and power lines in Maries County alone. The statewide damage estimate was almost $353 million.

According to the National Climatic Data Center, there have been a total of 23 extreme cold, snow or ice events reported in Maries County since 1996. Table 3.15 shows the dates, type of storm, magnitude and property damage estimates for each event.

Table 3.15 Snow and Ice Storms in Maries County 1996-2013

Location	Date	Type	Magnitude	Property Damage
Multi-County	11/24/1996	Ice Storm	0 Deaths, 0 Injuries	$50,000
Multi-County	1/8/1997	Heavy Snow	0 Deaths, 0 Injuries	$5,000
Multi-County	12/20/1998	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	1/1/1999	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	12/12/2000	Extreme Cold/Wind Chill	0 Deaths, 0 Injuries	0
Multi-County	12/15/2000	Ice Storm	0 Deaths, 0 Injuries	0
Multi-County	1/1/2001	Extreme Cold/Wind Chill	0 Deaths, 0 Injuries	0
Multi-County	2/21/2001	Ice Storm	0 Deaths, 0 Injuries	0
Multi-County	3/2/2002	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	12/24/2002	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	2/23/2003	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	3/5/2003	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	1/25/2004	Ice Storm	0 Deaths, 0 Injuries	0
Multi-County	11/30/2006	Winter Storm	0 Deaths, 0 Injuries	$500,000
Multi-County	1/12/2007	Ice Storm	0 Deaths, 0 Injuries	$3,300,000
Multi-County	1/20/2007	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	12/9/2007	Ice Storm	0 Deaths, 0 Injuries	$50,000
Multi-County	2/11/2008	Ice Storm	0 Deaths, 0 Injuries	0
Multi-County	2/21/2008	Ice Storm	0 Deaths, 0 Injuries	0
Multi-County	1/26/2009	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	2/28/2009	Winter Storm	0 Deaths, 0 Injuries	0
Multi-County	2/1/2011	Blizzard	0 Deaths, 0 Injuries	0
Multi-County	2/21/2013	Winter Storm	0 Deaths, 0 Injuries	0
TOTALS			0 Deaths, 0 Injuries	$3,905,000

Source: NOAA, National Climatic Data Center, http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms

Likely Locations

While severe winter weather is more prevalent north of the Missouri River, it frequently strikes all of Maries County during its seasonal pattern and often takes the form of ice storms, which are often more destructive than snow storms. No part of the county or the communities located within the county is exempt from this natural hazard. Winter storms typically occur from November through February. However, winter weather can occur as late as May or as early as October in Maries County.

Warning Time and Duration

Meteorologists predict most winter weather more than 24 hours before it happens. While the extent of the severity may not always be completely accurate, the prediction at least provides some warning to residents. Residents mainly learn about severe winter weather from local radio and television stations that provide advanced notice of this hazard. Based on the prediction technology available, the CPRI rating assigned is Probable warning time of more than 24 hours (1). Duration of less than one week (3).

Severity/Magnitude

Although severe winter weather can affect the entire county during a single storm, this hazard will most likely be negligible because major roads and facilities are usually rarely shut down for more than 24 hours. While some public schools may experience closing for up to two weeks, these facilities are not critical and cause little disturbance in day-to-day business or government activities. Injuries are usually limited to residents falling on icy sidewalks or cars sliding into each other on frozen thoroughfares. The most significant disruption in the past few years has been power outages associated with ice storms that can last for several days for some locations. Following the severe ice storms of the past seven years and the associated power outages that affected portions of southern Missouri, communities and utility companies have become much more aggressive in their tree trimming programs. This activity has mitigated a substantial portion of the power outage problem associated with winter storms. For these reasons, the CPRI rating assigned is Negligible (1) - Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged.

Probability

Severe winter weather can be predicted with a great degree of certainty to occur in the future. Based on past history, this hazard will likely occur at least once or twice every year and has occurred as frequently as four times during one winter season. For these reasons, the CPRI rating assigned is Highly Likely (4) – Event is probable within one year—a near 100 percent probability of occurring.

Recommendations

- The county and cities should enhance their weather monitoring to be better prepared for severe weather hazards. If the 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.

Hazard Summary – Severe Winter Weather for all Jurisdictions in Maries County

Calculated Priority Risk Index	Planning Priority
2.55	High

3.2.11 Wildfire

Description

A wildland fire is any fire occurring on grassland, forest, or prairie, regardless of ignition source, damages or benefits. According to the National Fire Plan issued by the U.S. Departments of Agriculture and Interior, the urban/wildland interface is defined as "…. the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels." Spawned by increases in population, urban expansion, creative land management decisions that place neighborhoods next to wildland preserves, parks and greenbelts, and the ever-present desire to intermingle with nature, the interface problem has grown dramatically over the last twenty years. This marriage between humans and their property of value with wildland areas has significantly increased the human exposure to wildfires.

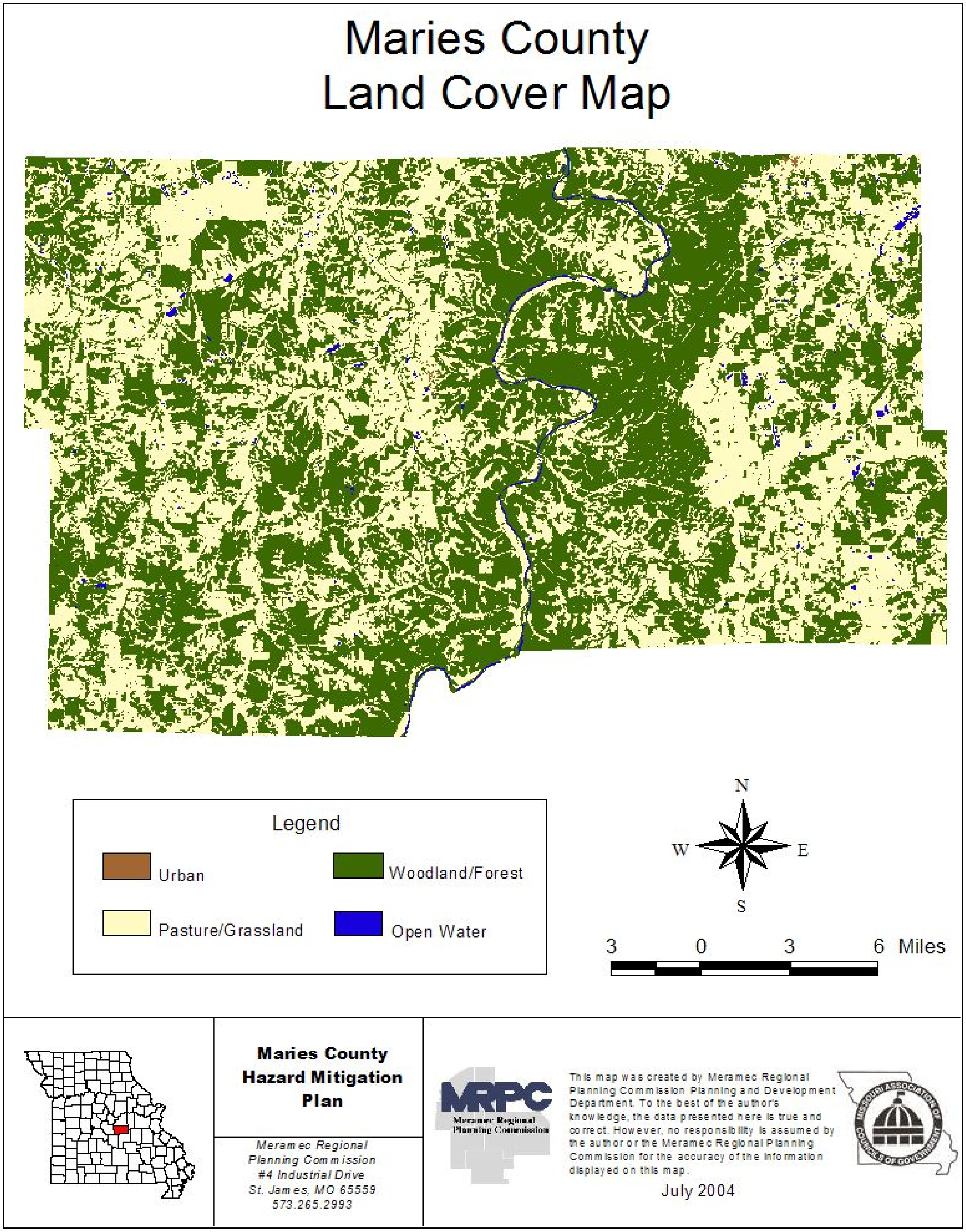
Forest fires have had a major impact on Missouri's forests. Burning the woods was a deep-rooted tradition in the Ozarks. It took many years of education to reduce the annual spring burning. Even now, some areas of the state still experience problems with fires deliberately set by arsonists. Humans cause most of the fire in Missouri: 50 percent start from escaped debris and trash fires and 31 percent are started by arsonists. These fires cause millions of dollars of damage to forests, wildlife habitat, watersheds, and property. The Department of Conservation and Forest Service rely on lookout towers, airplane petrol, and telephone reports to locate wildfires. Rural fire departments help these agencies suppress forest and grass fires in many parts of the state. [liv]

More and more people are making their homes in woodland settings in or near forests and rural areas. There, homeowners enjoy the beauty of the environment but they also face the very real danger of wildfire. Maries County is primarily comprised of wooded, rural areas. There are several conservation areas within the county, with the largest being Spring Creek Gap. All of these tree-filled areas are significant possibilities for wildfire disasters. Figure 3-19 is a land cover map for Maries County and which demonstrates the potential areas for wildfires.

In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Wildfires destroy existing vegetation – forests, pastures, croplands, as well as structures such as homes, barns and businesses. The initial burn can be catastrophic – completely destroying whatever is involved. The aftermath can cause long term problems and can include crop and habitat losses. Deforested hillsides are more prone to erosion and landslides. Erosion can damage watersheds and cropland.

Figure 3-19



Maries County
Land Cover Map
Legend
Urban
Woodland/Forest
Pasture/Grassland
Open Water
N
W
E
S
3
0
3
6
Miles
Maries County
Hazard Mitigation
Plan
Meramec Regional
Planning Commission
#4 Industrial Drive
St. James, MO 65559
573.265.2993
This map was created by Meramec Regional Planning Commission Planning and Development Department. To the best of the author's knowledge, the data presented here is true and correct. However, no responsibility is assumed by the author or the Meramec Regional Planning Commission for the accuracy of the information displayed on this map.
July 2004

Hazard Event History

Because building structures exist anywhere people live and work, fires can occur at anytime and anywhere throughout the state. The frequency of events depends on a wide range of factors. These factors could include and are not limited to: population/building density, building use, lack of fire codes, lack of enforcement when fire codes exists, fire safety practices or lack of by building occupants, lack of adequately equipped fire departments and criminal intent related to arson. Frequency of structural fire data may include the National Fire Incident Reporting System Statistics data provided by the Division of Fire Safety. According to Fire Safety, about 250 out of approximately 900 fire departments report the data utilized to compile the Missouri Incident Report statistics. For this reason, definitive conclusions are not possible. However, it is readily apparent that fire departments, law enforcement and other agencies spent considerable manpower and funding to respond to and investigate structural fires.

The Forest Division of the Missouri Department of Conservation is responsible for protecting the privately owned and state-owned woods and grasslands from wildfires. To accomplish this task, intensive forest fire protection districts have been established in the more heavily-timbered southern part of the state. At the present time, 18 forest districts afford intensive fire protection to approximately one-half of the state or about 16 million acres. Within these districts fairly accurate forest and grassland fire statistics are available from the Missouri Department of Conservation. In a typical year, there are approximately 3,500 wildfires. During the 2012 fiscal year, there were more than 850 fires in the Ozarks region alone, which destroyed over 9,000 acres.[lv]

<u>Spring 2000 Brush and Wildfires.</u> Due to extreme dry conditions, brush and wildfires whipped by 50 mph winds burned more than 17,000 acres in south-central Missouri in March 2000. In Camden County alone, there were 6,000 acres engulfed by flames and 40 structures destroyed by these fires. Some 200 homes were threatened by the approaching wildfires, prompting evacuations and shelters to be opened in Camdenton and Laurie. The brush and wildfires also erupted in the counties of: Morgan, Miller, Dallas, Laclede, Benton, Hickory, St. Clair, and Henry, causing considerable damage to thousands of acres. The State Fire Marshall's Mutual Aid was activated with 480 volunteer fire personnel from 31 fire departments responding from neighboring areas. The Missouri Department of Conservation also provided key assistance. To help these fire departments recover their expenses, Missouri applied for a federal Fire Suppression Grant through the Federal Emergency Management Agency, with $135,000 approved as a result. This was the first such grant ever awarded to the state, and also the first within FEMA's four-state Region VII, which includes Missouri, Iowa, Kansas and Nebraska.[lvi]

According to the Missouri Department of Conservation Forest Fire Reporting, there have been approximately 853 fires reported in Maries County between January 1, 1990 and January 1, 2014. The total acreage burned from those incidents was 3,328.75 acres. Two outbuildings were damaged and one outbuilding was destroyed by these fires.

Forest and grassland fires can and have occurred on any day throughout the year. The majority of the fires, however, and the greatest acreage loss will occur during the spring fire season, which is normally between February 15 and May 10. The length and severity of this burning period depends on the weather conditions. Spring in Missouri is noted for its low humidity and high winds. These conditions, together with below normal precipitation and high temperatures, result in extreme high fire danger. Not only is this the time of the year when fires are most difficult to control and suppress, it is also the time when most fire starts occur. Spring is the time of the year when rural residents normally burn their garden spots, brush piles, etc. Many landowners also still believe it is necessary to burn the woods in the spring of the year in order to get more grass, kill ticks, and "get rid of" the brush. Therefore, with the possibility of extremely high fire danger and the chances of a large number of fires starting, the spring months are the most dangerous for a wildfire standpoint. The second most critical period of the year is in the late fall. Depending on the weather conditions, there is a possibility of a sizeable number of fires occurring between mid-October and late November.[lvii]

Climatic conditions such as severe freezes and drought can significantly increase the intensity of wildland fires since these conditions kill vegetation, creating a prime fuel source for these types of fires. Disease and insect infestation of forests can also lead to more dry fuel in wooded areas. The intensity of fires and the rate at which they spread are directly related to wind speed, temperature, and relative humidity.

Warning Time and Duration

Warning times for wildfires are often minimal or none. Existing warning systems include local television and radio stations and weather radios. The warning time and duration CPRI ratings assigned for all jurisdictions in Maries County are Probable warning time of less than six hours (4). Duration of less than one day (2).

Severity/Magnitude

As long as drought conditions are not seriously inflamed, future wildfires in Maries County should have a negligible adverse impact on the county and its jurisdictions, as this hazard would affect a small percentage of the population. The history of the severity of wildfire in Maries County and all of its jurisdictions has been discussed earlier in this document. Based on the available historic data, the CPRI rating assigned is Negligible (1) - Injuries and/or illnesses are treatable with first aid; minor quality of life lost; shutdown of critical facilities and services for 24 hours or less; less than 10 percent of property is severely damaged.

Probability

Wildfire is another hazard where there is a difference in the probability of occurrences in incorporated and unincorporated areas of the county. Although fires that erupt in rural areas may burn longer and damage more acreage, the risk to property is lower because of the lower density of homes and businesses. The greater risk for property damage and injuries lies in those areas where developed areas meet densely vegetated areas. Figure 3-20 is a map showing the urban/wildland interface for Maries County. The city of Vienna shows a low density/no vegetation interface on the north, south and west portions of the community. On the east side of Vienna, the area would be classified as low density/intermixed. In the city of Belle, the southeast portion of the community is classified as low density interface. The north and south portions of the city are in an area classified as with the rest of the community being in an area considered medium density interface. The east side of Belle is considered very low density with no vegetation. The vast majority of the unincorporated areas of the county are considered very low density in population with and without vegetation. According to this map, there are no areas of Maries County or its jurisdictions which would be considered to have a high density wildland/urban interface. The probability of wild fires is considered likely, but may increase to high during certain periods, such as spring, late fall, or under conditions of excessive heat, dryness, and/or drought. The likelihood of wildfire in unincorporated areas of Maries County has been assigned a CPRI rating of Highly Likely (4) – Event is probable within one year—a near 100 percent probability of occurring.

The probability of wildfire affecting the communities of Belle and Vienna has been assigned a CPRI rating of Likely (3) - An event is probable within the next three years—a 33 percent probability of occurring.

As most school facilities are located either in the city limits of communities or immediately adjacent to city limits, the risk of wildfire to school districts would be similar to that of communities. However, as school districts have far fewer buildings and assets that are at risk, their probable risk/likeliness for future occurrence would be less than that for communities in general. The probability of wildfire affecting the Maries County R-I and R-II school districts has been assigned a CPRI rating of Unlikely (1) - An event is probable within the next ten years—a 10 percent probability of occurring.

Recommendations

- Design and implement a comprehensive community awareness and educational campaign on the wildland fire danger, targeted at areas of highest risk.
- Develop capabilities, systems and procedures to pre-deploy fire-fighting resources during times of high wildland fire hazard.
- Prepare local fire departments for wildfire scenarios through training and education.
- Encourage development and dissemination of maps relating to the fire hazard to help educate and assist builders and homeowners in being engaged in wildfire mitigation activities, and to help guide emergency services during response.

Hazard Summary – Wildfire – Maries County

Calculated Priority Risk Index	Planning Priority
2.9	High

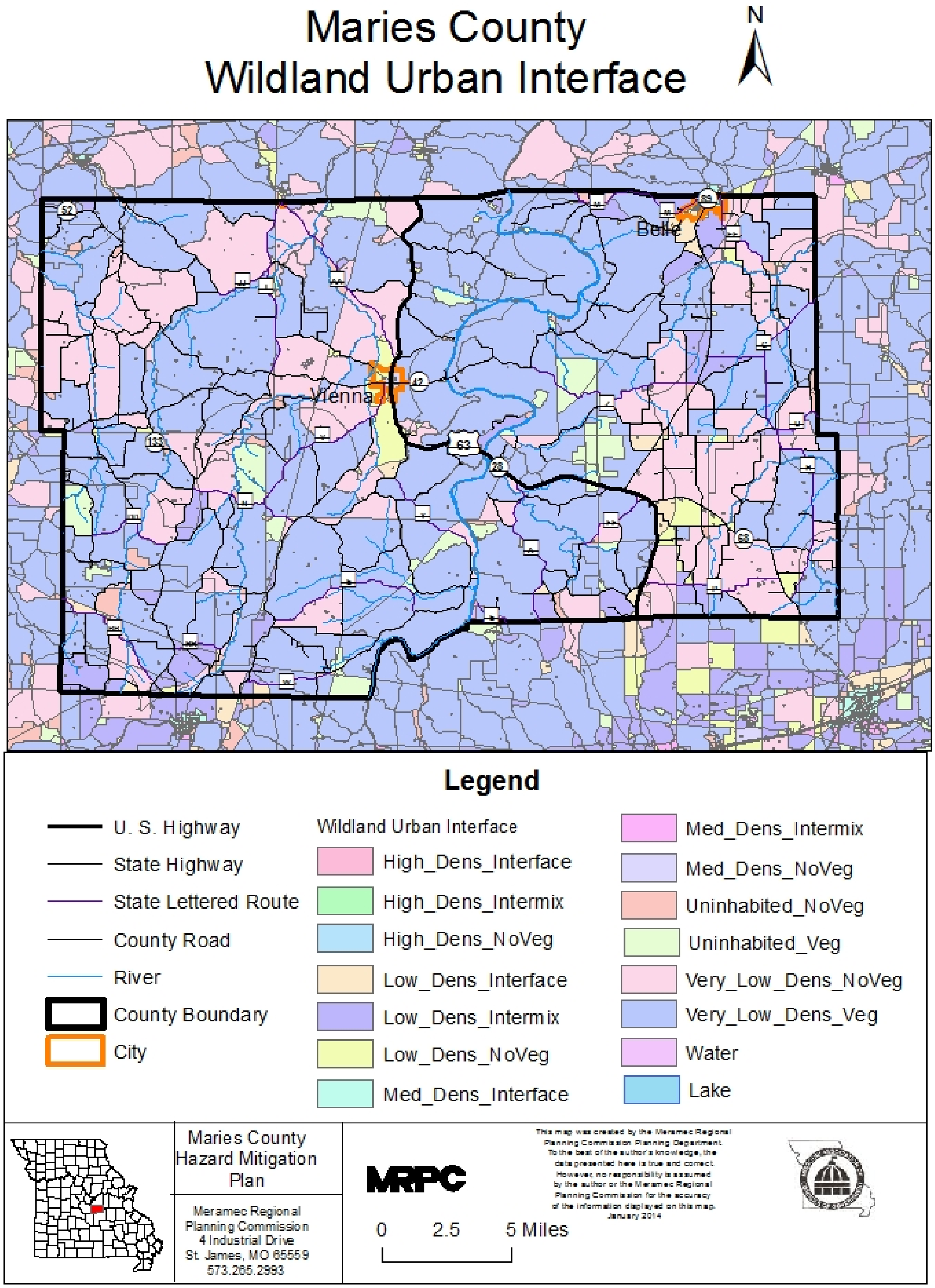
Hazard Summary – Wildfire – Belle and Vienna

Calculated Priority Risk Index	Planning Priority
2.45	Moderate

Hazard Summary – Wildfire – Maries County R-I and R-II School Districts

Calculated Priority Risk Index	Planning Priority
1.55	Low

Figure 3-20


Maries County
Wildland Urban Interface
N
Belle
Vienna
Legend
U. S. Highway
State Highway
State Lettered Route
County Road
River
County Boundary
City
Wildland Urban Interface
High_Dens_Interface
High_Dens_Intermix
High_Dens_NoVeg
Low_Dens_Interface
Low_Dens_Intermix
Low_Dens_NoVeg
Med_Dens_Interface
Med_Dens_Intermix
Med_Dens_NoVeg
Uninhabited_NoVeg
Uninhabited_Veg
Very_Low_Dens_NoVeg
Very_Low_Dens_Veg
Water
Lake
Maries County Hazard Mitigation Plan
Meramec Regional Planning Commission
4 Industrial Drive
St. James, MO 65559
573.265.2993
MRPC
0 2.5 5 Miles
This map was created by the Meramec Regional Planning Commission Planning Department. To the best of the author's knowledge, the data presented here is true and correct. However, no responsibility is assumed by the author or the Meramec Regional Planning Commission for the accuracy of the information displayed on this map.
January 2014

3.2.12 Hazard Profiles Summary

The following table (Table 3.16) provides a summary of the results of the hazard profiles and if there is any variation of hazards among the various jurisdictions.

Table 3.16 Hazard Profile Planning Priority Summary by Jurisdiction

Hazard	Maries County	Belle	Vienna	Maries Co R-I	Maries Co R-II
Dam Failure	Low	Low	Low	Low	Low
Drought	Low	Low	Low	Low	Low
Earthquake	Moderate	Moderate	Moderate	Moderate	Moderate
Extreme Heat	High	High	High	High	High
Flood	High	High	High	High	High
Land Subsidence/ Sinkhole	Low	Low	Low	Low	Low
Severe Storms Hail/Wind	High	High	High	High	High
Tornado	Low	Low	Low	Low	Low
Severe Winter Weather	High	High	High	High	High
Wildfire	High	Moderate	Moderate	Low	Low

3.3 Vulnerability Assessment for Maries County

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)©: [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 by floods.

3.3.1 Methodology

The vulnerability assessment further defines and quantifies populations, buildings, critical facilities and other community assets at risk from natural hazards. The vulnerability assessment for this plan followed the methodology described in the FEMA publication *Understanding Your Risks – Identifying Hazards and Estimating Losses (2002).*

The vulnerability assessment was conducted based on the best available data and the significance of the hazard. Data to support the vulnerability assessment was gathered from the following sources:

- Missouri Spatial Data Information Service (MSDIS)
- Statewide GIS datasets compiled by state and federal agencies
- FEMA's HAZUS software
- Existing plans and reports
- Personal interviews with HMPC members and representatives of other jurisdictions and stakeholders

The vulnerability assessment includes a description of:

- The community assets that are at risk from hazards in the county;
- The vulnerability to each hazard identified in the plan, including an overview of all the hazards and for those hazards with high or moderate planning priority a more in-depth analysis based on existing data;
- An overview of projected development trends;
- A summary of key issues and conclusions drawn from the assessment.

Those hazards ranked as High or Moderate risks include an estimated damage count of buildings for each jurisdiction. This damage count is estimated based on the calculated priority risk index

(CPRI) that takes into account four elements of risk: probability, magnitude/severity, warning time and duration. As explained in Section 3.2.1 Methodology, each element is weighted and a numerical value developed using a pre-determined formula. Based on the score, each jurisdiction can rank a hazard as high, moderate or low risk. At the same time, this formula provides an estimated percentage for the magnitude of the damage should a hazard event occur. The magnitude of each profiled hazard is classified and quantified in the following manner:

- Catastrophic – More than 50 percent of property severely damaged; shutdown of facilities for more than 30 days; and/or multiple deaths. (4)
- Critical – 25-50 percent of property severely damaged; shutdown of facilities for at least two weeks; and/or injuries and/or illnesses resulting in permanent disability. (3)
- Limited – 10-24 percent of property severely damaged; shutdown of facilities for more than a week; and/or injuries/illness do not result in permanent disability. (2)
- Negligible – Less than 10 percent of property severely damaged, shutdown of facilities and services for less than 24 hours; and/or injuries/illnesses treatable with first aid. (1)

By applying these percentages to the building counts for each jurisdiction, the impact of that hazard occurring within that jurisdiction can be estimated. These building damage estimates are included with the overview for each hazard that would result in property damage.

3.3.2 Community Assets

This section of the plan assesses the population, number of structures and estimated values. This data is provided based on HAZUS-MH data and 2000 US Census data. Values reflected here are on improvements (structures) and do not include land values. As would be expected, exposure is concentrated in populated areas.

According to HAZUS-MH, there is a total building replacement value (excluding contents) of $480,131,000 for Maries County. Residential housing makes up 74.6 percent of the total building value for Maries County, approximately $358,216,000. Non-residential building stock is valued at $121,915,000. Table 3.17 shows the breakout of type of buildings, exposure, and percentage of total building stock.

Table 3.17 Occupancy and Exposure of Overall Maries County Building Stock

Occupancy	Exposure	Percent of Total
Residential	$358,216,000	74.6%
Commercial	$40,426,000	8.4%
Industrial	$36,513,000	7.7%
Agricultural	$9,317,000	1.9%
Religion	$9,565,000	2.0%
Government	$9,687,000	2.0%
Education	$16,407,000	3.4%
Total	$480,131,000	100.0%

Source: HAZUS-MH

Table 3.18 Unincorporated Maries County Building Stock

Occupancy	Building Count	Percent of Total
Residential	3,565	96.05%
Commercial	74	2.0%
Industrial	28	0.75%
Agricultural	31	0.84%
Religion	7	0.2%
Government	6	0.16%
Education	0	0%
Total	3,711	100.0%

Source: HAZUS-MH

Table 3.19 City of Belle Building Stock

Occupancy	Building Count	Percent of Total
Residential	733	92.78%
Commercial	38	4.81%
Industrial	6	0.76%
Agricultural	2	0.25%
Religion	6	0.76%
Government	3	0.39%
Education	2	0.25%
Total	790	100.0%

Source: HAZUS-MH

Table 3.20 City of Vienna Building Stock

Occupancy	Building Count	Percent of Total
Residential	224	82.35%
Commercial	28	10.3%
Industrial	4	1.5%
Agricultural	4	1.5%
Religion	2	.75%
Government	7	2.5%
Education	3	1.1%
Total	245	100.0%

Source: HAZUS-MH

For the purposes of this report, a critical facility is defined as one that provides essential public safety or mitigation functions during response or recovery operations or facilities that have the potential to suffer high losses during a disaster. Examples include fire department buildings, city halls, the courthouse, long-term care facilities, and hospitals. In addition, critical infrastructure facilities need to be considered such as highways, airports, water treatment facilities, pipelines and communications facilities. Table 3.21 has a more comprehensive list of potential critical facilities. Not all of these examples may exist in Maries County.

Table 3.21 Critical Facilities Definitions and Examples

Essential Facilities	High Potential Loss Facilities	Transportation and Lifelines
Hospitals and other medical facilities	Power plants	Highways, bridges and tunnels
Police stations	Dams and levees	Railroads and rail facilities
Fire stations	Military installations	Airports
Sheriff department facilities	Schools	Water treatment facilities
Emergency operations centers	Shelters	Pipelines/pump stations
911 centers	Day care centers	Communications centers
	Nursing homes	
	Government buildings	

Source: FEMA HAZUS

Table 3.22 is an inventory of critical facilities and infrastructure in Maries County, based on the data available. Data was collected from HAZUS-MH, directly from jurisdictions and in some cases from various sources that are listed in the endnotes.

Table 3.22 Critical Facilities and Infrastructure by Jurisdiction - Maries County

Facility	Maries County	Belle	Vienna	Total
Airports	1	0	0	1
Bridges	28	0	0	28
Communications Centers	1	0	0	1
Dams	30	0	0	30
Licensed Daycare Centers[lviii]	0	2	3	5
Elder Care/ Long Term Care Facilities[lix][lx]	0	1	2	3
Health Care Facility	0	0	0	0
Fire Stations	4	1	1	6
EMS Stations	0	1	1	2
Emergency Operations Centers	0	0	0	0
Government Facilities	6	26	10	43
Law Enforcement Facilities	1	1	1	3
Major Interstate Highways	0	0	0	0
Military Installations	0	0	0	0
Railroads	0	0	0	0
Pipelines	3	0	0	3
Schools[lxi]	0	2	2	4
Emergency Shelters[lxii]	Not Available	Not Available	Not Available	Not Available
Wastewater Treatment Facilities	1	1	0	5
Public Wells	0	1	2	13

Source: Maries County Hazard Mitigation Planning Committee

There are 3 long term care facilities for the elderly and disabled in Maries County. They are located in Belle and Vienna. Table 3.23 provides specific information on the long term care facilities in Maries County.

Table 3.23 Long Term Elder Care and Elder Day Care Centers in Maries County

Elder Care Facility Name	Location	Capacity	Level of Licensure
Arbor Ridge Estates	Belle	30	RCF
Maries Manor	Vienna	98	SNF
Victorian Place of Vienna	Vienna	48	RCF

Assisted Living Facility=ALF; Residential Care Facility=RCF; Skilled Nursing Facility=SNF
Source: Missouri Department of Health and Senior Services

There are five licensed child daycare facilities in Maries County. Smaller daycares that do not have enough children to require licensing are not included as data is not available on these facilities. Table 3.24 provides information on the licensed daycare facilities in Maries County.

Table 3.24 Licensed Child Care Facilities in Maries County

Facility Name	Location	Facility Type
Missouri Ozarks Community Action, Inc.	Belle	Child Care Center
Reeves, Rata Lynn	Vienna	Family Home
Smith, Beth	Vienna	Family Home
Vineyard, Beverly	Vienna	Child Care Center
Walters, Jeana Rae	Belle	Group Home

Source: Missouri Department of Health and Senior Services

Other Assets

Vulnerability assessment involves more than just an inventory of critical infrastructure. It is also important to include assets of historic, cultural, natural and economic importance. Reasons for including these types of assets in the assessment are varied. The county may place priority on certain assets due to their uniqueness or irreplaceable nature. Having a list of these assets before a disaster can aid in their protection and restoration following an incident. In the case of historic structures, the rules for rebuilding or restoring them may be different or more restrictive than for ordinary buildings. Maries County has many natural resource based assets that are important not only to recreation and tourism, but to the protection of threatened or endangered species. Natural resources such as wetlands can help mitigate disasters such as floods. Damage to or the complete loss of some economic assets can have long-term devastating effects on a community and its ability to recover from a disaster.

The following assets are located in Maries County:

- Endangered, threatened, species of concern:
  - Mussels: Black Sandshell , Ebonyshell, Elephatear, Elktoe, Pink Mucket, Scaleshell and Spectaclecase;

  - Fish: Alabama Shad, Crystal Darter, highfin Carpsucker and Niangua Darter
  - Amphibians: Eastern Hellbender
  - Insects: Frison's Seratellan Mayfly and the Ozark Stone (stonefly)
  - Plants: Running Buffalo Clover
- Historic and Cultural Resources: Maries County Jail and Sheriff's Residence at Fifth and Mill streets in Vienna are listed as state historic sites.
- Economic Resources: Kingsford Charcoal near Belle, Maries County R-I School District in Vienna, Maries County R-II School District in Belle; Maries County Government; Maries Manor Nursing Home; Maries County Bank; Belle State Bank; South Central Regional Stockyards
- Natural Resources: there are seven state public use areas and conservation areas in Maries County; four significant springs; and three major watersheds.

Community Assets by Jurisdiction

The following table shows community assets by jurisdiction. Data has been collected from the various jurisdictions and from HAZUS-MH. (It has been determined that HAZUS-MH data is limited and may have errors.) Replacement values are, in some cases, estimates based on the available data. These assets have been identified for planning purposes as those structures and facilities that should receive priority consideration in hazard mitigation planning and projects in order to minimize risk for these assets.

Table 3.25 Specific Community Assets in Maries County by Jurisdiction

Name of Asset	Replacement Value ($)	Occupancy/Capacity
Unincorporated Area (Including County Government Assets)		
County buildings (including courthouse, jail, county offices)	$4,211,783.00	N/A
Maintenance Building (1)	$115,763.00	N/A
Airport (1)	$2,828,305.00	N/A
County Highway Department Sheds (2)	$256,502.00	N/A
911 Dispatch Center in courthouse (1)	$128,610.00	N/A
Dams (30)	Information not available	N/A
Machine Shed (1)	$46,305.00	N/A
Transmission Tower (1)	$31,907	N/A
Belle		
Government Buildings - includes city hall, and other buildings owned by city (13)	$452,944.00	N/A
Fire Department	$512,400.00	N/A
Waste Water Facilities (9)	$41,221.00	N/A
City Wells and Water Towers (3)	$547,050.00	N/A
Community Center	$525,000.00	N/A
City Park Facilities (16)	$491,931.00	N/A
Vienna		
Government Buildings – includes city hall, and public works buildings/sheds (3)	$397,117.00	N/A

Name of Asset	Replacement Value ($)	Occupancy/Capacity
Senior Center (1)	$270,000.00	N/A
Park Facilities (7)	$346,000.00	N/A
Wells and Water Towers (3)	$641,800.00	N/A
Waste Water Facilities (4)	$929,486.00	N/A
Maries County R-I School District – Assessed Valuation $47,911,180		
Vienna Elementary		266
Vienna High School		270
Maries R-II School District – Assessed Valuation $60,288,646		
Belle Elementary School		356
Maries County Middle School		253
Belle High School		226

3.3.3 Vulnerability by Hazard

This section describes the overall vulnerability of Maries County to the hazards described earlier in this chapter. It also includes, where data is available, estimates of potential losses for buildings, infrastructure and critical facilities located in hazard prone areas. The hazards that will be discussed in this section are only those hazards that were classified through the CPRI process as being moderate or high priority. Hazards that were classified as low priority will not have detailed vulnerability assessments. A vulnerability overview will be provided for the following hazards that were ranked as low priority in the CPRI process:

- Dam Failure
- Drought
- Landslide
- Land Subsidence/Sinkhole

The vulnerability assessment for high and moderate hazards is limited by the data available and the analysis varies based on the data available and the type of hazard being assessed. Most weather related hazards affect the entire county and all of the jurisdictions and so cannot be mapped geographically. This is also the case for wildfire, which can occur anywhere, although the highest risk for property damage lies in the urban/wildfire interface zones. For these weather related hazards, which include extreme heat, severe storm/wind/hail, tornado and severe winter storm, vulnerability is discussed in qualitative terms because good data on potential losses to structures and infrastructure is not available. Good data on structures and infrastructure is also not available for dam failure. As this is ranked low as a hazard, the vulnerability assessment for dam failure is an overview. In regards to unique construction characteristics or other conditions that may differentiate between jurisdictions, there appears to be no substantial differences between each of the participating jurisdictions. Construction and development trends are fairly uniform across the county. Mobile homes are found in every community and throughout the county. The county would benefit from collecting data on these issues to improve future planning efforts.

Of the high and moderate ranked hazards, flood is the highest ranking hazard that's effects vary between jurisdictions and has clearly defined hazard areas based on NFIP and HAZUS data. Floods will be discussed first and the remaining moderate and high ranked hazards will be presented in alphabetical order.

Flood Vulnerability of Maries County and Jurisdictions

Overview

Planning Significance: High. Overall vulnerability to flooding is highest in developed areas of the floodplains of the Gasconade River and its tributaries. Based on the vulnerability analysis and the loss estimates provided in Table 3.28, the unincorporated areas of the county would be most severely impacted by a 100-year flood.

Methodology

FEMA's software program for estimating potential losses from disasters, HAZUS-MH MR3 was used to generate the flood data for Maries County. HAZUS-MH was used to generate a 100-year floodplain for major rivers and creeks in the County that drain at least one square mile. The software produces a flood polygon and flood-depth grid that represents the base flood. While not as accurate as official flood maps, these floodplain boundaries are useful in GIS-based loss estimation. Once the floodplain was generated, the software's census-block level population and building inventory data was used to estimate numbers of residents potentially displaced by flooding as well as potential structural damages.

Flood Vulnerability: Estimated Potential Losses to Existing Development

HAZUS provides reports on the number of buildings impacted, cost of repairs and the loss of contents and business inventory. The loss of the use of a building, as well as the loss of income associated with the property can affect an entire community, whether the building be a business or rental property. Income loss data in HAZUS takes into account business interruption, rental income losses and the resources associated with repairing damages, and job and housing losses. These losses are calculated by HAZUS using a methodology based on the building damage estimates. Flood damage is directly related to the depth of the flood waters. For example, a two foot flood generally results in approximately 20 percent damage to the structure or replacement value. HAZUS uses depth-damage curves to estimate building losses as the flood depth varies across the area that has been inundated by flood waters.

HAZUS data was the best available data, but may still have some inaccuracies. The damaged building counts produced by HAZUS may be rounded and sometimes have errors that can be associated with the use of census block data for analysis.

A 100-year flood scenario was run to determine damage estimates for Maries County. There was a problem with the building damage county by general occupancy report generated by HAZUS. Although damage was reflected in other reports generated at the same time, this report indicated that there were no structures that would be damaged in a 100-year flood. Instead, aerial photographs of the 100-year floodplain were reviewed. 24 structures were identified as being located in the floodplain and likely to be damaged in the event of a 100-year flood. All of these structures were in unincorporated areas of the county. No other jurisdictions were found to have structures located in the floodplain. The HAZUS report Building Damage by General Occupancy showed that there were religious, commercial, industrial and agricultural structures located in the floodplain, but review of aerial photos of the floodplain showed residential structures only. The breakdown of percentage of damage was used to determine the level of damage done to these 24 structures. Twenty percent (two structures) of these structures would not be affected; .4 (0 structures) percent would have 1-10 percent damage; three percent (one structure) would have 11-20 percent damage; 4.6 percent (one structure) would have 21 to 30 percent damage; nine percent (two structures) would have 31-50 percent damage; 17 percent (four structures) would have 41 – 50 percent damage and 46 percent (11 structures) would be substantially damaged by a 100-year flood.

According to HAZUS data, 85.3 percent of the structures in Maries County are residential. Eight percent of structures are commercial buildings. Two percent are industrial buildings. The remainder are agricultural (.4 percent); religious (3.3 percent); government (.7 percent); and education (.3 percent). The total financial exposure for structures in the county is an estimated $804,605,000.

Based on the results of the HAZUS analysis for the 100-year flood event and review of aerial maps of the floodplain, the building inventory loss estimates, which are linked to census block geography, were sorted by jurisdiction to show how the potential for losses varies across the county. Table 3.28 shows the estimated building losses by jurisdiction, as well as contents damage, inventory damage, relocation loss, capital related loss, rental income loss and wage loss. As mentioned earlier, there were some anomalies in the flood data provided. The information in Table 3.26 is based on the data provided and may have some insufficiencies. Based on the data available and analysis, the unincorporated portions of Maries County are the most vulnerable to flood losses.

Table 3.26 Estimated Direct Economic Flood Losses by Jurisdiction

Jurisdiction	Building Damage	Contents Damage	Inven-tory Damage	Reloca-tion Loss	Capital Related Loss	Rental Income Loss	Wage Loss	Total	% of Total
Unincorp. Maries Co	$3,735,000	$2,973,000	$86,000	-0-	$2,000	-0-	$2,000	$6,798,000	100%
Belle	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
Vienna	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-
TOTAL	$3,735,000	$2,973,000	$86,000	-0-	-0-	-0-	$2,000	$6,798,000	100%

Source: HAZUS-MH MR3

Total economic losses for Maries County in the 100 year flood scenario are estimated at $6.798 million. The total building related losses were $6.794 million (building damage, contents damage, inventory damage and rental income loss) –1.4 percent of the total value of the county's structures.

Tables 3.27 through 3.29 show the estimated number of buildings that could be damaged should a flood occur in each jurisdiction. As properties prone to flood damage do not include every building in the county, these damage counts were figured differently from the other hazard damage counts. As HAZUS cannot provide the estimated number of buildings damaged by jurisdiction, per the directions from the Missouri State Emergency Management Agency, planners overlaid floodplain and city boundaries with aerial photos and counted the number of structures found in the floodplain for each jurisdiction The maps showing the floodplain and critical facilities were also reviewed to determine if any critical facilities such as schools or government buildings were located in the floodplain. If not, those types of buildings were shown with zero damage. It was determined that the structures showing in the floodplain were residential, with no other types of buildings located in flood hazard areas. This method provided an estimate of the number and type of buildings that would be damaged in a 100-year flood.

Table 3.27 Estimated Damaged Building Count for Belle- Flood

Occupancy	Total Building Count	Number of Buildings in the 100-Year Floodplain	Estimated Number of Buildings Damaged
Residential	733	0	0
Commercial	38	0	0
Industrial	6	0	0
Agricultural	2	0	0
Religion	6	0	0
Government	3	0	0
Education	2	0	0
Total	790	0	0

Source: HAZUS-MH

Table 3.28 Estimated Damaged Building Count for Vienna - Flood

Occupancy	Total Building Count	Number of Buildings in the 100-Year Floodplain	Estimated Number of Buildings Damaged
Residential	224	0	0
Commercial	28	0	0
Industrial	4	0	0
Agricultural	4	0	0
Religion	2	0	0
Government	7	0	0
Education	3	0	0
Total	272	0	0

Source: HAZUS-MH

Table 3.29 Estimated Damaged Building Count for Maries County

Occupancy	Total Building Count	Estimated Number of Buildings Damaged IN 100-Year Flood
Residential	3,565	24
Commercial	74	0
Industrial	28	0
Agricultural	31	0
Religion	7	0
Government	6	0
Education	0	0
Total	3,711	24

Source: HAZUS-MH

Flood Vulnerability: Potential Population Displaced

HAZUS-MH estimates for the population displaced during a 100-year flood event using U.S. Census data and flood depths. The software estimates that out of a total population of 9,176, approximately 177 people will be displaced due to the flood. Displacement includes households evacuated from within or very near the inundated area. Of this number, it is estimated that eight will seek temporary shelter in public shelters.

Flood Vulnerability: Critical Facilities and Pipelines

Critical facilities data was pulled from the HAZUS-MH and was used along the floodplain generated by HAZUS-MH to identify any critical facilities in the floodplain. Figure 3-21 shows critical facilities in relation to the 100-year floodplain. Figure 3-22 shows transportation infrastructure in relation to the 100-year floodplain, including highways, bridges, bus stations, airports and railroads. Past history shows that Maries County secondary roads, low water crossings and bridges have sustained damage in past flood incidents. Figure 3-23 shows the pipelines in the county in relation to the 100-year floodplain.

Flood Vulnerability: Critical Facility Locations by City

Figures 3-21 and 3-25 map the locations of critical facilities in relation to the 100-year floodplain for the incorporated cities of Maries County. Based on HAZUS-MH data, there are no critical facilities located in or immediately adjacent to the 100-year floodplain in any of the incorporated cities or in any unincorporated areas of the county.

National Flood Insurance Program and Repetitive Loss Properties

Of the three local government jurisdictions participating in this plan, two are currently participating in the National Flood Insurance Program (NFIP): Maries County and the City of Vienna. The City of Belle does not participate in the NFIP. According to repetitive loss data provided by SEMA, there are 15 repetitive loss properties located in unincorporated Maries

County. One of the 15 properties has been mitigated. There are also two severe repetitive loss properties - one that has had four losses and one that has had two losses.

Figure 3-21

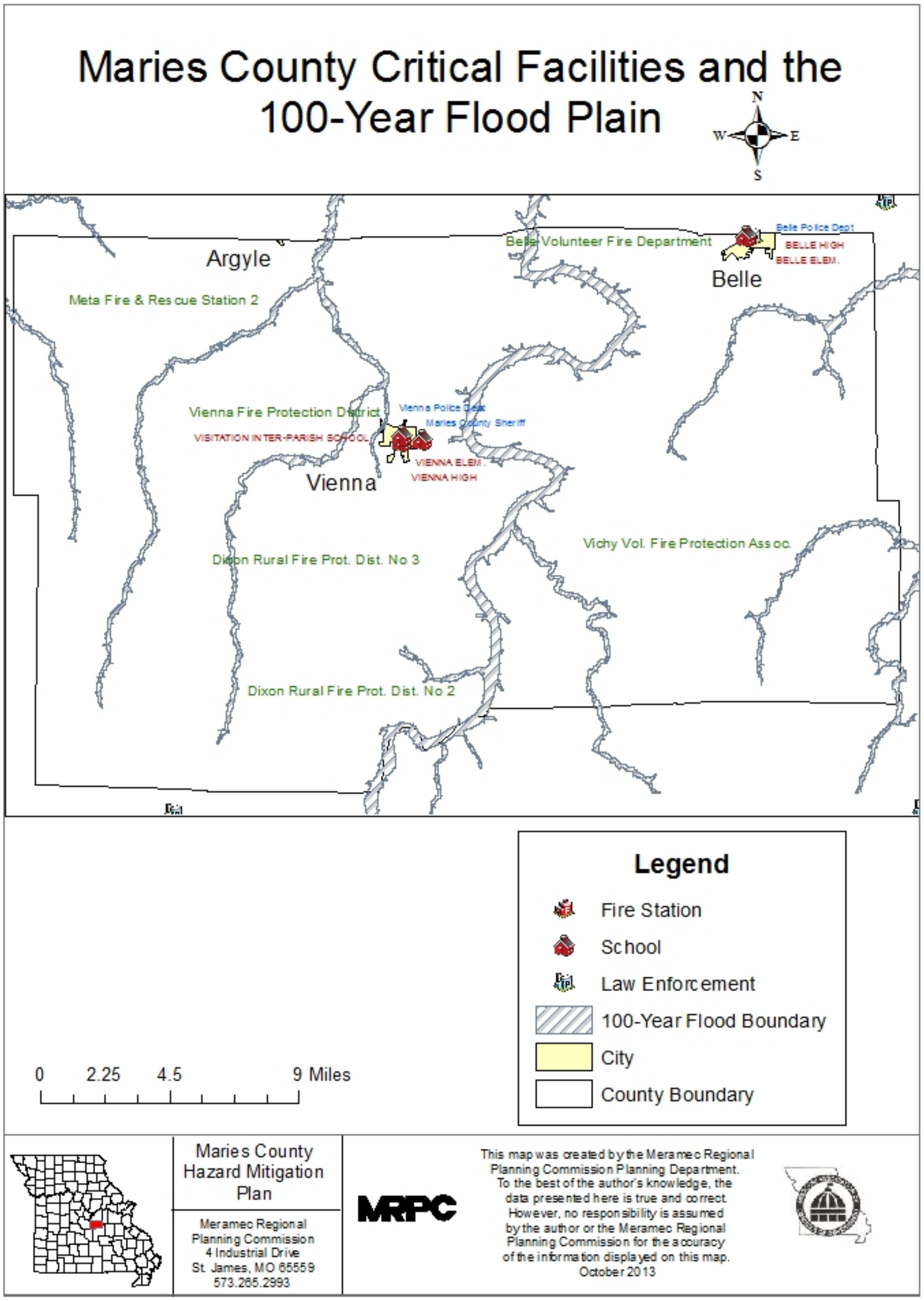


Figure 3-22

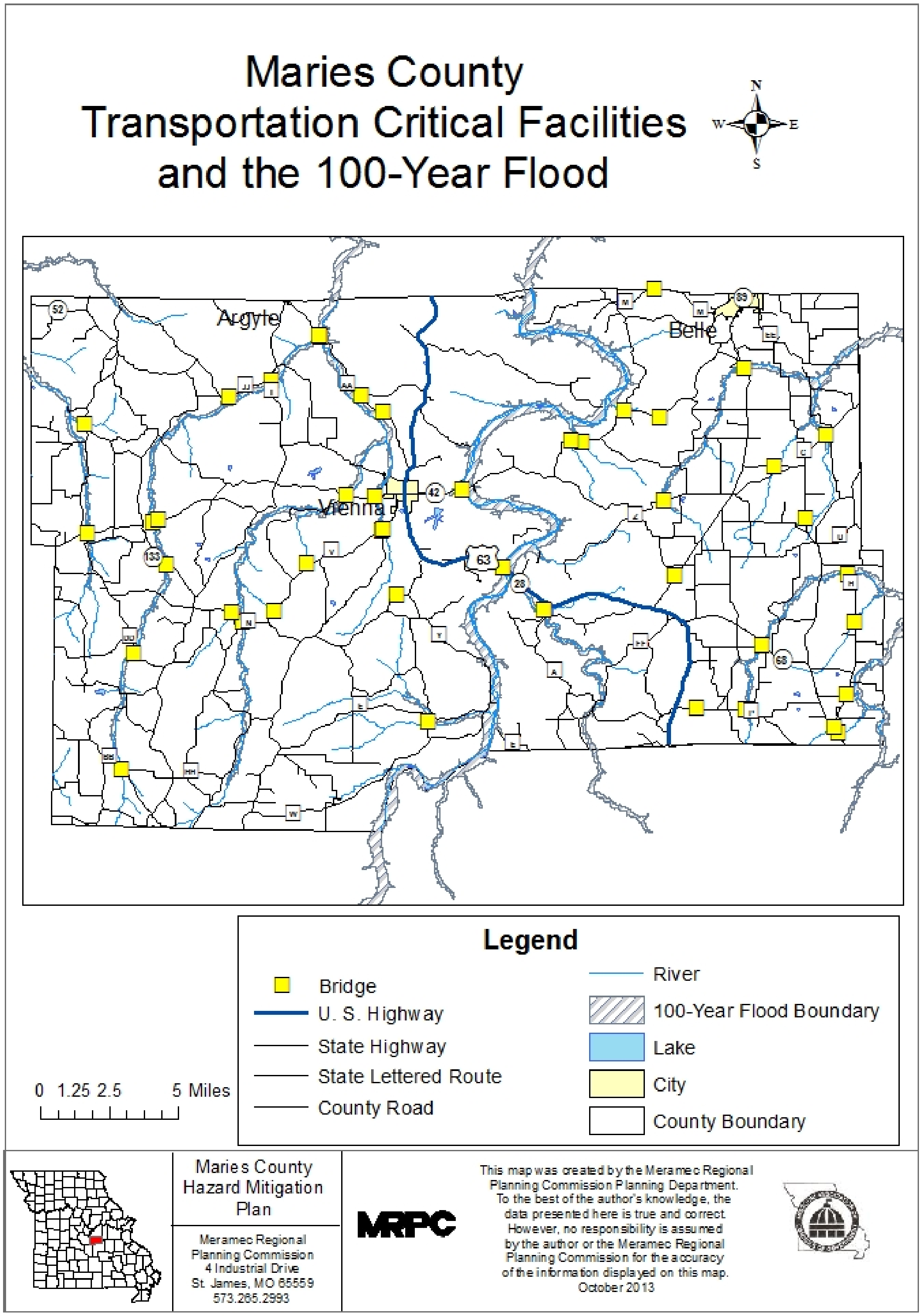
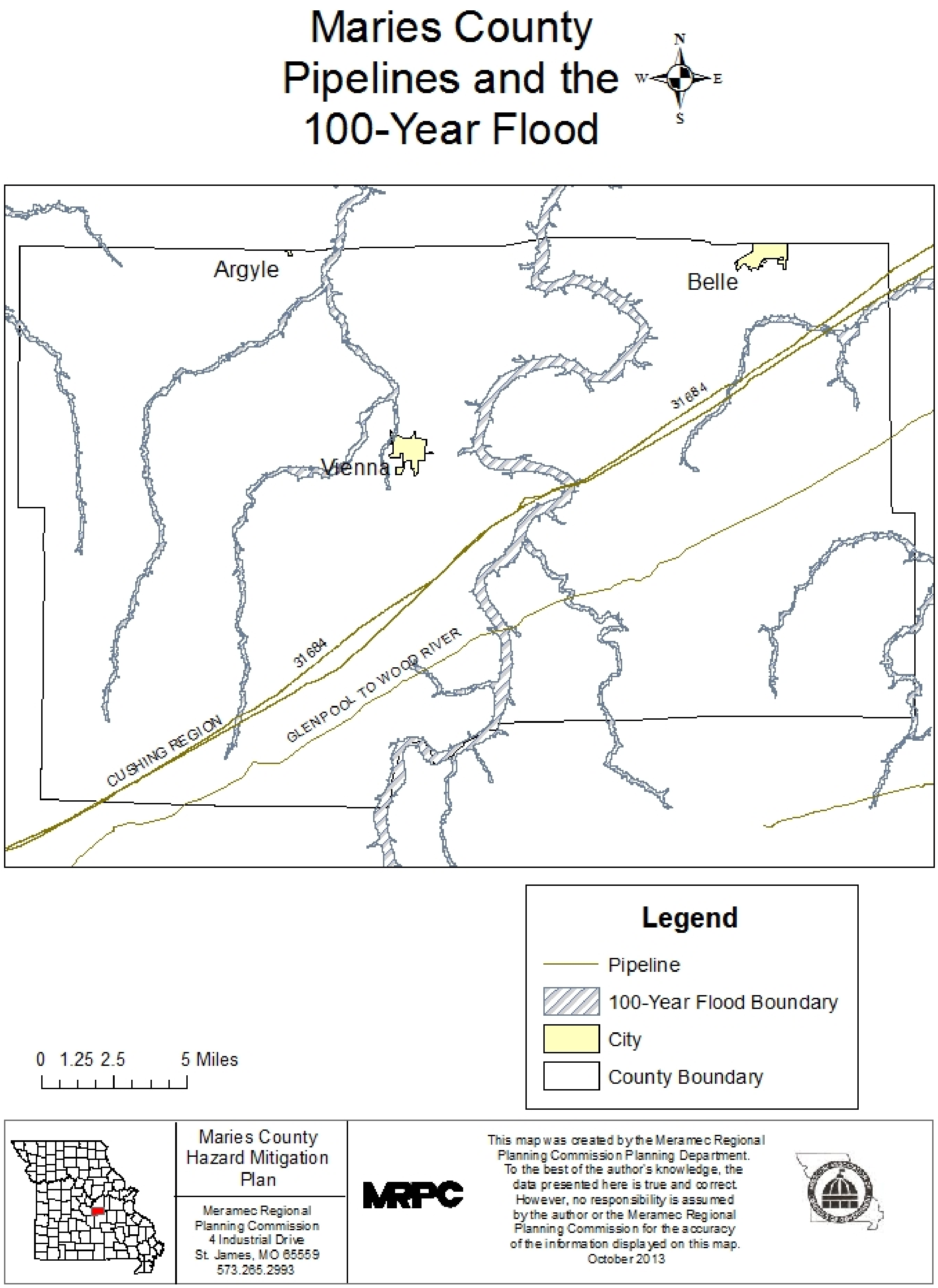

Maries County
Transportation Critical Facilities
and the 100-Year Flood
N
W
E
S
Argyle
Belle
Vienna
Legend
Bridge
U. S. Highway
State Highway
State Lettered Route
County Road
River
100-Year Flood Boundary
Lake
City
County Boundary
0 1.25 2.5 5 Miles
Maries County Hazard Mitigation Plan
Meramec Regional Planning Commission
4 Industrial Drive
St. James, MO 65559
573.265.2993
MRPC
This map was created by the Meramec Regional Planning Commission Planning Department.
To the best of the author's knowledge, the data presented here is true and correct.
However, no responsibility is assumed by the author or the Meramec Regional Planning Commission for the accuracy of the information displayed on this map.
October 2013

Figure 3-23



Maries County
Pipelines and the
100-Year Flood
N
S
E
W
Argyle
Belle
Vienna
31684
CUSHING REGION
GLENPOOL TO WOOD RIVER
Legend
Pipeline
100-Year Flood Boundary
City
County Boundary
0 1.25 2.5 5 Miles
Maries County Hazard Mitigation Plan
Meramec Regional Planning Commission
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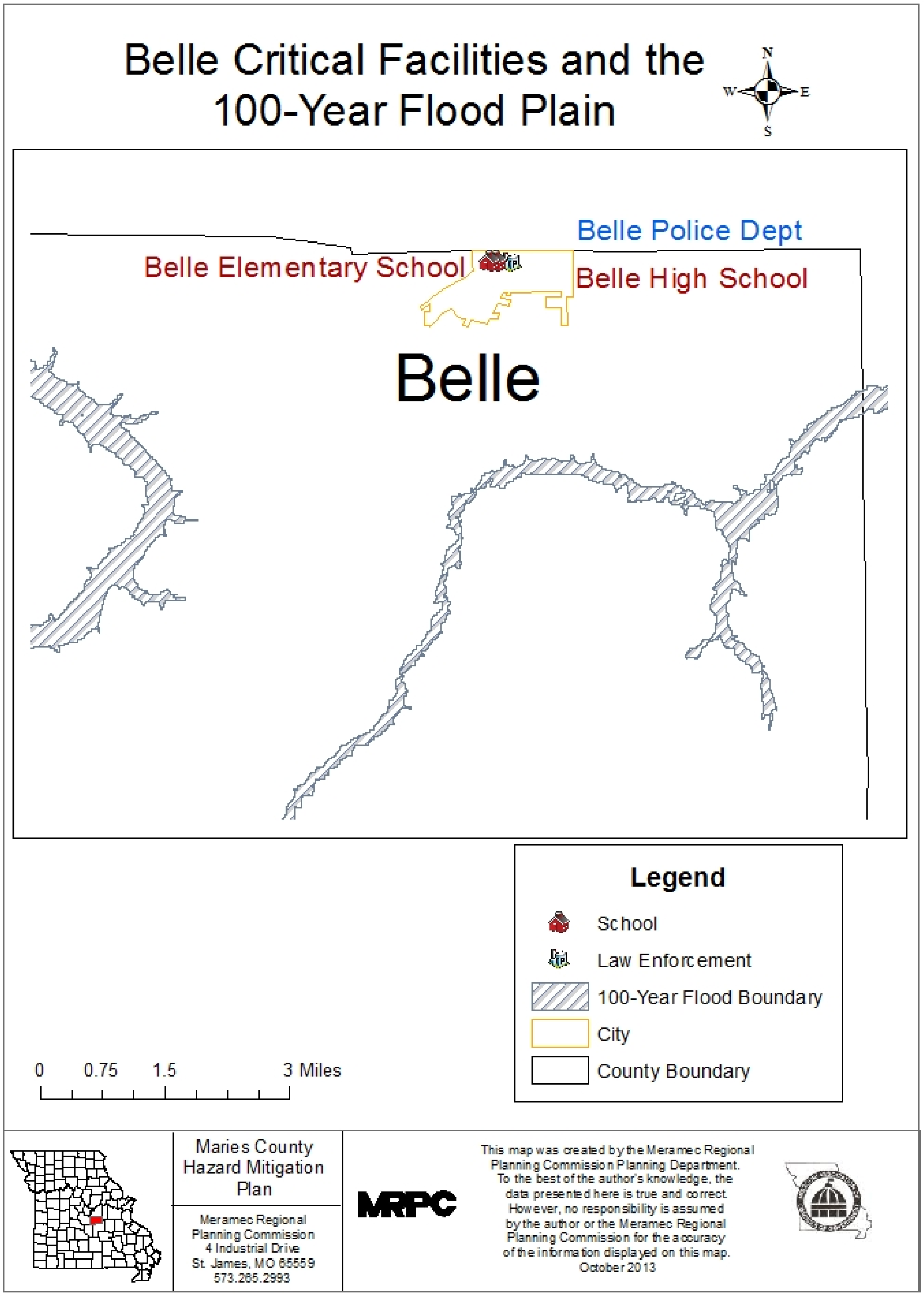
Figure 3-24



Belle Critical Facilities and the 100-Year Flood Plain
N
W
E
S
Belle Police Dept
Belle Elementary School
Belle High School
Belle
Legend
School
Law Enforcement
100-Year Flood Boundary
City
County Boundary
0 0.75 1.5 3 Miles
Maries County Hazard Mitigation Plan
Meramec Regional Planning Commission
4 Industrial Drive
St. James, MO 65559
573.265.2993
MRPC
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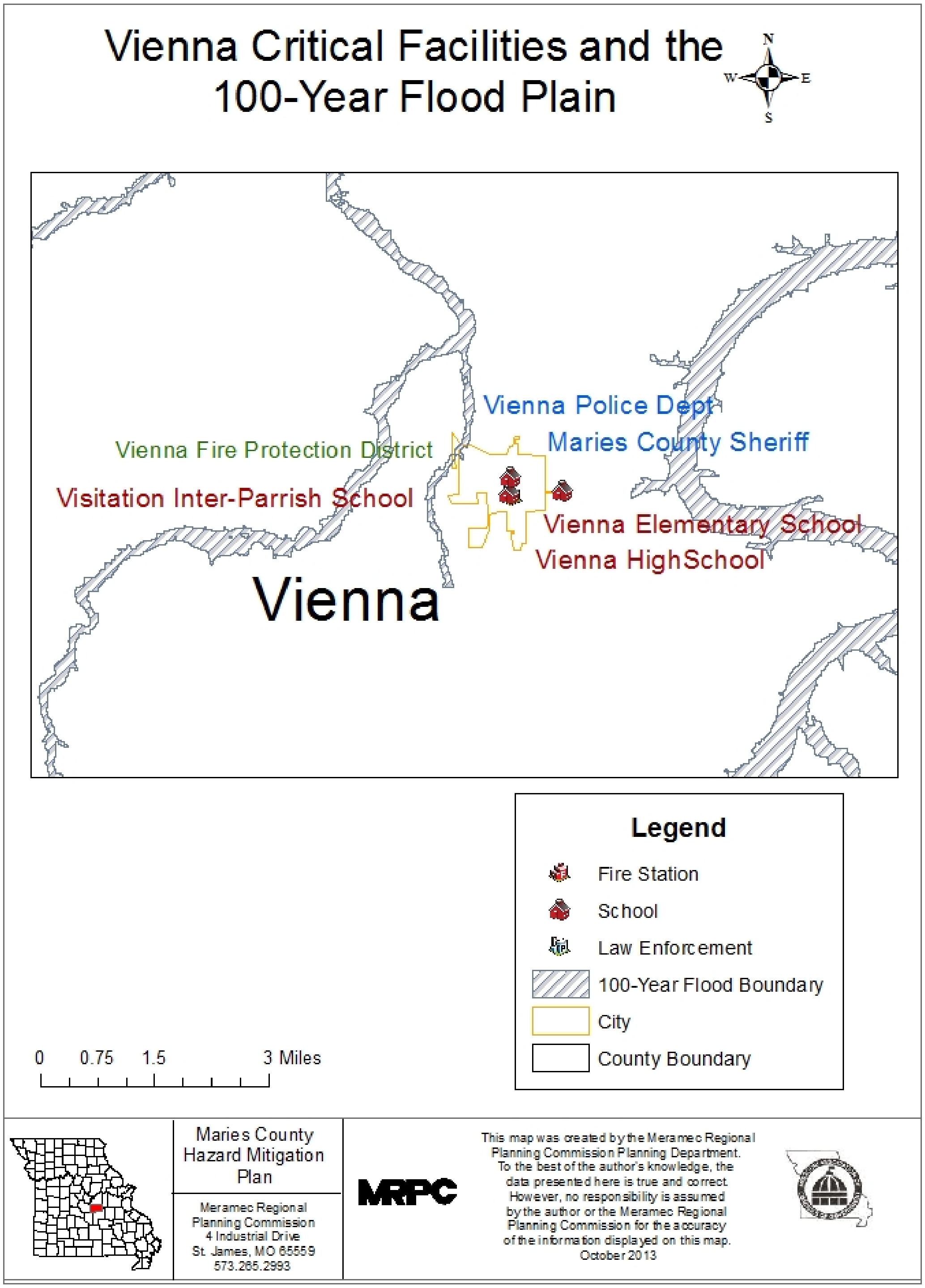
Figure 3-25


Vienna Critical Facilities and the
100-Year Flood Plain
N
W
E
S
Vienna Police Dept
Maries County Sheriff
Vienna Fire Protection District
Visitation Inter-Parrish School
Vienna Elementary School
Vienna HighSchool
Vienna
Legend
Fire Station
School
Law Enforcement
100-Year Flood Boundary
City
County Boundary
0
0.75
1.5
3 Miles
Maries County
Hazard Mitigation
Plan
Meramec Regional
Planning Commission
4 Industrial Drive
St. James, MO 65559
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MRPC
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Dam Failure Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: Low. Due to insufficiencies in the available data, it is not possible to provide detailed information on the construction types and values of structures that might be affected by this hazard. As discussed under the probability and magnitude sections of the profile for this hazard (Section 3.2.2), this hazard was rated as Low for all of the jurisdictions. Although there are six dams in the county rated as high hazard by the Missouri Department of Natural Resources, there has never been a dam failure in the county and there is very little development that would be affected if a dam should fail. During the vulnerability assessment it was determined that the city of Vienna was slightly more vulnerable to damage from dam failure than other jurisdictions due to the location of a dam just outside of the city limits Failure of this dam could cause damage to one or more streets, and nearby properties– but because a dam failure would still affect less than 10 percent of the communities buildings and infrastructure – it was scored the same as the rest of the jurisdictions. There have been no incidents of dam failure, nor of injuries or property damage. The majority of the dams are located in rural, undeveloped areas. For these reasons dam failure was given a low planning priority rating and it has been determined that Maries County and its jurisdictions are not vulnerable to significant damage from dam failure.

In regards to future development, the county does not have a planning and zoning to regulate development, so the only recourse is to educate the public on the dangers of dam failure and discourage future development in hazard prone areas. The city of Vienna has the potential for damage from a dam failure and should consider limiting additional development in those areas that might be affected by the failure of the dam located just outside of the community.

Drought Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: Low. As discussed under the probability and magnitude sections of the profile for this hazard (Section 3.2.3), historically, drought has not had a significant impact on Maries County or the jurisdictions located in the county. Drought is not a hazard that would typically result in damage to structures or infrastructure. The probability for drought in the area is low due to geographic location and historic weather patterns and due to high quality groundwater resources drought is not considered a significant threat to the area. The threat of drought would have no effect on future development in Maries County or its jurisdictions.

Earthquake Vulnerability

Overview

Planning significance: Moderate. As discussed under the probability and magnitude sections of the profile for this hazard (Section 3.2.4), there is a risk from earthquakes, but due to the distance to the nearest significant fault lines and the nature of the area's geology, it is expected that damage would be negligible. The HAZUS scenario provided by SEMA uses a 7.7 magnitude earthquake – which is significant. Although the HAZUS scenario shows damage to buildings in Maries County, there will be little impact to critical infrastructure and no effect on the functionality of critical services. Damage will impact less than 10 percent of building stock. The greater significance will likely be the disruption of transportation and communications based on damage in southeast Missouri and the impact of evacuations from affected areas and staging of response and aid.

Methodology

FEMA's software programs for estimating potential losses from disasters, HAZUS-MH was used to generate a scenario of a magnitude 7.7 earthquake occurring on the New Madrid Fault. Once the earthquake scenario was generated, the software uses census-block level population and building and infrastructure inventory data to estimate damage and the number of people potentially displaced by the event. Although the damage estimates created seem significant, when compared to building stock values, the damage is still less than 10 percent and so considered negligible.

Estimated Potential Losses to Existing Development

It is highly unlikely that even a major earthquake in southeast Missouri would cause more than negligible damage in Maries County. According to the Modified Mercalli Scale, the earthquake would likely be felt by most residents and they might experience the movement of some heavy furniture and fallen plaster. Damage to existing development would be slight.

HAZUS data was the best available data, but the reports generated for Maries County were strikingly different from the reports generated for surrounding counties and so there may be a problem with the data. The damaged building counts produced by HAZUS may be rounded and sometimes have errors that can be associated with the use of census block data for analysis. The

The HAZUS generated reports estimated that 920 structures in the county could have up to moderate damage, with 39 buildings damaged beyond repair. The expected damage by occupancy is illustrated in Table 3.26.

According to HAZUS, a 7.7 magnitude quake would result in $8.8 million in structural building damages, or a little over one percent of the total building stock value for the county ($851 million). HAZUS does not provide a breakdown of estimated building losses by jurisdiction. Table 3.27 provides an estimate of building losses by jurisdiction assuming that losses would be equal across the county and two cities.

Table 3.26 Estimated Building Damage Count by Occupancy

Building Type	No Damage	Slight Damage	Moderate Damage	Extensive Damage	Complete Damage	Totals
Agriculture	13	8	10	5	1	37
Commercial	51	34	35	15	4	139
Education	2	1	1	0	0	4
Government	6	4	4	1	0	15
Industrial	13	9	10	5	1	38
Residential	2618	1,125	621	170	32	4,566
Religion	7	3	3	1	0	14
Total	2,710	1,184	685	198	39	4,816

Source: HAZUS-MH

Table 3.27 Estimated Earthquake Losses by Jurisdiction *(Millions of Dollars)*

Jurisdiction	Building Damage (structural and non-structural)	Contents Damage	Inventory Damage	Relocation Damage	Capital Related Loss	Rental Income Loss	Wage Loss	Total	% of Total
Unincorporated Maries County	$27.24	$6.92	$.26	$4.23	$0.71	$1.30	$1.15	$41.81	78%
Belle	$5.93	$1.51	$0.06	$0.92	$0.15	$0.28	$0.25	$9.10	17%
Vienna	$1.76	$0.45	$0.01	$0.27	$0.05	$0.09	$0.08	$2.71	5%
TOTAL	$34.93	$8.88	$0.33	$5.42	$0.91	$1.67	$1.48	$53.62	100%

Source: HAZUS-MH

Total economic losses for Maries County in the 7.7 magnitude earthquake scenario are estimated at $53.62 million, with $4.06 million in losses related to income, wage and rental income losses.

Based on the HAZUS reports, critical facilities would not be heavily damaged and there would be little if any interruption of critical services. The report estimated that three bridges in the county might sustain damage but would remain functional. In regards to potential population displacement, the report indicated that as many as 22 households might be displaced and of this number, 13 might seek temporary shelter in public shelters.

Future Development

It is anticipated that the threat of earthquake would have no effect on future development in Maries County, although it would benefit local governments to include earthquake resilience in building codes if they are not already incorporated.

Extreme Heat Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: High. The entire planning area is susceptible to the hazards associated with extreme heat. The most vulnerable portions of the population are people age 65 and over and those who live in poverty. The elderly are often more prone to suffering from heat related illness. People living at or below the poverty line often cannot afford air conditioning. Based on information from the 2010 U.S. Census, estimates shown in Table 3.28 compares the percentage of persons over age 65 and the percentage of persons below the federal poverty line living in Maries County and its jurisdictions to averages for Missouri and the United States.

Table 3.28 Maries County Demographic and Economic Characteristics (2011)

Jurisdiction	2010 Population*	Age 65 and Over (%)*	Individuals Below the Poverty Level (%)**
United States	308,745,538	13.0	13.8
Missouri	5,988,927	14.0	14.0
Maries County	9,176	18.0	14.3
Belle	1,545	21.5	32.4
Vienna	610	12.4	12.6

**Source: 2010 U. S. Census*
***Source: www.city-data.com (2009 estimates)*

The City of Belle has a higher than average percentage of people over the age of 65 as well as as individuals living below the poverty level. According to the 2010 U.S. Census, the average rate of poverty in Missouri is 15 percent, with a national average of 14.9 percent. The City of Vienna's poverty rate is slightly below the average, as is the County overall, while Belle's poverty rate is considerably higher. Both of these populations are vulnerable to the effects of heat waves. The power grid in Maries County is vulnerable to brown outs or outages during periods of high use associated with extreme heat when the use of air conditioning places additional stress on the power distribution system.

Potential Losses to Existing Development

Extreme heat does not generally have an impact on infrastructure or property and it is difficult to identify specific hazard areas. Stress on livestock and crops are also likely effects of severe heat, but are also difficult to quantify.

Long term care facilities for the elderly and disabled are especially vulnerable to extreme heat events. These facilities are listed in Table 3.23 in Section 3.3.2. The power distribution system is also known to be at risk during extreme heat events; however, there is little data to estimate potential financial losses as a result of power failure during these types of events. Extended power failures certainly have a negative impact on economic activities in the affected areas, but power outages associated with extreme heat are generally brown outs or short term power losses.

Future Development

A growing population increases the number of people vulnerable to extreme heat events. New development also increases the stress on the existing power distribution system. In the past ten years there has been growth in both development and population in areas in Maries County. It is anticipated that growth will continue at a slow but steady level into the future.

Landslide Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: Low. Due to insufficiencies in the available data, it is not possible to provide detailed information on the types and values of structures that might be affected by this hazard. As discussed under the magnitude section of the profile for this hazard (Section 3.2.7), historically, landslides have not had a significant impact on Maries County or the jurisdictions located within the county. The threat of a landslide causing damage in this area is very low due to the nature of the geology and soil types. As there has been only one recorded landslide in the county or its communities, and it resulted in negligible damage and no injuries, and the probability for damage from this hazard is very low, landslides are not considered a significant threat to the area. The threat of landslides would have no effect on future development in Maries County.

Land Subsidence/Sinkhole Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: Low. As discussed under the past history and magnitude sections of the profile for this hazard (Section 3.2.8), although there are some sinkholes in Maries County, there are no recorded incidents of sinkhole collapse that caused injury or property damage. All of the sinkholes are located in rural areas of the county. The potential for this hazard certainly exists, but based on history and analysis, it is not considered a significant threat to the area. The threat of land subsidence/sinkholes would have no effect on future development in Maries County.

Severe Storms Hail/Wind Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: High. The entire county and all of its jurisdictions are vulnerable to severe storms, including hail and wind storms. Assets that are likely to incur the most damage from either of these types of severe storms are built structures. Crops are also at risk but row cropping is not widespread in Maries County and is mainly limited to bottomlands. Large hail and strong winds can damage crops and result in major crop losses. Structural damage that can occur with either wind or hail damage includes damage to roofs, siding and windows. But as all of this type of damage is generally covered under private insurance policies, data on the extent of these losses is not available.

Personal injury is also a potential threat during severe storms from lightening, windblown debris and large diameter hailstones.

Potential Losses to Existing Development

According to data from the National Climatic Data Center (NCDC), from 1957 through 2013, Maries County reported a total of $122,000 in property damage from severe storm winds. There was $5,000 in damages reported attributed to hail. Most of the property damage caused from storms is covered by private insurance and data is not available. As stated earlier, most damage from these types of storms occurs to vehicles, roofs, siding and windows and cost data is not available for property damage covered by private insurance.

Based on CPRI scores and the rating system used determine magnitude of impact, which includes percentages for damage, we can estimate the number of buildings that might be impacted by severe storms for each jurisdiction. Using HAZUS data, the census tracts were separated out to get the building counts for each jurisdiction.

Damage counts in the following tables are based on the magnitude score given to each jurisdiction and applying the corresponding estimated percentage of damage to the total building count. As the percentage of damage is expressed in a range (i.e. 10 to 25 percent), a range is provided for the maximum damage estimate and the minimum damage estimate. Numbers have been rounded to the nearest whole number. All of the jurisdictions rated the magnitude for severe storms/wind/hail as negligible – less than 10 percent of property severely damaged. All damage estimates have been figured using nine percent and one percent. School district properties are included in the city and county tables, however, separate tables were developed for each school district based on nine percent and one percent damage to the total number of school buildings as provided by each school district. Due to the smaller number of buildings involved, a percentage of damage is shown and numbers have not been rounded for school districts in order to provide a clearer picture of estimated damage.

Table 3.29 Estimated Damaged Building Count for Belle - Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	733	66	7
Commercial	38	3	0
Industrial	6	1	0
Agricultural	2	0	0
Religion	6	1	0
Government	3	0	0
Education	2	0	0
Total	790	71	7

Source: HAZUS-MH

Table 3.30 Estimated Damaged Building Count for Vienna - Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	224	20	2
Commercial	28	3	0
Industrial	4	0	0
Agricultural	4	0	0
Religion	2	0	0
Government	7	1	0
Education	3	0	0
Total	272	24	2

Source: HAZUS-MH

Table 3.31 Estimated Damaged Building Count for Maries County - Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	3,565	321	36
Commercial	74	7	1
Industrial	28	3	0
Agricultural	31	3	0
Religion	7	1	0
Government	6	1	0
Education	0	0	0
Total	3,711	336	36

Source: HAZUS-MH

Table 3.32 Estimated Damaged Building Count for Maries County R-I School District - Storms

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number/Percentage of Buildings Damaged With 1% Minimal Damage
2	.18	.02

Source: www.dese.mo.gov/directory

Table 3.33 Estimated Damaged Building Count for Maries County R-I School District - Storms

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
3	.27	.03

Source: www.dese.mo.gov/directory

Future Development

Development trends in Maries County are not likely to increase vulnerability to this type of hazard.

Severe Winter Storm Vulnerability of Maries County and Jurisdictions

Overview

Planning Significance: High. All of Maries County is vulnerable to the effects of winter storms. During periods of heavy snow or ice transportation can be extremely hazardous. The most significant damage from winter storms is accumulating ice. Freezing rain and drizzle collects on utility lines and supporting poles and can cause the collapse of this infrastructure. This results in widespread power outages. As these storms occur during cold weather, the population that loses power also becomes vulnerable to the cold as heating systems are often dependent upon electricity. As with extreme heat events, the elderly are considered to be more vulnerable to injury or death during these types of disasters.

Potential Losses to Existing Development

Homes and businesses with trees are more vulnerable to damage from winter storms, not only to utility lines but to the structures themselves. Falling trees and limbs can cause considerable damage to property and injury or death to occupants. Power distribution infrastructure is the most vulnerable and the most critical during these types of storms. Downed power lines can cause electrocution of unwary residents or even power company employees. Emergency responders can be hampered in their response by treacherous or impassable roads. Power outages can impact local economies if businesses are not able to stay open. Another hazard that frequently occurs during power outages is carbon monoxide related injuries or death due to the improper use of alternate heating or cooking sources.

Based on CPRI scores and the rating system used to determine magnitude of impact, which includes percentages for damage, we can estimate the number of buildings that might be impacted by severe winter storms for each jurisdiction. Using HAZUS data, the census tracts were separated out to get the building counts for each jurisdiction.

Damage counts in the following tables are based on the magnitude score given to each jurisdiction and applying the corresponding estimated percentage of damage to the total building count. As the percentage of damage is expressed in a range (i.e. 10 to 25 percent), a range is provided for the maximum damage estimate and the minimum damage estimate. Numbers have been rounded to the nearest whole number. All of the jurisdictions rated the magnitude for severe winter storms as negligible – less than 10 percent of property severely damaged. All damage estimates have been figured using nine percent and one percent. School district properties are included in the city and county tables, however, separate tables were developed for each school district based on nine percent and one percent damage to the total number of school buildings as provided by each school district. Due to the smaller number of buildings involved, a percentage of damage is shown and numbers have not been rounded for school districts in order to provide a clearer picture of estimated damage.

Table 3.34 Estimated Damaged Building Count for Belle – Winter Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	733	66	7
Commercial	38	3	0
Industrial	6	1	0
Agricultural	2	0	0
Religion	6	1	0
Government	3	0	0
Education	2	0	0
Total	790	71	7

Source: HAZUS-MH

Table 3.35 Estimated Damaged Building Count for Vienna – Winter Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	224	20	2
Commercial	28	3	0
Industrial	4	0	0
Agricultural	4	0	0
Religion	2	0	0
Government	7	1	0
Education	3	0	0
Total	272	24	2

Source: HAZUS-MH

Table 3.36 Estimated Damaged Building Count for Maries County – Winter Storms

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	3,565	321	36
Commercial	74	7	1
Industrial	28	3	0
Agricultural	31	3	0
Religion	7	1	0
Government	6	1	0
Education	0	0	0
Total	3,711	336	36

Source: HAZUS-MH

Table 3.37 Estimated Damaged Building Count for Maries County R-I School District – Winter Storms

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number/Percentage of Buildings Damaged With 1% Minimal Damage
2	.18	.02

Source: www.dese.mo.gov/directory

Table 3.38 Estimated Damaged Building Count for Maries County R-I School District – Winter Storms

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
3	.27	.03

Source: www.dese.mo.gov/directory

Future Development

Future development could potentially increase risk through the addition of utility lines that would increase exposure of these systems.

Tornado Vulnerability of Maries County and Jurisdictions

Overview

Planning Significance: Low. Based on the history of frequency and severity of tornados in Maries County, this hazard was ranked as a low risk due to the few number of tornados that have occurred in the last 50 plus years; relative low cost of damages caused; and no deaths. As with all weather related hazards, the entire county and all of its jurisdictions are vulnerable to tornados. According to the NCDC, a total of six tornados have occurred in Maries County between 1957 and 2014. Total damages were $5.1275 million during the 57 year period. Of that total, $5 million was caused by one tornado event in July of 2008 when it caused damage at the Rolla Regional Airport. No one has been killed by a tornado and there has been one tornado related injury in the county.

Warning time for tornados can be relatively short. Children, the elderly and the disabled are all more vulnerable to this type of hazard because of the speed of the onset. There is a need for additional storm shelters/safe rooms in Maries County that can provide protection for residents and in particularly vulnerable populations. There are a number of residences in the area that do not have basements or cellars and several schools have identified the construction of tornado safe rooms as a high priority.

Potential Losses to Existing Development

Maries County has never experienced a tornado greater than an F2. Two tornados were classified as F1 and two were F0. Historical data statewide supports the possibility of a large tornado occurring, and safe rooms/storm shelters should be constructed to provide protection during the most severe of tornados. Of the six recorded events, three resulted in damages costing $25,000 or less. One had damages of $75,000. One tornado caused $5 million in damages and one resulted in no damage in the county. If the total losses are averaged over the 57 year period, the annual cost of tornados in Maries County is $89,956.00.

Based on CPRI scores and the rating system used determine magnitude of impact, which includes percentages for damage, we can estimate the number of buildings that might be impacted by tornados for each jurisdiction. Using HAZUS data, the census tracts were separated out to get the building counts for each jurisdiction.

Damage counts in the following tables are based on the magnitude score given to each jurisdiction and applying the corresponding estimated percentage of damage to the total building count. As the percentage of damage is expressed in a range (i.e. 10 to 25 percent), a range is provided for the maximum damage estimate and the minimum damage estimate. Numbers have been rounded to the nearest whole number. All of the jurisdictions rated the magnitude for tornados as negligible – less than 10 percent of property severely damaged. All damage estimates have been figured using one percent and nine percent. School district properties are included in the city and county tables, however, separate tables were developed for each school district based on one percent and nine percent damage to the total number of school buildings as provided by each school district. Due to the smaller number of buildings involved, a percentage of damage is shown and numbers have not been rounded for school districts in order to provide a clearer picture of estimated damage.

Table 3.39 Estimated Damaged Building Count for Belle - Tornado

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	733	66	7
Commercial	38	3	0
Industrial	6	1	0
Agricultural	2	0	0
Religion	6	1	0
Government	3	0	0
Education	2	0	0
Total	790	71	7

Source: HAZUS-MH

Table 3.40 Estimated Damaged Building Count for Vienna - Tornado

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	224	20	2
Commercial	28	3	0
Industrial	4	0	0
Agricultural	4	0	0
Religion	2	0	0
Government	7	1	0
Education	3	0	0
Total	272	24	2

Source: HAZUS-MH

Table 3.41 Estimated Damaged Building Count for Maries County - Tornado

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	3,565	321	36
Commercial	74	7	1
Industrial	28	3	0
Agricultural	31	3	0
Religion	7	1	0
Government	6	1	0
Education	0	0	0
Total	3,711	336	36

Source: HAZUS-MH

Table 3.42 Estimated Damaged Building Count for Maries County R-I School District - Tornado

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number/Percentage of Buildings Damaged With 1% Minimal Damage
2	.18	.02

Source: www.dese.mo.gov/directory

Table 3.43 Estimated Damaged Building Count for Maries County R-I School District - Tornado

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
3	.27	.03

Source: www.dese.mo.gov/directory

Future Development

Future development projects, particularly those that serve vulnerable populations such as children and the elderly, should consider tornado hazards in the planning and construction phase of development. New construction of schools and nursing homes should make safe rooms a priority.

Wildfire Vulnerability of Maries County and Jurisdictions

Overview

Planning significance: High for unincorporated areas of Maries County; Moderate for all cities; and Low for all school districts. As discussed under the past history and magnitude sections of the profile for this hazard (Section 3.2.11), historically there have been 853 fires reported between January 1, 1990 and January 1, 2014. The total acreage burned from those incidents was 3,328.75 acres. Two outbuildings were damaged and one outbuilding was destroyed by these fires. Fortunately there were no reported deaths or injuries from these fires. Due to the rural nature of the county and the sizeable expanse of Missouri Department of Conservation lands, this hazard should be considered a high priority. For the cities in the county, the risk is somewhat lower. Wildfires are detected more quickly and response time by fire departments is typically faster in populated areas. The planning significance for cities was considered moderate. As the school districts have their buildings located in populated areas, in or adjacent to communities, and because the schools have relatively small number of buildings, the risk to school districts was considered to be low.

Potential Losses to Existing Development

In a rural, wooded region like Maries County, there is certainly potential for damage to existing development. The trend toward developing subdivisions outside of incorporated areas in isolated rural areas contributes to the potential for damage to property from wildfires. Historically, considering the large number of wildfires reported, Maries County has had little property damage from this hazard, but the potential exists.

Based on CPRI scores and the rating system used determine magnitude of impact, which includes percentages for damage, we can estimate the number of buildings that might be impacted by wildfires for each jurisdiction. Using HAZUS data, the census tracts were separated out to get the building counts for each jurisdiction.

Damage counts in the following tables are based on the magnitude score given to each jurisdiction and applying the corresponding estimated percentage of damage to the total building count. As the percentage of damage is expressed in a range (i.e. 10 to 24 percent), a range is provided for the maximum damage estimate and the minimum damage estimate. Numbers have been rounded to the nearest whole number. All of the jurisdictions rated the magnitude for wildfire – less than 10 percent of property severely damaged. All damage estimates have been figured using nine percent and one percent. School district properties are included in the city and county tables, however, separate tables were developed for each school district based on nine percent and one percent damage to the total number of school buildings as provided by each school district. Due to the smaller number of buildings involved, a percentage of damage is shown and numbers have not been rounded for school districts in order to provide a clearer picture of estimated damage.

Table 3.44 Estimated Damaged Building Count for Belle - Wildfire

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	733	66	7
Commercial	38	3	0
Industrial	6	1	0
Agricultural	2	0	0
Religion	6	1	0
Government	3	0	0
Education	2	0	0
Total	790	71	7

Source: HAZUS-MH

Table 3.45 Estimated Damaged Building Count for Vienna - Wildfire

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	224	20	2
Commercial	28	3	0
Industrial	4	0	0
Agricultural	4	0	0
Religion	2	0	0
Government	7	1	0
Education	3	0	0
Total	272	24	2

Source: HAZUS-MH

Table 3.46 Estimated Damaged Building Count for Maries County - Wildfire

Occupancy	Total Building Count	Estimated Number of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
Residential	3,565	321	36
Commercial	74	7	1
Industrial	28	3	0
Agricultural	31	3	0
Religion	7	1	0
Government	6	1	0
Education	0	0	0
Total	3,711	336	36

Source: HAZUS-MH

Table 3.47 Estimated Damaged Building Count for Maries County R-I School District - Wildfire

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number/Percentage of Buildings Damaged With 1% Minimal Damage
2	.18	.02

Source: www.dese.mo.gov/directory

Table 3.48 Estimated Damaged Building Count for Maries County R-I School District - Wildfire

Total Building Count	Estimated Number/Percentage of Buildings Damaged With 9% Worst Case Damage	Estimated Number of Buildings Damaged With 1% Minimal Damage
3	.27	.03

Source: www.dese.mo.gov/directory

Future Development

New development, particularly residential or commercial buildings that are located outside of incorporated areas and farther from fire services, should consider fire suppressive landscaping and other measures to reduce vulnerability. Residents should be educated on the dangers of wildfire and provided information on how to make their property less vulnerable.

3.3.4 Future Land Use and Development

Table 3.49 shows the changes in population for Maries County and its jurisdictions.

Table 3.49 Historic Population Trends for Maries County and Jurisdictions

Jurisdiction	Maries County	Belle	Vienna
2010 Population % Change	9,176 3.1	1,545 15	610 -2.9
2000 Population % Change	8,903 11.6	1,344 10.3	628 2.8
1990 Population % Change	7,976 5.6	1,218 -1.2	611 18.9
1980 Population % Change	7,551 10.2	1,099 -3	514 1.8
1970 Population % Change	6,851 -5.9	1,133 11.5	505 -5.8
1960 Population % Change	7,282 -1.9	1,016 12.1	536 13.8
1950 Population % Change	7,423 -14.1	906 45.9	471 -8.7

Source: U.S. Census Bureau

According to the Missouri Office of Administration, Division of Budget and Planning, the population for Maries County is projected to grow slightly over the next 20 years at a rate of 2.7 to 3.0 per decade. Much of the growth since 1970 can be attributed to growth in adjacent Phelps County and the nearby state capitol of Jefferson City. Belle has seen significant growth over the past two decades – 10.3 percent in the 2000 Census and 15 percent in the 2010 Census. Vienna’s population has remained fairly constant since 1990. Maries County is the smallest county by population in the Meramec Region, but overall the county continues to see steady, though slow growth.

3.3.5 Summary of Key Issues

In comparison to the 2006 Hazard Mitigation plan, no significant changes have been made to the vulnerability assessment other than providing a more in-depth study, analysis and incorporating additional data and hazards. The general premise and outcomes remain largely the same with additional and updated information and clarification provided for all hazards. A more in-depth method of scoring and ranking the hazards was used in the plan revision. Table 3.50 shows the results of the Hazard Ranking in order of High to Low Planning Significance based on the methodology described in section 3.1.

Table 3.50 Maries County Hazard Ranking High to Low Planning Significance

Hazard Type	Probability	Magnitude	Warning Time	Duration	CPRI	Planning Priority
Dam Failure	1	1	4	3	1.65	Low
Drought	1	1	1	4	1.3	Low
Earthquake	2	1	4	4	2.05	Moderate
Extreme Heat	4	3	1	3	3.15	High
Flood -Maries Co. -Belle Vienna Maries R-I Maries R-II	 4 4	 2 2	 4 4	 3 2	 3.0 2.9	 High High
Land Subsidence/ Sinkholes	1	1	4	3	1.45	Low
Severe Storm (Hail storm/Wind storm)	4	1	4	1	3.0	High
Tornado	1	2	4	1	1.75	Low
Severe Winter Storm	4	1	1	3	2.55	High
Wildfire – County Cities Schools	4 3 1	1 1 1	4 4 4	2 2 2	2.9 2.45 1.55	High Moderate Low

Sources: Maries County hazard mitigation planning committee, Missouri Hazard Mitigation Plan (2007), Missouri Hazard Analysis (2008)

The HMPC will focus efforts for hazard mitigation projects on those hazards that have a High or Moderate planning priority ranking. The following section highlights key issues brought out by the risk assessment.

Flood

- The City of Belle does not currently participate in the National Flood Insurance Program.
- Homes and businesses throughout the county and in all of the communities have been impacted by riverine or flash flooding
- Several roads, bridges and low water crossings in the county are vulnerable to flooding, including state highways 42 and 63. Highway 63 is the main north south

route through the region. Detours around the Gasconade River bridge on Highway 63 can be time consuming. Shutdowns typically last two or three days and can have a significant impact on travel in and through the area.
- A number of homes that flooded in the past did not have flood insurance.
- There are a number of low water bridges in the county that could be mitigated
- There are a number of vulnerable properties that could be considered for flood buyouts.

Severe Storm Hail Storm/ Wind Storm
- Severe storms can damage power lines through sheer force of wind or windblown debris such as tree limbs
- Mobile homes and other unsecured buildings such as carport awnings and sheds are vulnerable to windstorms
- Roofs are frequently damaged by wind and/or hail

Earthquake
- The New Madrid Fault has the potential to cause catastrophic damage to eastern and southeast Missouri
- Although Maries County is not located in an area that will likely see catastrophic damage from an earthquake, the area will be impacted by loss of communications, transportation disruption of roads, rail and pipelines and the likely flow of refugees out of the impacted area and response going into the impacted region

Extreme Heat
- Stress on the power distribution system can lead to brown outs or power outages
- Need to identify and publicize cooling centers
- Elderly populations and those living below the poverty line are especially vulnerable. All of the communities in Maries County have a higher than average percentage of people over the age of 65 and higher than average percentage of individuals living below the poverty level.

Severe Winter Storm
- Ice accumulation damages power lines and power infrastructure causing prolonged power outages for large portions of the region
- Roads become hazardous for motorists and emergency responders
- Schools and businesses close due to power outages and poor travel conditions

Tornado
- Maries County has had an average cost of approximately $90,000 per year from tornado events and one documented injury.
- Mobile homes and unsecured structures such as carport awnings and sheds are particularly vulnerable
- Public may not be aware of the locations of shelters
- May need to increase the number of weather shelters and publicize their availability
- Not all schools, public buildings or other facilities serving vulnerable populations may have adequate safe rooms

Wildfire

- Maries County has frequent wildfires and is considered high risk for wildfire. Those areas of the county where population and vegetation densities are greater are at higher risk of property damage and potential for injuries should a wildfire occur.
- Belle and Vienna are all considered to be at moderate risk for wildfire
- Homes and businesses located in unincorporated areas are at higher risk from wildfires due to proximity to woodland and distance from fire services
- Although the magnitude of a wildfire may be lessened in the incorporated areas due to the proximity to fire services, they are not exempt from the dangers of wildfires.

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[i] United States Geological Survey. Damage Evaluation of the Taum Sauk Reservoir Failure using LiDAR. http://mcgsc.usgs.gov/publications/t_sauk_failure.pdf
[ii] The Alert. Spring 2006. After the Deluge…What's Ahead for Taum Sauk? By Dan Sherburne.
[iii] Ibid.
[iv] United States Geological Survey Fact Sheet 131-02. October 2002
[v] Missouri State Hazard Mitigation Plan, May 2007
[vi] United States Geological Survey Fact Sheet 131-02. October 2002
[vii] Ibid.
[viii] Missouri Department of Natural Resources, Water Resources Center, website: http://www.dnr.mo.gov/env/wrc/damsft/Crystal-Reports/crawford_dams.pdf
[ix] United States Geological Survey Fact Sheet 131-02. October 2002
[x] National Drought Mitigation Center. http://www.drought.unl.edu/whatis/concept.htm
[xi] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xii] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xiii] Ibid.
[xiv] National Oceanic and Atmospheric Administration. http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
[xv] Missouri State Hazard Mitigation Plan 2013
[xvi] National Drought Mitigation Center. http://www.drought.unl.edu/whatis/concept.htm
[xvii] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xviii] National Disaster Education Coalition. http://www.disastercenter.com/missouri/heat.html
[xix] United States Geological Survey. http://neic.usgs.gov/neis/general/handouts/mercalli.html
[xx] Missouri State Hazard Mitigation Plan May 2007
[xxi] United States Geological Survey. http://neic.usgs.gov/neis/states/missouri/missouri_history.html
[xxii] Missouri State Hazard Mitigation Plan May 2007
[xxiii] United States Geological Survey Fact Sheet 131-02. October 2002
[xxiv] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xxv] Ibid.
[xxvi] National Weather Service. http://weather.noaa.gov/weather/hwave.html
[xxvii] Missouri State Hazard Mitigation Plan, May 2007
[xxviii] Ibid.
[xxix] Ibid.
[xxx] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xxxi] Ibid.
[xxxii] http://ga.water.usgs.gov/edu/earthgwlandsubside.html
[xxxiii] Ibid.
[xxxiv] Missouri Department of Natural Resources, Missouri Resources Magazine, Spring/Summer 2003 – Volume 20, Number 1, *That Sinking Feeling – a Void, A Collapse*, by Jim Van Dyke
[xxxv] Ibid.
[xxxvi] Ibid.
[xxxvii] Midwest Lakes Policy Center. http://blog.midwestlakes.org

[xxxviii] Missouri Department of Natural Resources, Missouri Resources Magazine, Spring/Summer 2003 – Volume 20, Number 1, *That Sinking Feeling – a Void, A Collapse*, by Jim Van Dyke
[xxxix] Missouri Department of Natural Resources. http://www.dnr.mo.gov/env/wrc/springsandcaves.htm
[xl] Sinkhole.org. http://www.sinkhole.org/CommonSigns.php
[xli] Missouri Department of Natural Resources, Missouri Resources Magazine, Spring/Summer 2003 – Volume 20, Number 1, *That Sinking Feeling – a Void, A Collapse*, by Jim Van Dyke
[xlii] Midwest Lakes Policy Center. http://blog.midwestlakes.org
[xliii] National Disaster Education Coalition. http://www.disastercenter.com/missouri/tornado.html
[xliv] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xlv] National Disaster Education Coalition. http://www.disastercenter.com/guide/thunder.html
[xlvi] National Disaster Education Coalition. http://www.disastercenter.com/guide/tornado.html
[xlvii] Missouri Hazard Analysis, State Emergency Management Agency, August 1999.
[xlviii] National Oceanic and Atmospheric Administration. http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms
[xlix] Missouri State Hazard Mitigation Plan, 2013
[l] Ibid.
[li] Ibid.
[lii] Ibid.
[liii] Ibid.
[liv] Missouri Department of Conservation.
[lv] Ibid.
[lvi] Ibid.
[lvii] Missouri Hazard Analysis. State Emergency Management Agency. 1999.
[lviii] Missouri Department of Health and Senior Services, Show Me Childcare, http://ccregu.dhss.mo.gov/smcc/pnpCCSearch
[lix] Missouri Department of Health and Senior Services, http://www.dhss.mo.gov/cgi-bin/nhomes2.pl?facid=15510
[lx] Missouri Department of Health and Senior Services, http://www.dhss.mo.gov/NursingHomes/ADC-licensed.pdf
[lxi] Missouri Department of Elementary and Secondary Education, http://dese.mo.gov/directory
[lxii] Region I Homeland Security Oversight Committee and American Red Cross lists of shelters