ANNEX A

TORNADOES AND SEVERE THUNDERSTORMS (DOWNBURSTS, LIGHTNING, HAIL, HEAVY RAINS, WIND)

I. TYPE OF HAZARD

Tornadoes and Severe Thunderstorms (Downbursts, Lightning, Hail, Heavy Rains, Wind).

II. DESCRIPTION OF HAZARD

Tornadoes are cyclical windstorms often associated with the midwestern areas of the United States. Weather conditions conducive to tornadoes often produce a wide range of other dangerous storm activities, including severe thunderstorms, downbursts, straight-line winds, lightning, hail, and heavy rains. For the purpose of this analysis, tornadoes are considered in one category. Other severe weather activities, noted above, are referenced separately in the Synopsis section of this annex (see Part VI).

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

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

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

The average forward speed of a tornado is 30 miles per hour but may vary from nearly stationary to 70 miles per hour. The average tornado moves from southwest to northeast, but tornadoes have been

known to move in any direction. Tornadoes are most likely to occur in the afternoon and evening, but have been known to occur at any hour of the day or night.

Tornadoes are classified according to the F- Scale (developed by Dr.Theodore Fujita, a renowned severe storm researcher). The F- Scale attempts to rank tornadoes according to wind speed based on the damage caused (Table A-1).

TABLE A-1

FUJITA TORNADO DAMAGE SCALE

SCALE	WIND SPEED**(MPH)	TYPICAL DAMAGE
F0	<73	Light damage: Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; signboards damaged.
F1	73-112	Moderate damage: Surface peeled off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable damage: Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe damage: Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown some distance.
F4	207-260	Devastating damage: Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown, and large missiles generated.
F5	261-318	Incredible damage: Strong frame houses leveled off foundations and swept away; automobile-sized missiles propelled through the air more than 100 meters (109 yards); trees debarked; incredible phenomena will occur.

Notes:

Developed in 1971 by T. Theodore Fujita of the University of Chicago.

**Do not use F-scale wind speeds literally. These wind speed numbers are actually estimates and have never been scientifically verified. Different wind speeds may cause similar damage from place to place – even from building to building. Without a thorough engineering analysis of tornado damage in any event, the actual wind speeds needed to cause that damage are unknown.

The National Weather Service, 2003

TABLE A-2

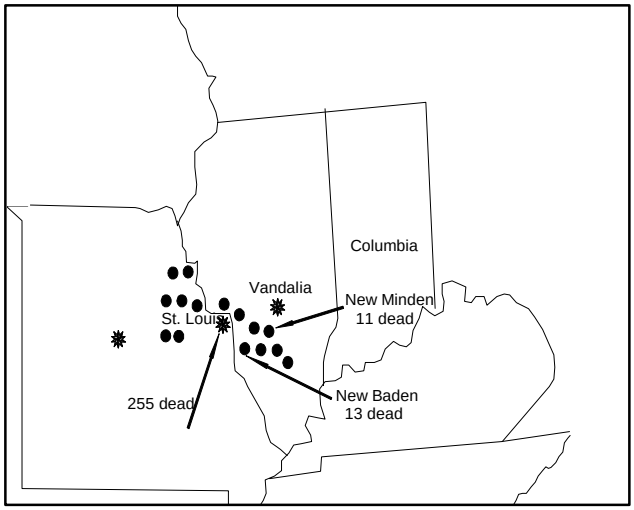
MISSOURI TORNADOES BY F-SCALE, 1950-1996

SCALE	PERCENTAGE
F0	47
F1	24
F2	16
F3	12
F4	1
F5	0

III. HISTORICAL STATISTICS

Historically, the State of Missouri has experienced numerous tornadoes of varied intensities. On May 27, 1896, between the hours of 2 and 8 p.m., a series of 18 tornadoes known as the "St. Louis, Missouri, Outbreak" struck Missouri and Illinois. These tornadoes resulted in 306 deaths and $15 million in damages (see Figure A-1).

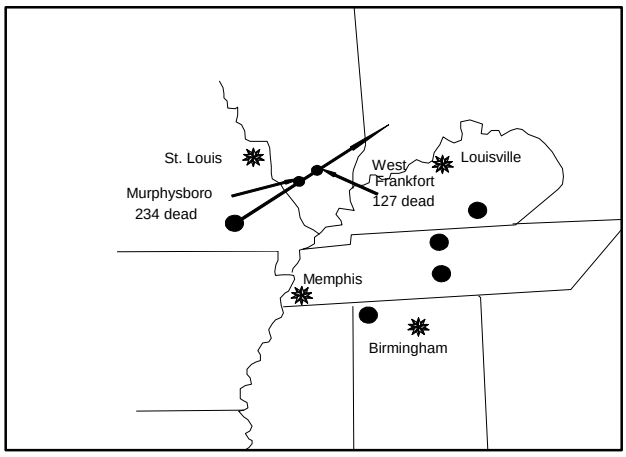
Figure A-1
St. Louis, Missouri, Tornado Outbreak



The National Weather Service reported that 1400 tornadoes had occurred in Missouri from 1950 to 2002, with 160 deaths and over $900 million in damages. This averages 26 tornadoes per year and 3 deaths per year.

The worst tornado in U. S. history, in terms of deaths and destruction, occurred in Missouri on March 18, 1925, between 1 and 6 p.m. (see Figure A-2). The great "tri-state" tornado originated in Reynolds County. It proceeded east-northeast through the southern quarter of Illinois and into Indiana, covering 219 miles. It caused over $18 million in damage, affected six states, and killed 689 persons.

Figure A-2
The Great Tri-State Tornado of 1925

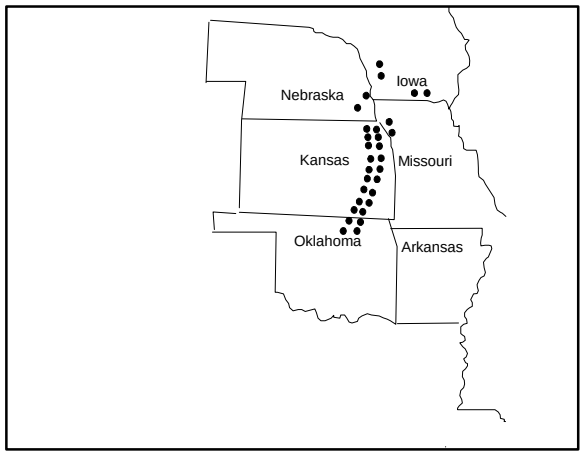


The City of Poplar Bluff, Missouri, was almost wiped out by a tornado on May 9, 1927. This tornado cost 92 lives and $2 million in damages. The same day, two severe tornadoes struck St. Louis, Missouri. The first tornado moved across the entire city from the western city limits to the Mississippi River through the Lafayette Park area, killing 306 people in Missouri and Illinois and causing almost $13 million in damages. The second tornado started in the southwestern part of the city and proceeded through the Tower Grove

and Vanderventer areas, then on to Granite City, Illinois. Seventy-nine people were killed, and about $23 million in damages resulted from this storm.

During the afternoon and evening of April 3, and the early morning of April 4, 1974, a "super outbreak" of 148 tornadoes across 13 states killed more than 300 people, injured more than 6,000 and caused $600 million in damages (see Figure 3).

Figure A-3
The Tornado Super Outbreak in 1974

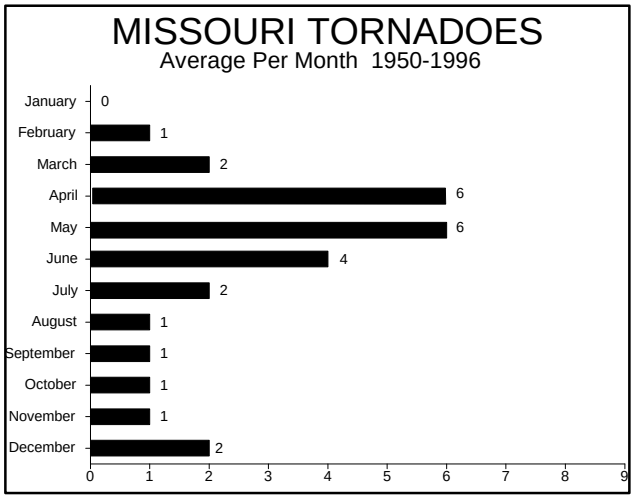


On the afternoon of April 26, and the early morning of April 27, 1991, an outbreak of 54 tornadoes covering six states, including Missouri, resulted in 21 deaths, 308 injuries, and damages exceeding $277 million. There were two deaths in vehicles and 15 deaths in and near mobile homes.

On July 4, 1995, at approximately 5:40 p.m., a tornado struck the Randolph County community of Moberly. The initial touchdown of the storm was south of town. The storm then moved through the eastern half of the community. The tornado uplifted approximately 7 miles northeast of Moberly. At least 15 people were injured, 25 businesses damaged, along with the courthouse, and some 300 families affected. This resulted in a Small Business Administration disaster declaration for low interest loans. The tornado was characterized by the National Weather Service as a class F3 tornado.

Figure A-4

Figure A-4 shows that tornadoes in Missouri occur most frequently between April and June, with April and May usually producing the most tornadoes. However, tornadoes can occur any time of the year, such as the storms that struck in St. Charles and Barry Counties in November 1988.



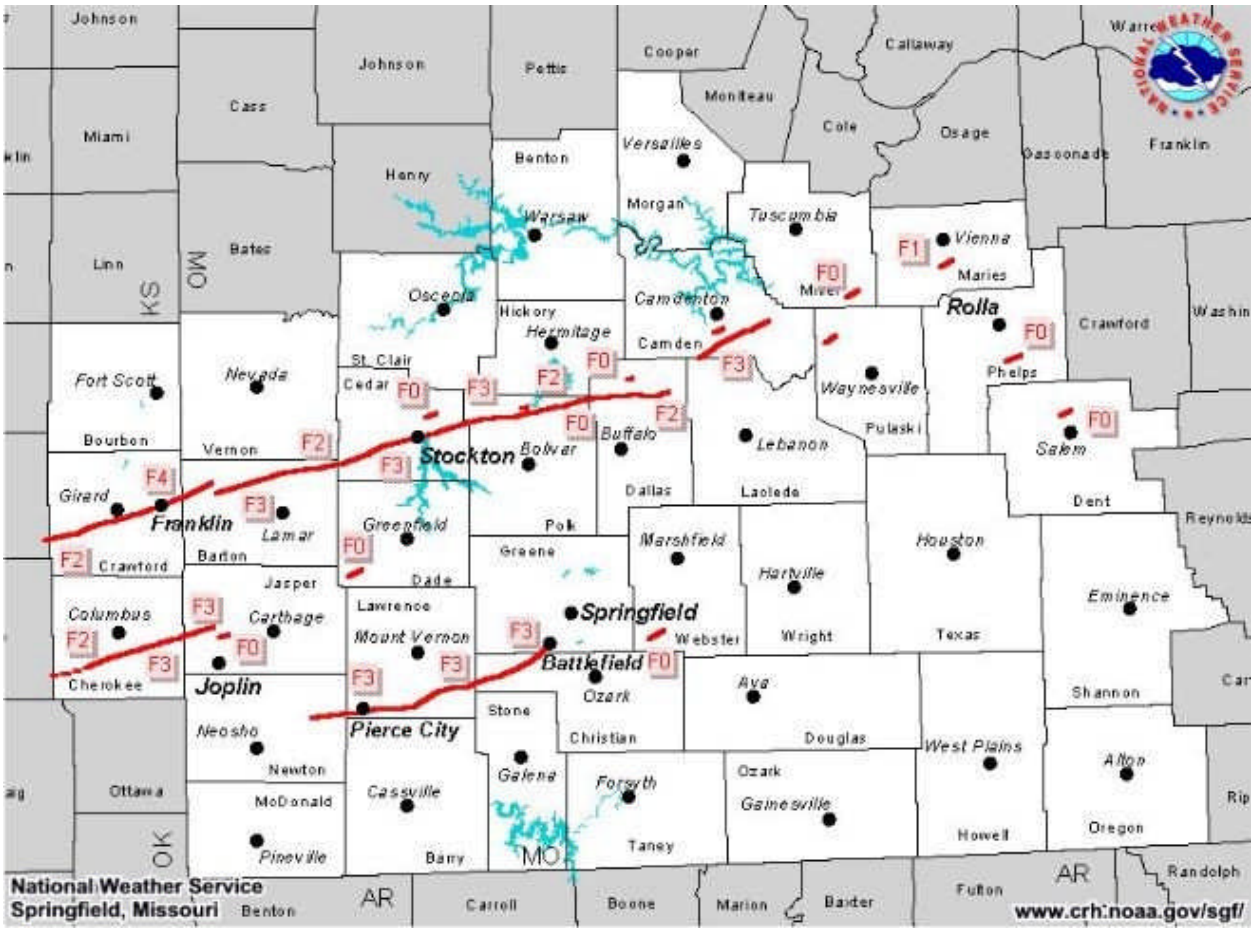


Figure A-5 Map of the May 4, 2003 Tornadoes

A record 84 tornadoes were recorded in Missouri in 2003. During the week of May 4, 2003, 79 of those tonadoes occurred and mostly in the southwest portion of Missouri. There were several f$ tornadoes which occurred on May 4 in Platt, Clay and Barton counties. Their were nineteen people killed by the tornadoes in Southwest Missouri. That is the highest total since 1959 when 21 were killed. It is only the fourth year in which double digit deaths from tornadoes occurred in Missouri since 1950. The killer tornadoes all occurred on May 4th, The tornados which hit Newton, Lawrence, Christian and Greene counties killed 7 people. Five people were killed by a tornado which hit cedar and Dallas counties. A tornadoe which hit Camden county killed 4 people, Two people died from a tornado in Japser county and one person died in Barton County. The tornadoes injured 171 people. That is the highest total since 310 were injured in 1957. See map in Figure A-4. This information provided by the NWS.

For a listing of Missouri tornadoes that resulted in federal disaster declarations since 1975, see Table A-3 in Section VII.

IV. MEASURE OF PROBABILITY AND SEVERITY

The United States has 10 times more tornadoes than any other nation in the world. Missouri averages 26 tornadoes per year, and has recorded 1,400 tornadoes from 1950 through 2002. Missourians have a high probability that tornadoes will continue to affect their lives. The natural phenomena that create tornadoes will continue to occur beyond our ability to control them.

The enormous power and destructive capability of tornadoes are beyond mankind's capabilities to control. The potential severity of effects from tornadoes will continue to be high. We will continue to experience deaths, injuries, and property damages from tornadoes. However, technological advances will facilitate earlier warnings than previously available. This, combined with a vigorous public education program and improved construction techniques, provides the potential for significant reductions in the number of deaths and injuries, as well as reduced property damage.

V. IMPACT OF THE HAZARD

Every tornado is a potential killer, and many are capable of great destruction. Tornadoes 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 tornado winds. In 1975, a Mississippi tornado carried a home freezer for more than a mile. Once, a tornado in Broken Bow, Oklahoma, carried a motel sign 30 miles and dropped it in Arkansas. Tornadoes do their destructive work through the combined action of their strong rotary winds and the impact of windblown debris. In the most simple case, the force of the tornado's winds push 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.

VI. SYNOPSIS

Tornadoes are usually associated with severe thunderstorms, which by themselves, possess destructive potential. Such storms most often occur in the spring and summer, during the afternoon and evenings, but can occur at any time. In addition to tornadoes, other hazards associated with thunderstorms include the following:

- Damaging winds
- Lightning and resulting fires
- Hail
- Heavy rains causing flash flooding.

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.

In May 1996, a Memorial Day weekend storm identified by the National Weather Service as a microburst caused more than $10 million in damage to homes in Lee’s Summit, Missouri. The storm destroyed at least 13 homes and damaged more than 100 others in several Lee’s Summit subdivisions. The city also incurred a substantial cost for debris removal and cleanup activities resulting from this devastating storm.

Damaging straight-line winds are high winds across a wide area that can reach speeds of 140 miles per hour. 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. In addition, lightning kills 75 to 100 people each year. During the period of 1992 through 1996, seven people died in Missouri as a result of lightning strikes, compared to two deaths from tornadoes during the same period. The thunderstorms associated with tornado development also contribute to the number one weather killer–flash floods. Flash flooding causes 146 deaths annually throughout the nation. During the period from 1992 through 2002, flooding and flash floods claimed the lives of 60 Missourians. Thunderstorms and severe winds claimed five lives over this same period.

VII. MAPS OR OTHER ATTACHMENTS

The following charts and maps depict additional Missouri tornado information, generally for the period between 1950 and 2000:

- Disaster Declarations For Missouri Tornadoes Since 1975: Table A-3
- Missouri Tornadoes by County, Top Twenty-Five, 1950-2003: Figure A-5
- Missouri Tornadoes by County, 1950-2003: Figure A-6
- Missouri Tornado Deaths by County, Top Ten, 1950-2003: Figure A-7
- Missouri Tornado Deaths by County, 1950-2003: Figure A-8
- Missouri Tornado Statistics, 1950-2002: Table A-4
- Spring 2003 Tornados: Table A-9
- Spring 2004 Tornado: Table A-10

TABLE A-3

DISASTER DECLARATIONS FOR MISSOURI TORNADOES SINCE 1975

DATE	INCIDENT TYPE	COUNTIES DECLARED	TYPE OF ASSISTANCE
May 3, 1975	Tornadoes, High Winds, Hail	Caldwell, Newton, Macon, Shelby	PA & IA
May 7, 1977	Tornadoes, Flooding	Carroll, Clay, Lafayette, Ray, Cass, Jackson, Pettis	PA & IA
May 15, 1980	Severe Storms, Tornadoes	Pettis	IA Only
May 1986	Tornadoes	Scott, Mississippi, Cape Girardeau, Perry	SBA Loans
November 1988	Tornadoes	St. Charles, Barry	SBA Loans
July 1995	Tornadoes	Randolph, (City of Moberly)	SBA Loans
May 6, 2003	Tornadoes, Severe Storms, Flooding	Barry, Barton, Bates, Benton, Bollinger, Buchanan, Camden, Cape, Cass, Cedar, Christian, Clay, Clinton, Cooper, Crawford, Dade, Dallas, Dent, Douglas, Franklin, Knox, Gasconade, Girardeau, Greene, Henry, Hickory, Iron, Jackson, Jasper, Jefferson, Johnson, Laclede, Lafayette, Lawrence, McDonald, Miller, Monroe, Morgan, Newton, Osage, Perry Pettis, Phelps, Platte, Polk, Pulaski, Ray, St. Francois, St. Louis, Sainte Genevieve, Saline, Scott, St. Clair, Stoddard, Stone, Taney, Vernon, Washington, Webster	IA
May 6, 2003	Tornadoes, Severe Storms, Flooding	Bollinger, Crawford, Franklin, Gasconade, Knox, Maries, Miller, Oregon, Osage, Pulaski, Washington	PA
June 10, 2004	Tornadoes, Severe Storms, Flooding	Adair, Andrew, Bates, Benton, Caldwell, Carroll, Cass, Cedar, Chariton, Clay, Clinton, Daviess, DeKalb, Gentry, Grundy, Harrison, Henry, Hickory, Jackson, Johnson, Knox, Linn, Livingston, Macon, Mercer, Monroe, Nodaway, Platte, Polk, Randolph, Ray, Shelby, St. Clair, Sullivan, Vernon, and Worth	IA

Notes:

IA Individual Assistance
PA Public Assistance
SBA Small Business Administration

FIGURE A-5

MISSOURI TORNADOES BY COUNTY
TOP TWENTY-FIVE – 1950-2003

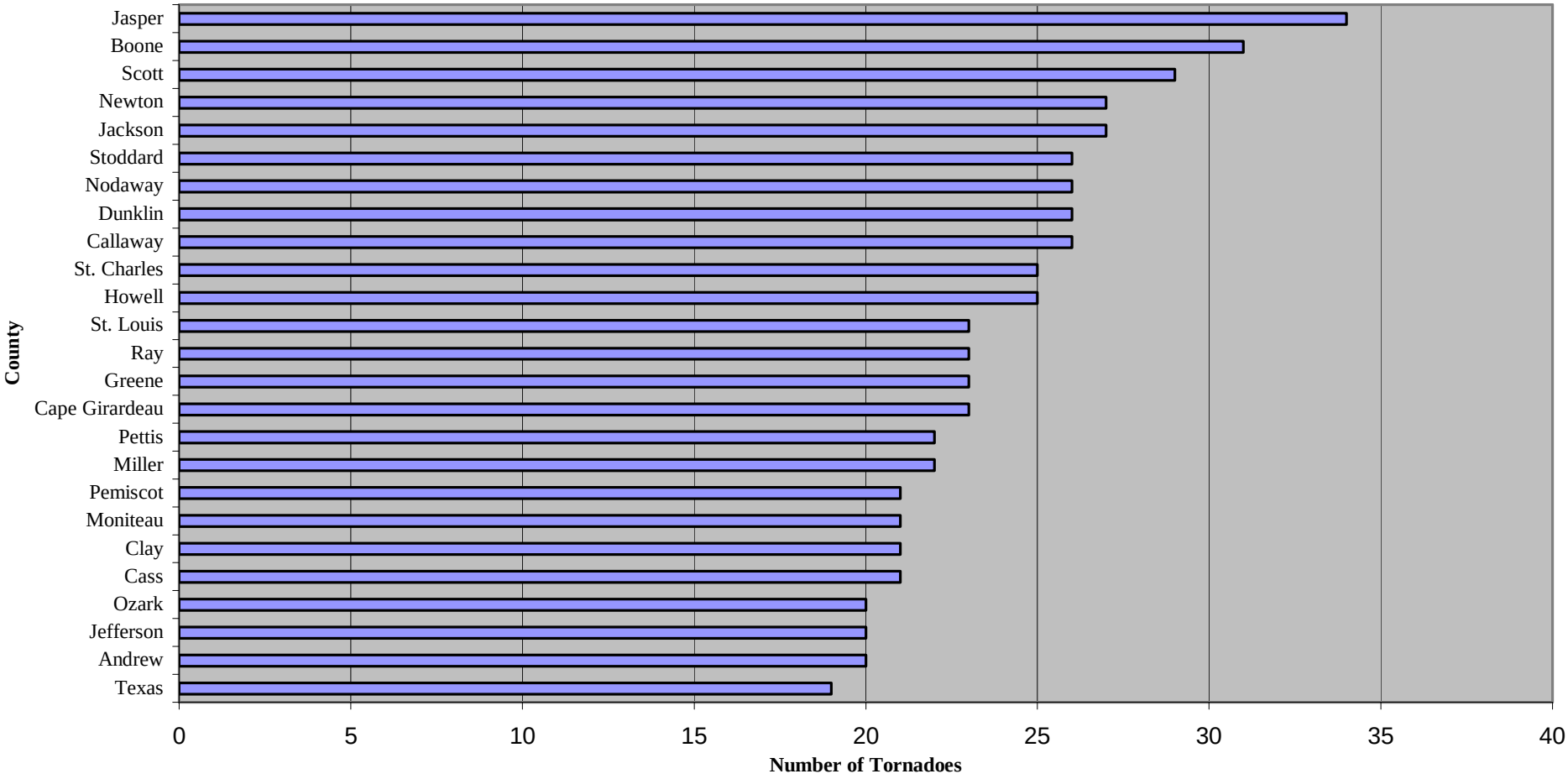


FIGURE A-6

MISSOURI TORNADOES BY COUNTY (1950-2003)

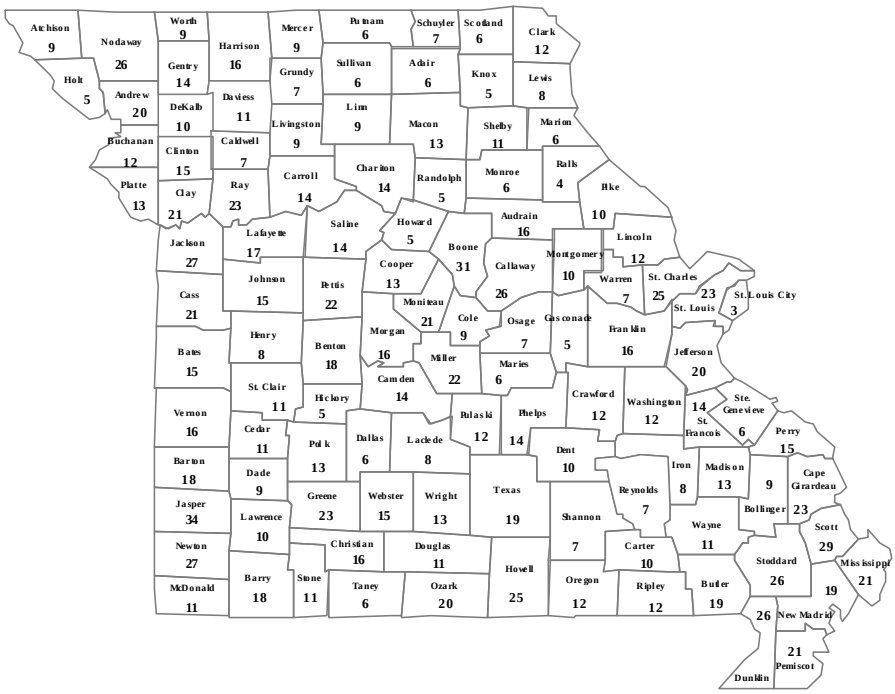


FIGURE A-7

MISSOURI TORNADO DEATHS BY COUNTY
TOP TEN 1950-2003

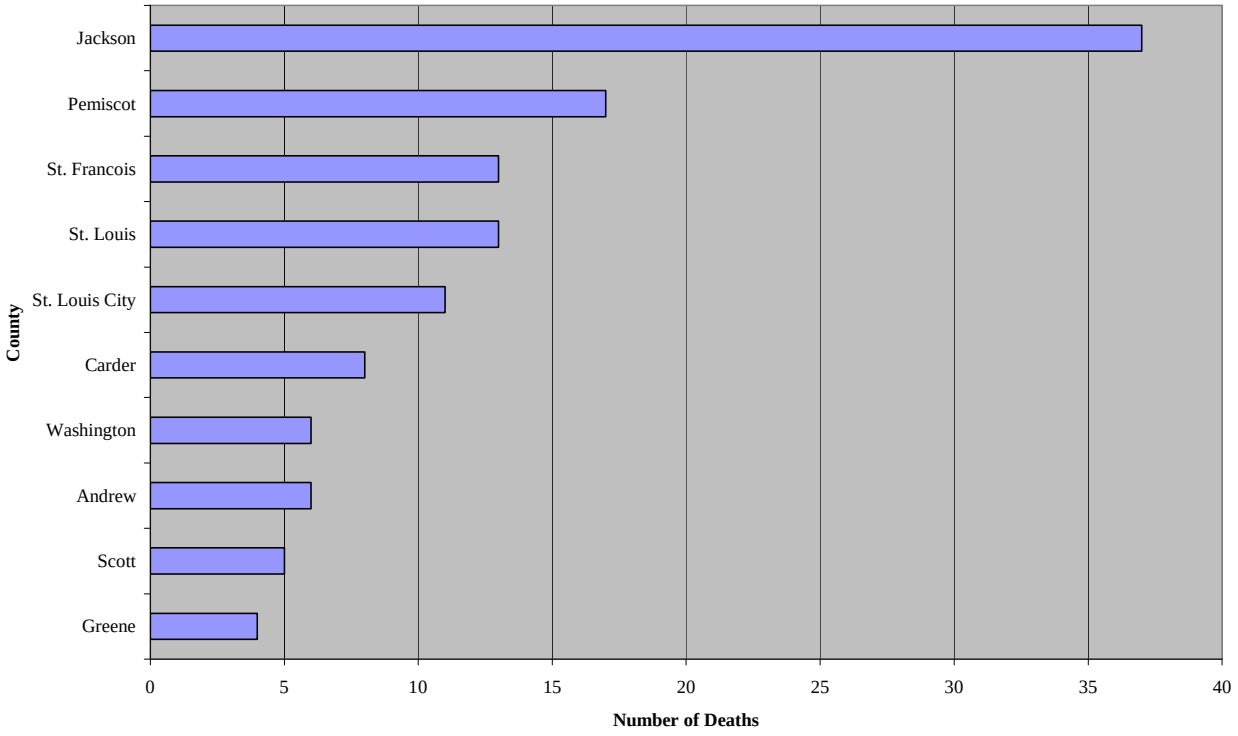


FIGURE A-8

MISSOURI TORNADO DEATHS BY COUNTY (1950-2003)

TABLE A-4

MISSOURI TORNADO STATISTICS
1950 – 2004

Total Number of Tornadoes	1,553
Total Number of Deaths	186
Total Number of Injuries	2,551
Yearly Average of Tornadoes	28
Yearly Average of Deaths	3
Yearly Average of Injuries	46
Tornado Deaths 1916 - 2004	773

FIGURE A-9

SPRING 2003 TORNADOS

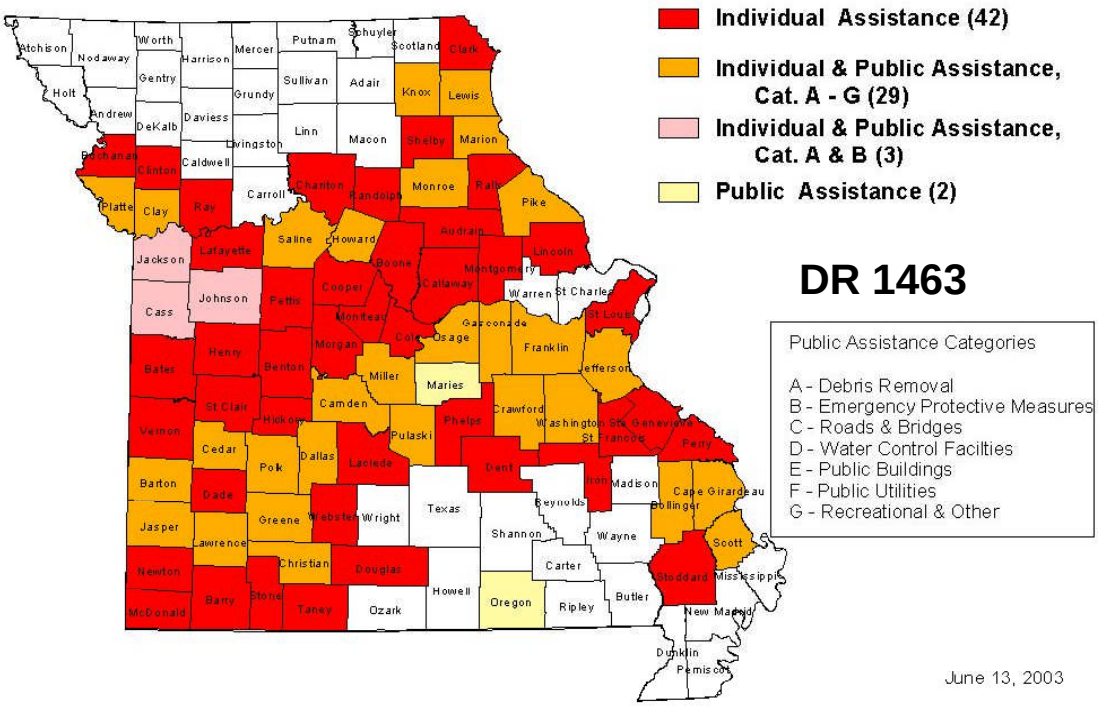
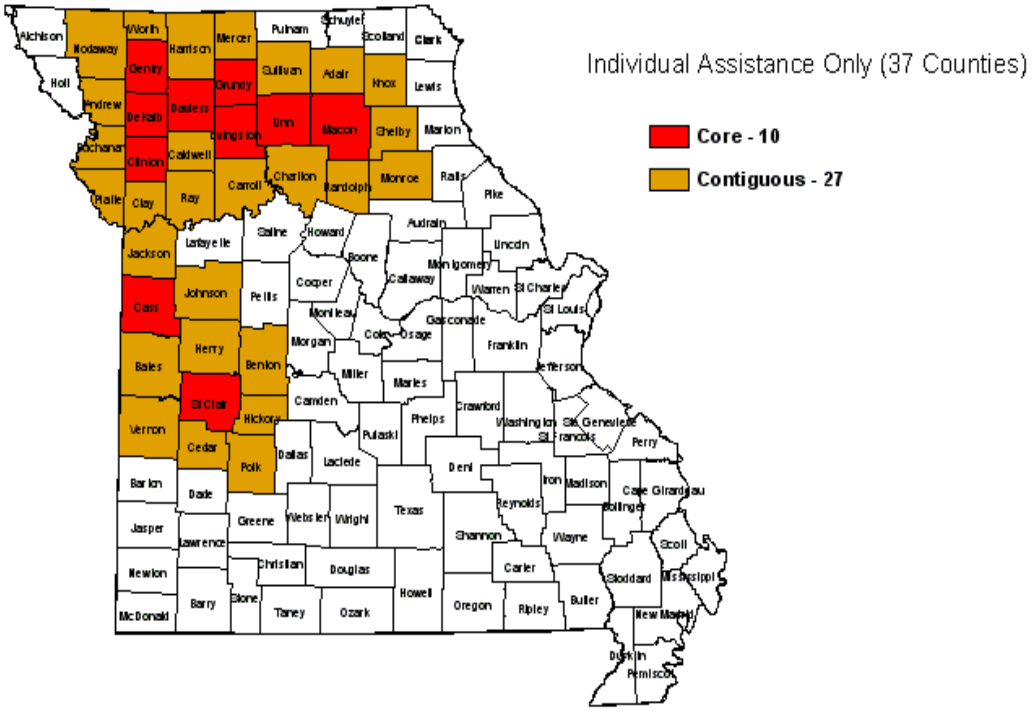


FIGURE A-10

Missouri Declared Counties
FEMA-DR-1524-MO



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