Section 7. Tornadoes

Contents

Contents 7-1
Why Tornadoes are a Threat 7-1
Hazard Profile 7-4
Location of Hazardous Areas 7-4
History of Tornadoes 7-5
People and Property at Risk 7-8
Potential Impact of Large, Violent Tornado on the City of Plano 7-11
Computer-Determined Worst Paths 7-15

Why Tornadoes are a Threat

Tornadoes are considered to be the most erratic, most unpredictable and most violent of all atmospheric storms. Winds in the strongest of these storms can exceed 250 miles per hour. By definition, a tornado is often described as a violently rotating column of air, in contact with the ground, either pendant from a cumuliform cloud or underneath a cumuliform cloud, and often (but not always) visible as a condensation funnel cloud. Significant damage can occur even when the condensation funnel does not reach the ground.

Tornadoes generally fall into two types of categories. A Type I tornado is associated with thunderstorms containing a larger parent circulation, often called a "supercell". Large and violent tornadoes, almost without exception, fall into this class. The generally weaker Type II tornado (or non-supercell tornado) is a smaller circulation that forms along windshift lines and other boundaries without a vigorous parent circulation.

The intensity of these storms is rated using the Fujita Scale of wind damage, which was developed decades ago in response to identifiable trends in structural failures due to wind. A tornado is given a

Texas is the tornado capital of the United States.
- National Academy Press

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Fujita rating of 0-5, based on the most intense damage along its path. Wind velocities necessary to produce the particular damage are often associated with the Fujita category, but that practice is often misleading at best. The Fujita wind estimates are intended to be based upon the expected damage to a well-built residential structure. Poorly built structures can suffer significant structural damage under lesser winds than the Fujita Scale might suggest.

Table 7-1. The Fujita Tornado Scale

F-Scale Number	Intensity	Wind Speed (mph)	Type of Damage Done	Percent of Appraised Structure Value Lost Due to Damage
F0	Gale tornado	40-72	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages sign boards.	--
F1	Moderate tornado	73-112	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off roads; attached garages may be destroyed.	0% - 20%
F2	Significant tornado	113-157	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.	50% - 100%
F3	Severe tornado	158-206	Roof and some walls torn off well constructed houses; trains overturned; most trees in forest uprooted.	100%
F4	Devastating tornado	207-260	Well-constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.	100%
F5	Incredible tornado	261-318	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles flying through the air in excess of 100 meters; trees debarked; steel reinforced concrete badly damaged.	100%

Tornadoes occasionally accompany tropical storms and hurricanes that move over land. Tornadoes are the most common to the right and ahead of the path of the storm center as it comes ashore. Tornadoes vary in terms of duration, wind speed and the toll that they take, as shown in Table 7-1.

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Table 7-2. Variations Among Tornadoes

Weak Tornadoes F0 or F1	Strong Tornadoes F2 or F3	Violent Tornadoes F4 or greater
• 69% of all tornadoes • Less than 5% of tornado deaths • Lifetime 1-10+ minutes • Winds less than 112 mph	• 29% of all tornadoes • Nearly 30% of all tornado deaths • May last 20 minutes or longer • Winds 113 – 206 mph	• 2% of all tornadoes • 70% of all tornado deaths • Lifetime can exceed one hour • Winds greater than 206 mph

Since 1950, approximately 280 tornadoes have been observed as occurring in the NCTCOG region, 63 of which have had a F-Scale of F2 or F3. A few of the more well-known tornadoes in the North Central Texas region are as follows: an F3 tornado that moved through Dallas and Collin Counties on April 2, 1957 caused 200 injuries, 10 fatalities, and $4 million in damages. On June 19, 1965 severe tornadoes and flooding caused Navarro County to be declared a Presidential Disaster. On April 25, 1994 an F4 tornado within Dallas County claimed 3 lives and injured 48 persons. And most recently, Tarrant County received a Presidential Disaster Declaration when severe storms and tornadoes devastated parts of the county on March 28, 2000.

Because it lies in Tornado Alley, the NCTCOG region has developed a long history with tornadoes. According to the map below developed by the Storm Prediction Center at the National Oceanic and Atmospheric Administration (NOAA) entitled "Tornado Activity in the United States," the North Central Texas area is only one of two hot spots in the entire United States where there have been more than 15 recorded tornadoes per 1,000 square miles.

Hazard Profile

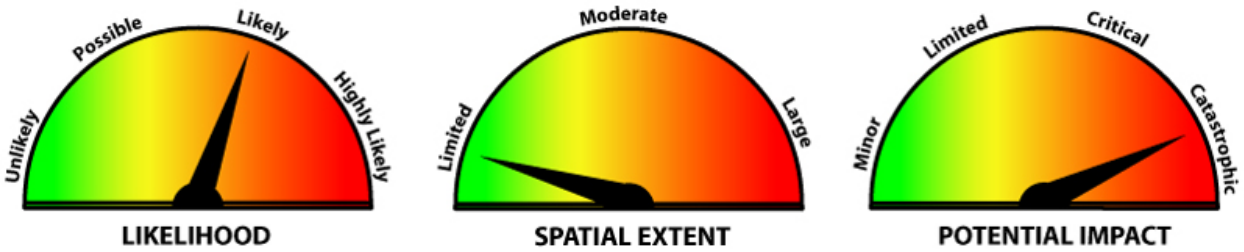

Figure 7- 1. Tornado Hazard Profile Summary for the City of Plano

The frequency, or likelihood, of a tornado in the City of Plano is "Likely", with an event probable in the next two to three years. Seasonal patterns are relevant to tornadoes. Thunderstorms form when warm, moist air collides with cooler, drier air. Since these masses tend to come together during the transition from summer to winter, most thunderstorms and resulting tornadoes occur during the spring (March, April, May and June) and, at a lesser intensity, during the fall (September, October, and November). Warning time for tornadoes is minimal.

The spatial extent of a tornado in Plano is expected to be limited, affecting 10% or less of property. The potential impact of tornadoes may be catastrophic. "Catastrophic" impacts may result in a high number of deaths and injuries and more than 50% of property in the affected area damaged or destroyed. There may be a complete shutdown of facilities for 30 days or more.

Location of Hazardous Areas

Tornadic storms can occur anywhere throughout the United States, but they are far more frequent in a zone that stretches from northern Texas through Oklahoma and into Nebraska, commonly called "Tornado Alley." The North Central Texas region is the largest metropolitan area in Tornado Alley. Tornadoes seem to occur more frequently in Tornado Alley because recent research suggests that Tornado Alley is a breeding ground for conditions which are ripe for tornado formation—high instability, strong veering (turning) of the wind direction in the lowest half mile of the atmosphere, and often in the vicinity of weak boundaries. The flat terrain enhances rapid movement of air, while high humidity of the Gulf Stream further induces instability in the atmosphere. Tornadic storms can occur at any time of year and at any time of day, but they are typically more common in the spring months during the late afternoon and evening hours. A typically smaller, high frequency period can emerge in the fall during the brief transition between the warm and cold seasons.

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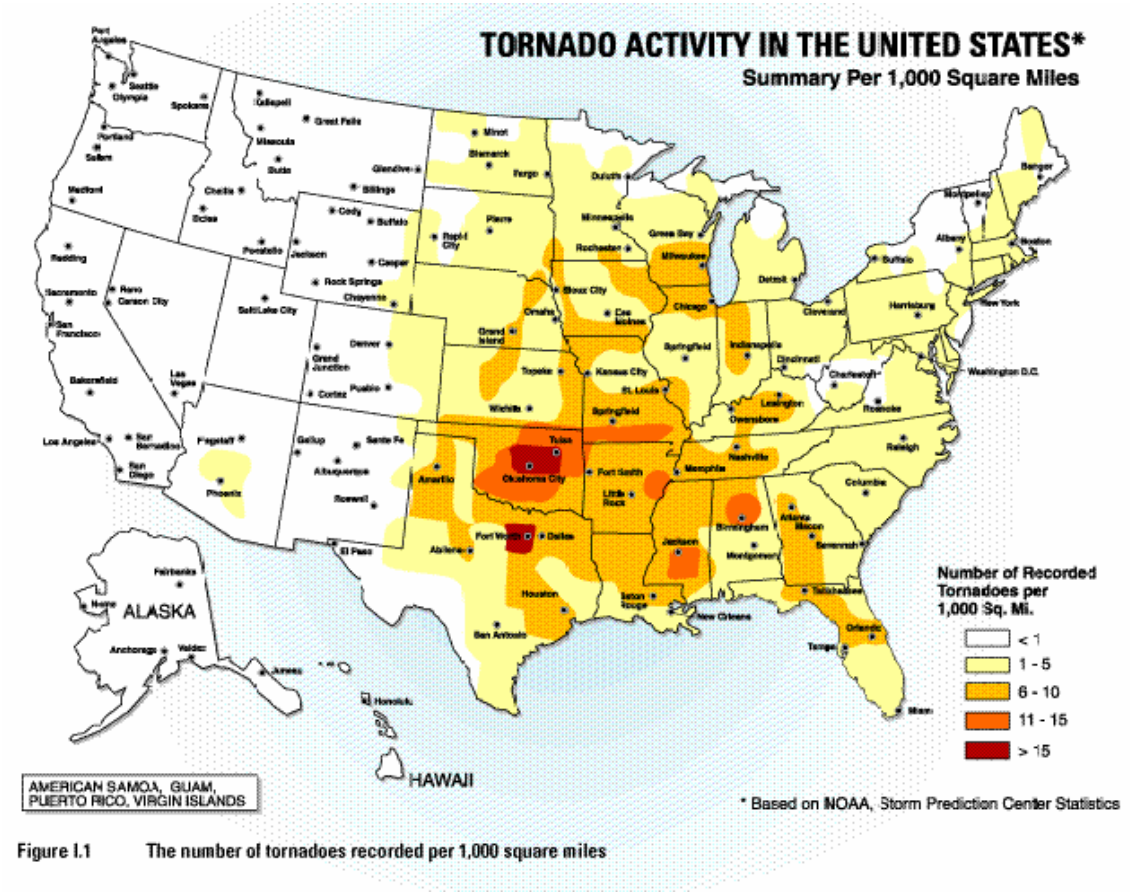

Figure 7-2. Tornado Activity in the United States

History of Tornadoes

One of the more well-known tornadoes in the North Central Texas region was an F3 tornado that moved through Dallas and Collin Counties on April 2, 1957 causing over 200 injuries, 10 fatalities, and $4 million in damages. There have been 30 tornadoes reported in Collin County, Texas to the National Oceanic and Atmospheric Administration between January 1, 1950 and April 30, 2005. The intensity of these tornadoes varied, with eleven of them F0, nine F1, seven F2 and three F3. Those that hit the City of Plano are depicted in Figure 7-3.

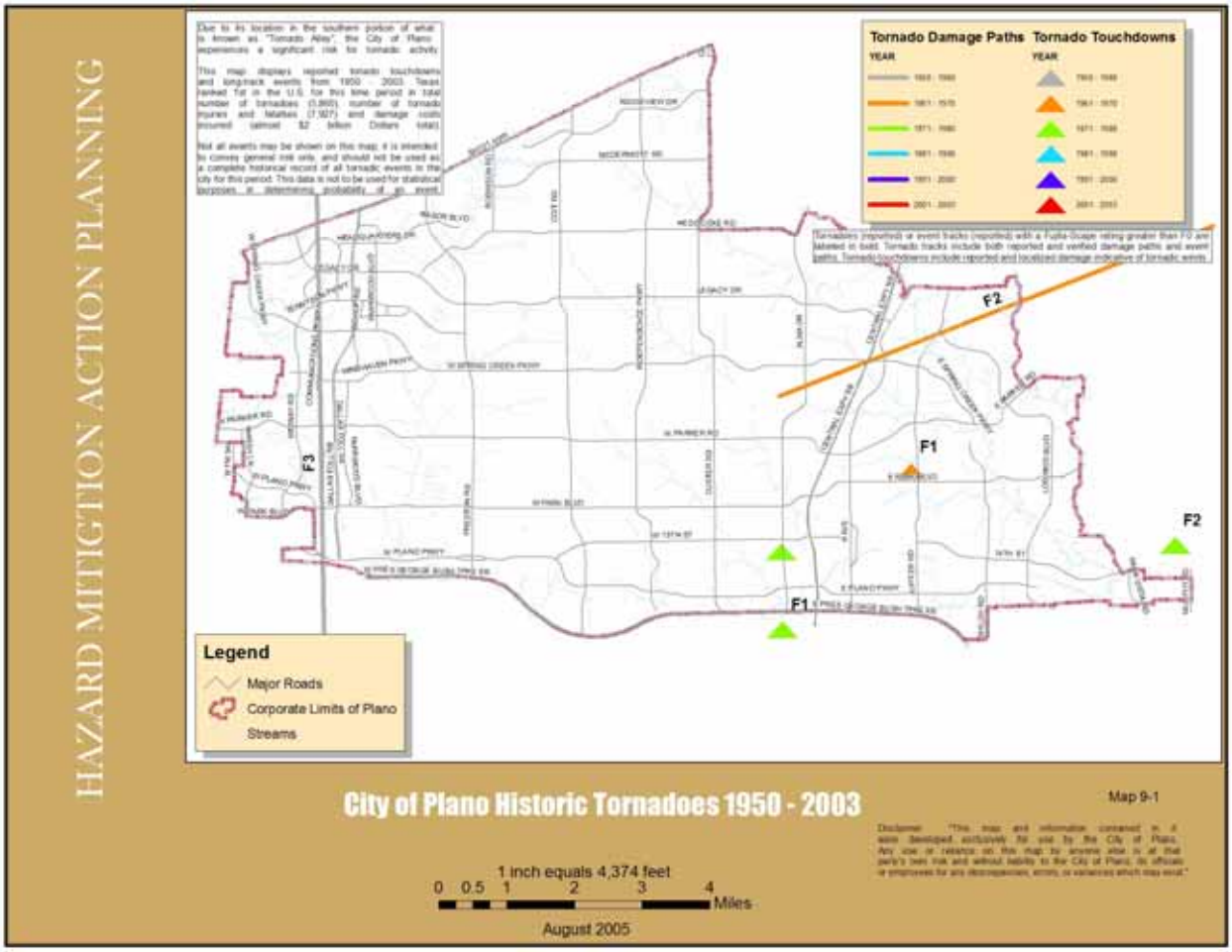

Figure 7-3. City of Plano Historic Tornadoes, 1950 - 2003

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Table 7-3. Reported Tornado Events in Collin County and the City of Plano, according to the National Oceanic and Atmospheric Administration, January 1, 1950 to April 30, 2005

Event	Location	Date	Magnitude	Deaths	Injuries	Property Damage	Crop Damage
Collin County							
Tornado	Collin	03/24/1954	F1	0	4	$25K	0
Tornado	Collin	05/25/1954	F0	0	0	0K	0
Tornado	Collin	04/02/1957	F3	0	2	250K	0
Tornado	Collin	04/27/1958	F2	0	0	250K	0
Tornado	Collin	10/04/1959	F3	0	5	250K	0
Tornado	Collin	04/22/1963	F2	0	0	250K	0
Tornado	Collin	04/28/1963	F1	0	0	3K	0
Tornado	Collin	05/19/1963	F0	0	0	0K	0
Tornado	Collin	03/25/1967	F0	0	0	0K	0
Tornado	Collin	03/25/1967	F0	0	0	0K	0
Tornado	Collin	04/22/1968	F1	0	0	25K	0
Tornado	Collin	05/13/1968	F2	0	0	25K	0
Tornado	Collin	04/27/1969	F2	0	45	250K	0
Tornado	Collin	10/12/1969	F3	0	0	3K	0
Tornado	Collin	04/18/1970	F1	0	2	3K	0
Tornado	Collin	09/01/1970	F1	0	0	0K	0
Tornado	Collin	07/19/1971	F1	0	0	25K	0
Tornado	Collin	12/14/1971	F0	0	0	25K	0
Tornado	Collin	08/10/1972	F0	0	0	3K	0
Tornado	Collin	11/20/1973	F1	0	3	25K	0
Tornado	Collin	06/09/1975	F0	0	0	0K	0
Tornado	Collin	03/27/1977	F2	0	0	250K	0
Tornado	Collin	09/07/1977	F1	0	0	3K	0
Tornado	Collin	09/12/1977	F2	0	0	25K	0
Tornado	Collin	03/29/1979	F0	0	0	0K	0
Tornado	Collin	07/27/1982	F0	0	0	3K	0
Tornado	Collin	03/27/1984	F1	0	0	3K	0
Tornado	Collin	10/18/1985	F2	0	2	250K	0
Tornado	Collin	03/17/1987	F0	0	0	0K	0
Tornado	Collin	09/13/1993	F0	0	0	0	0

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People and Property at Risk

It cannot be predicted where a tornado will touch down. All the population, buildings, critical facilities, infrastructure and lifelines, and hazardous materials facilities in the City of Plano are considered exposed to the hazard and could potentially be impacted. The following sections assess the potential impacts of a "typical (average) tornado and a large, violent tornado on the City of Plano.

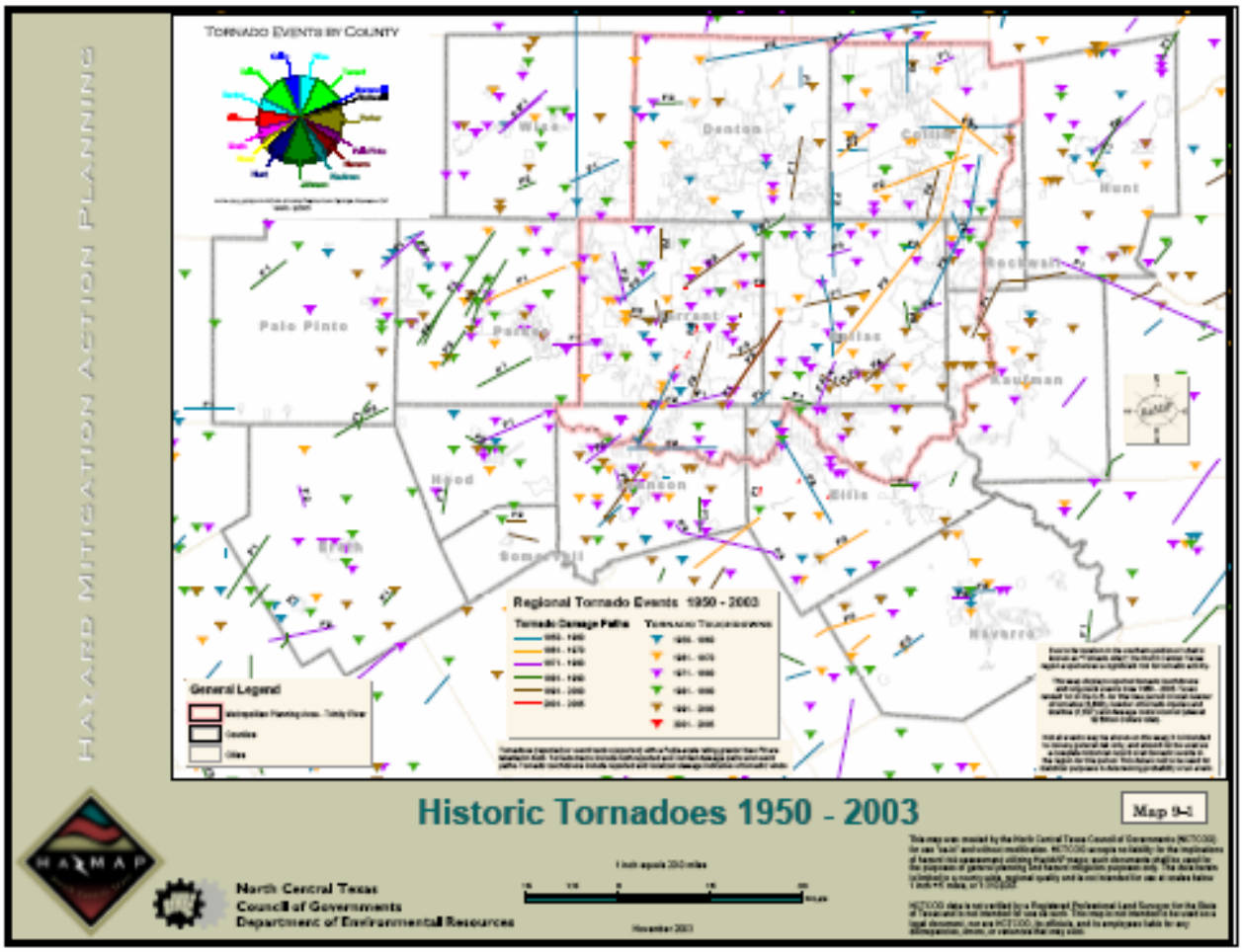

Figure 7-4. Potential Impact of "Typical"(Average) Tornado on the City of Plano

The NCTCOG used the 50-year data set from the NOAA Storm Prediction Center and cross-verified it with data from their Tornado Project to determine the width, length and damage from an "average" tornado in the North Central Texas region. Over 1200 tornadoes in the dataset had

information on the beginning point and ending point of the tornado path, as well as median path width. Averaging this collection of records reveals an average path description of:

- 10 miles long
- 0.15 miles wide
- 960 impacted acres

Thus, for the purpose of statistical representation, the typical average tornado in the North Central Texas region has a straight 10-mile long continuous path with a 0.15 mile wide impact width, with approximately 960 acres of impact area. This average unit tornado has been mapped in the NCTCOG's Report entitled, "HazMAP "Average "Unit" Tornado Exposure: Comparison of Texas Events, 1950-2003."

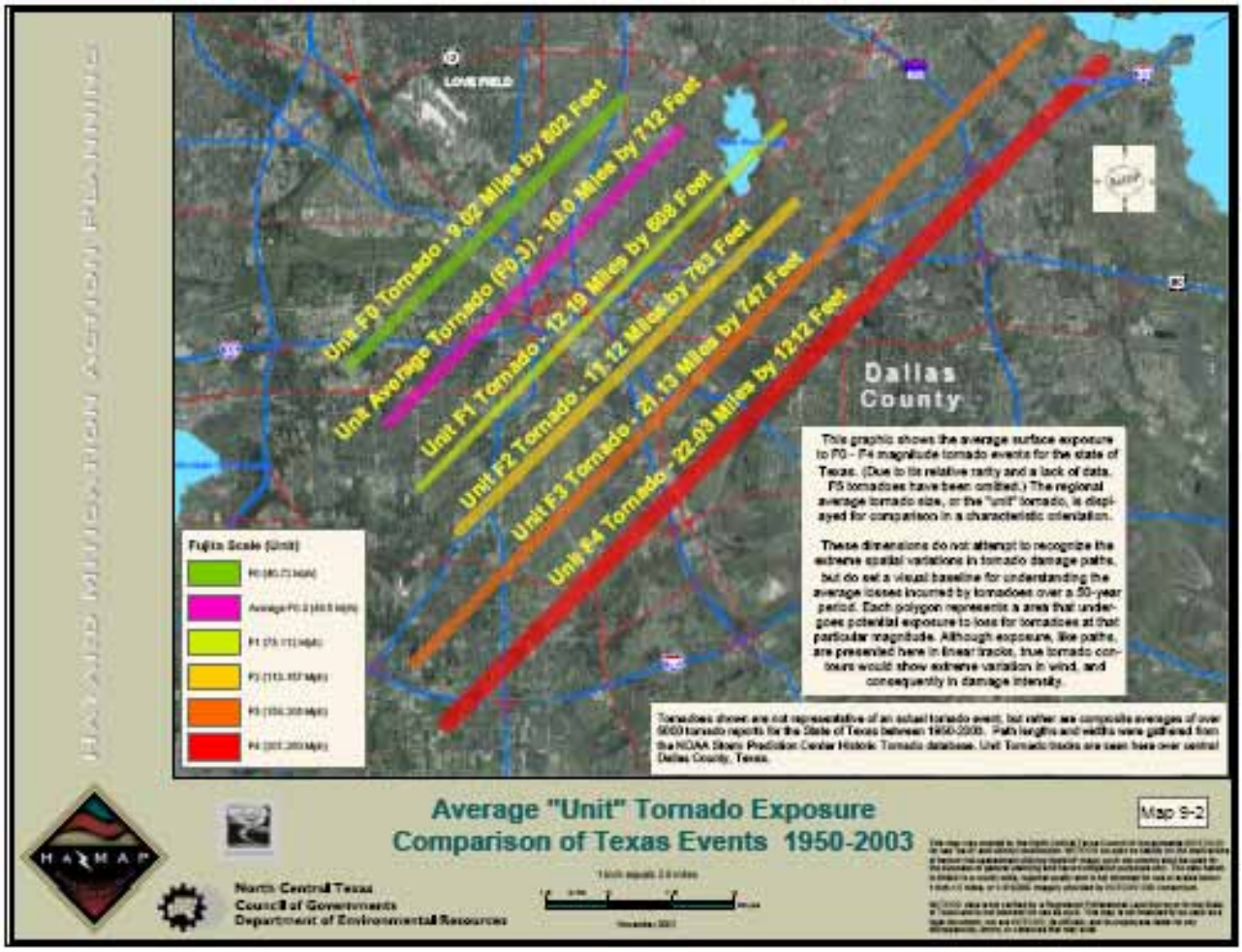

Figure 7-5. Average "Unit" Tornado Exposure

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Table 7-4 shows the land use and structural composition of a typical acre in the City of Plano as of January 2004 in order to demonstrate the potential impact of a typical tornado path.

Table 7-4. Land Use and Density for a "Typical" (Average) Acre in the City of Plano

Category	Percentage of Total Acreage	Average # of Structures or Apartment Units Per Acre
Single Family	(23,952 acres) 51.6%	4 Units Per Acre
Multi-Family	(2,021 acres) 4.4%	18 Units (Apartment) Per Acre
Commercial/Industrial	(9,833 acres) 21.2%	Data not available for Commercial Structures Per Acre
Vacant	(6,968 acres) 15.0%	-
Roadway	(3,375 acres) 7.3%	-
Other	(236 acres) 0.5%	-

Thus, an "average" tornado hitting the City of Plano could impact 1,981 single family structures valued at $297 million (based on an average value of $150,000 per residential structure); 760 apartment units; an undetermined number of commercial structures; and additional roadways and other infrastructure. The percentage of appraised structure value expected to be lost varies by intensity of the tornado, as depicted in Table 7-5.

Table 7-5. Average Loss Expected by Fujita Damage Scale

Fujita Scale	Percentage of Appraised Structure Value Lost due to Damage
F1	0% to 20%
F2	50% to 100%
F3	100%
F4 and above	100%

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Potential Impact of Large, Violent Tornado on the City of Plano

The typical tornado is likely a good measuring point for the typical damage expectation for the City. However, the threat of a much larger, stronger, and persistent tornado is very real. As with extremely large hail, 100-year floods, and other extreme phenomena, the statistical probability of such a storm occurring in the City of Plano in any given year is small, but over a larger number of years, it is a significant probability.

Violent class tornadoes are those that produce damage in the F-4 to F-5 range. There is no rule that says they have to have a wide damage path or a slim one, but of particular concern are those that can reach widths of 1/2 mile or more and travel 25 to 50 miles. Examples of such storms include Wichita Falls, Texas (1979), Wichita, Kansas (1990), Waco, Texas (1953), and Moore, Oklahoma (1999). In particular, the Moore, Oklahoma damage path was well mapped by experts in tornadoes and wind engineering. Often, the conditions present to favor strong tornado development can extend to multiple storms across a region, resulting in a tornado outbreak. The Moore tornado was accompanied by 70 other regional tornadoes in a 6-hour period.

As part of the Spring 2000 severe weather-planning season, the NCTCOG, in cooperation with the National Weather Service, developed a Tornado Damage Risk Assessment. The project estimated the potential impact of the Moore, Oklahoma tornado outbreak (1999) if it were to occur over the Dallas/Fort Worth Metroplex. Using over 55 damage path scenarios, GIS technology was used to estimate *structures, property, residents, employees, and traffic* that would be in tornado damage paths. An assessment of property values was also included, and potential damages were estimated based on mapped Fujita scale damage contours. In some cases, population at risk exceeded 150,000. Potential structural damages in some scenarios reached estimates exceeding $4.5 billion. If a mile-wide portion of the Moore tornado were to move into downtown Dallas, over 100,000 employees and nearly $3 billion dollars of property would be inside the tornado simultaneously.

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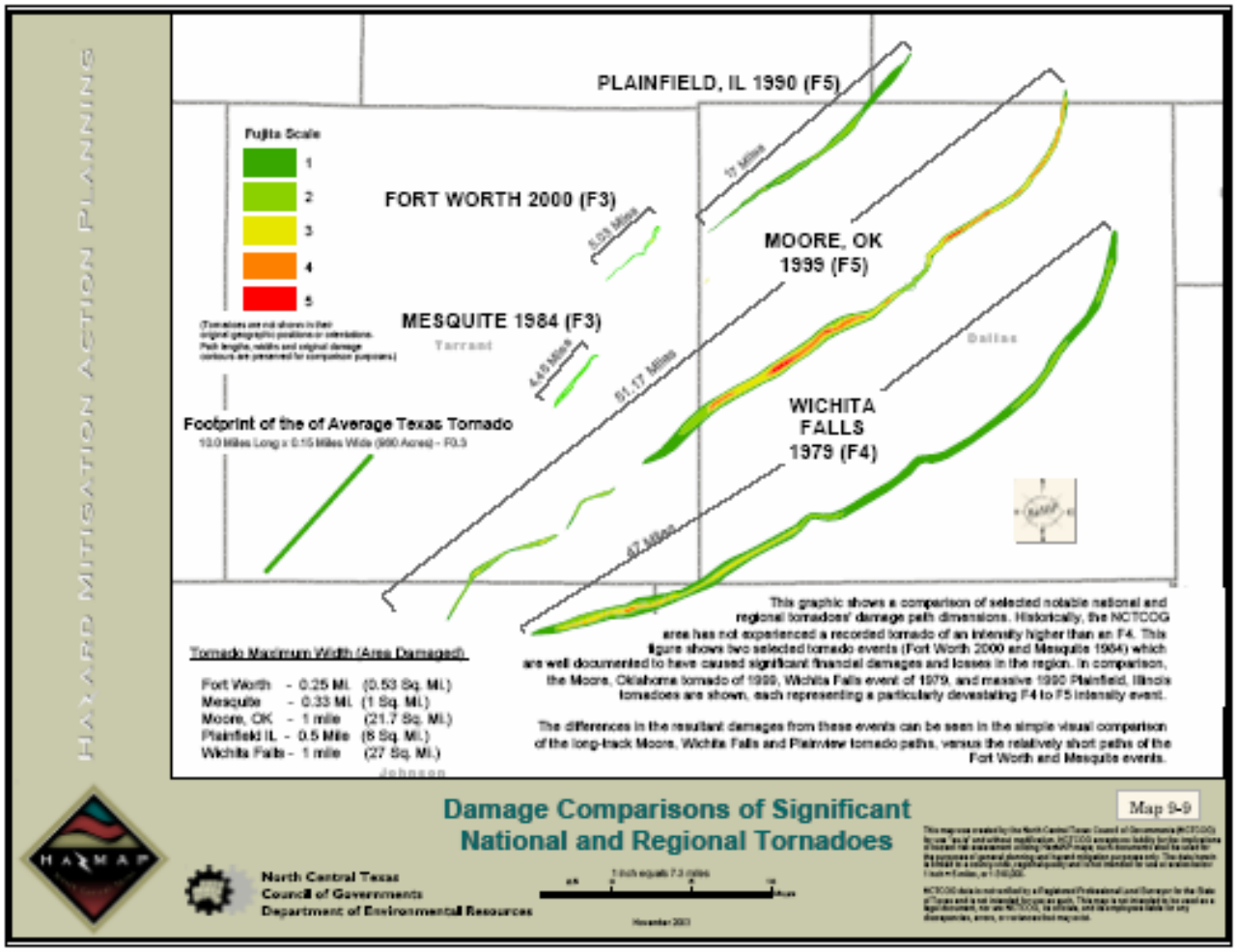

Figure 7-6. Damage Comparisons of Significant National and Regional Tornadoes

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Table 7-6. Characteristics of the Moore, Oklahoma F-5 Tornado Impact Area

Fujita Scale	Width(Feet)	Acres	Square Miles	Path Miles	Main Hour
5	5280	12,242	19.12	37.5	7 P.M.

Fort Worth tornado (White) and Moore Tornado Paths

Comparison of Moore, Oklahoma Tornado to the Fort Worth Tornado of March 28, 2000

	Fort Worth	Moore
Total Damage Area	344 Acres	12,242
Significant Damage Area (F-2+)	63 Acres	7,750 Acres
Path Percentage With Significant Damage	20%	63%
Path Length	6 Miles	37.5 Miles

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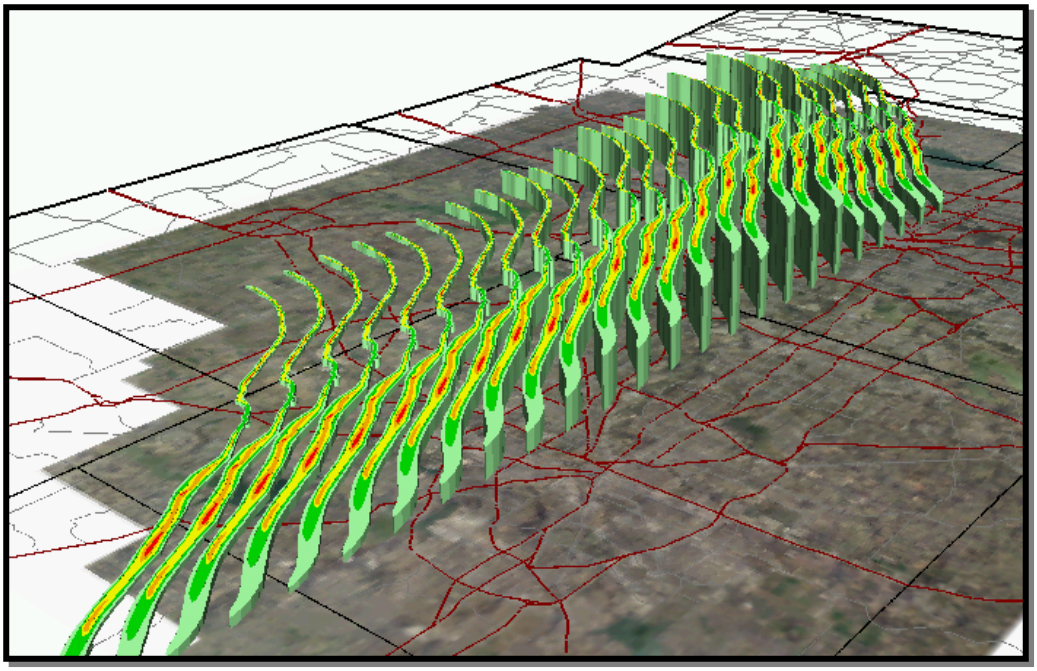

Figure 7-7. Tornado Paths Tested in the Risk Assessment for the NCTCOG

Figure 7-7 shows 25 of the 55 ultimate paths tested in the risk assessment. Each path was evaluated separately to identify both demographic and development characteristics that fell within its boundaries and within the particular Fujita-scale damage contours. The extruded paths on the map are based on the level of development falling within the path's impact area. Higher paths are more heavily developed than lower ones. Tarrant County is in the foreground on this map and Dallas County is to the right center.

As expected, these paths are highly developed and, thus, present great risks. When all of the 50 paths are averaged together, a typical profile is described in the table below:

Table 7-7. Average Impact from a Large, Violent Long-Track Tornado in the North Central Texas Region (Average of over 50 Tornado Paths)

Structures and Residents in Path		Values in Path	
Total Structural Units*	20,140	Total Property Value	$2.7 Billion
Single-Family Units	11,800	Estimated Damages	$1.5 Billion
Multi-Family Units	7,350	Residential Damages#	$1.04 Billion

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Residents	46,770	
* Single Family Homes, Apartment Units, and Commercial Property Buildings		

Several of the scenarios that passed through the northern portions of Collin and Dallas County contained very large numbers of people and expensive property. Such a combination is particularly threatening in a wide violent-class tornado. With such high winds, there is little hope of structures avoiding demolition, particularly residential buildings. Total loss is highly likely. The below path is one of those that ranked high in potential risk.

Characteristics of Potentially High-Impact Path	
Structures in Path	33,300
Property Value in Path	$7.9 Billion
Potential Damages	$4.7 Billion
Residents Living in Path	73,000
Percent of Path that is Developed	63.13%

Computer-Determined Worst Paths

When Dallas-Fort Worth development information is tabulated, the computer can be remarkably efficient in determining its own worst path for a tornado. Based on number of structures distributed across the surface, the computer can use a cost-path analysis to choose a route containing the most structures possible to impact.

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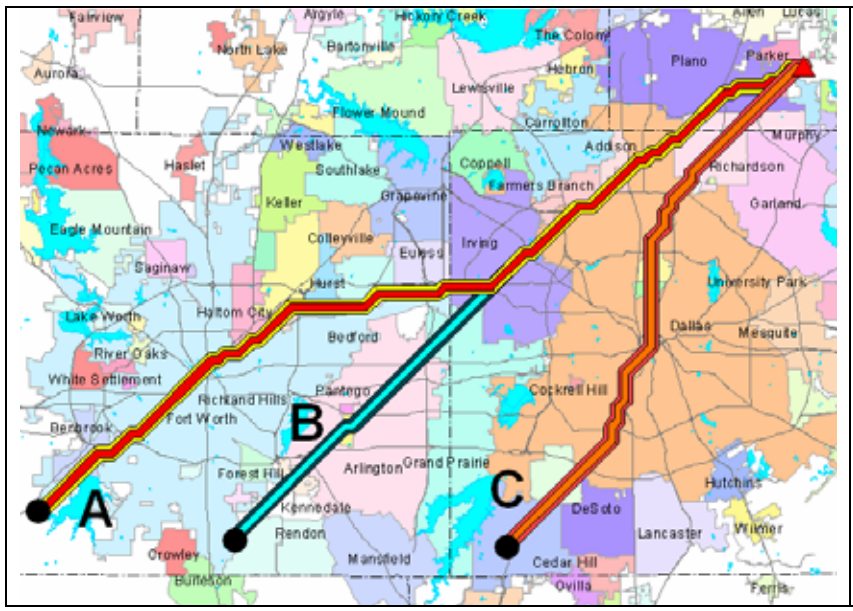

The computer is asked, given three random starting points and a destination, to find the worst possible damage path between the 2 locations. The concept of a least-cost path is modified slightly to make the highest values and the largest number of structures more attractive to the tornado. The tornado width is then calculated as 1/4 wide and again at 1/2 mile wide. The quantity and value of structures can then be tabulated.

Path	¼ Mile Width			½ Mile Width		
	Structures	Residents	Property in Path	Structures	Residents	Property In Path
A	60,000	122,000	$13 Billion	103,000	212,000	$15 Billion
B	36,000	81,000	$11 Billion	70,000	157,000	$18 Billion
C	33,000	73,000	$10 Billion	69,000	149,000	$18 Billion

Figure 7-8. Computer-Determined Worst Path for Tornado in the North Central Texas Region

These computer simulations do not represent forecasts of where a tornado may actually hit. They do, however, demonstrate the City's vulnerability to catastrophic losses in lives and property from a range of tornado scenarios – from a "typical" average tornado in the NCTOG region to a large, violent tornado.

An assessment of the best available historical tornado data shows that the risk of a tornado hazard is uniform across the City of Plano and the NCTCOG region. There is no specific hazard boundary for tornadoes. Any area of the jurisdiction can be affected equally. Tornado hazards are one of the top concerns of the City of Plano. As a result, tornado hazards deserve mitigation consideration.

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