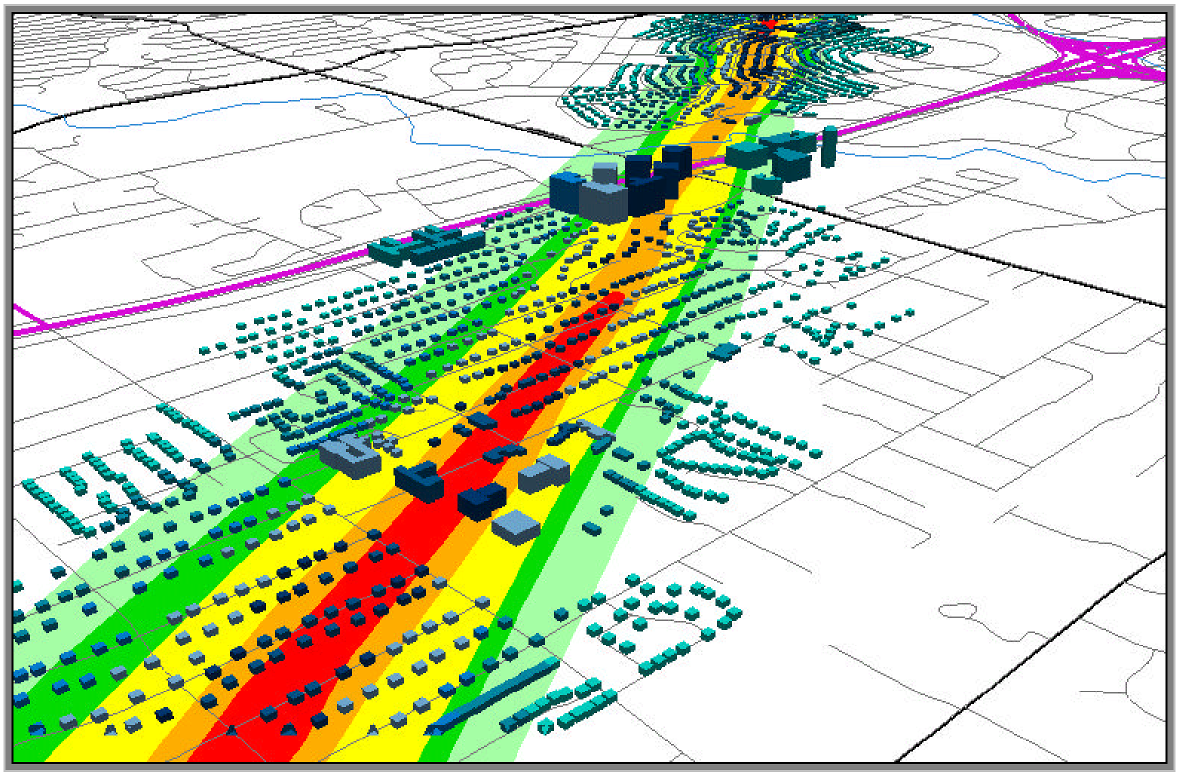
Tornado Damage Risk Assessment

Dallas-Fort Worth Metroplex

A Regional Exercise in Demographic,
Environmental, and Urban Analysis
January, 2000



Potential Damage Impact of the May 3, 1999 Oklahoma Tornado
Outbreak if it had Occurred over North Central Texas

Study Summary
Performed as a Public Service for the National Weather Service
And the Emergency Management Community

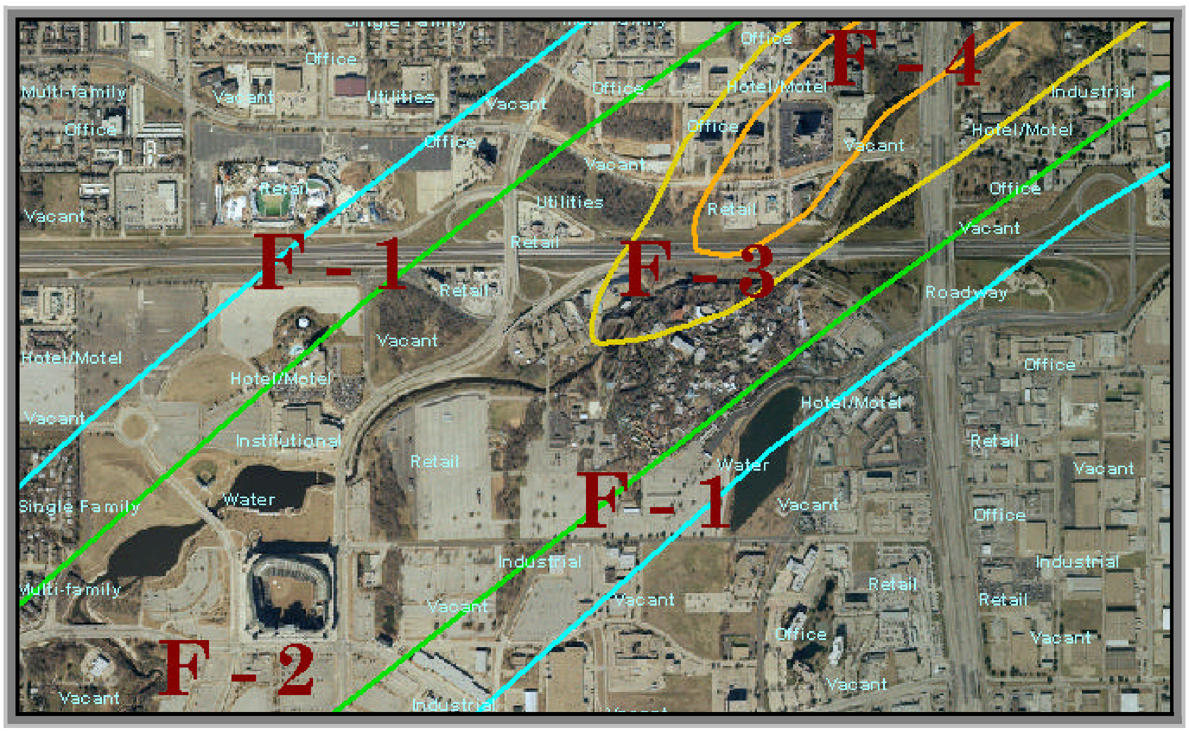
North Central Texas Council of Governments
616 Six Flags Drive, Suite 200, Centerpoint Two
P.O. Box 5888
Arlington, Texas 76005-5888

Tornado Damage Risk Assessment
Dallas-Fort Worth Metroplex

North Central Texas Council of Governments
616 Six Flags Drive
Arlington, Texas 76005
Phone: (817) 640-3300

National Weather Service Forecast Office
3401 Northern Cross Blvd
Fort Worth, Texas 76137
Phone: (817) 429-2631

An analysis of detailed urban geographic data to estimate the potential impacts of a major tornado outbreak on the Dallas Fort-Worth Metroplex. Features the application of Geographic Information System (GIS) Technology.



Aerial Image Maps Courtesy of VARGIS LLC

Fujita Scale Wind Velocity contours from the Moore, Oklahoma tornado of May 3, 1999 projected atop color aerial digital photography for eastern Arlington, Texas.

Front Cover: Computer model of the path of the Moore, Oklahoma projected upon structure data for North Dallas. Path colors differentiate between different Fujita Scale wind velocities. Structures are given 3-D perspectives through the use of Geographical Information System software.

Data Analysis and Geographic Information System Data Compilation

Scott Rae
Senior Research Associate
Department of Research and Information Services
North Central Texas Council of Governments

Advisory Group

Jim Stefkovich
Warning Coordination Meteorologist
National Weather Service Forecast Office
Fort Worth, Texas

Gary Woodall
Warning Coordination Meteorologist
Meteorological Services Division
National Weather Service Southern Region Headquarters

Bob O'Neal
Director
Department of Research and Information Services
North Central Texas Council of Governments

Rocky Gardiner
Manager of Research
Department of Research and Information Services
North Central Texas Council of Governments

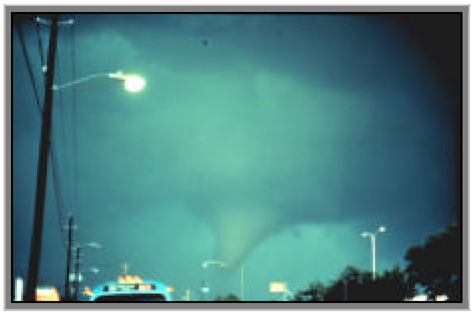
Jack Tidwell
Senior Environmental Planner
Department of Environmental Resources
North Central Texas Council of Governments

Special Thanks for Data Contributions and Suggestions

Greg Stumpf, National Severe Storms Laboratory
Dr. Charles A. Doswell III, National Severe Storms Laboratory
Tim Marshall, Haag Engineers
Amy Wyatt, North Central Texas Council of Governments
Angi Young, North Central Texas Council of Governments
Tamara Schells, North Central Texas Council of Governments
Arash Mirzaei, North Central Texas Council of Governments
Mitch Lestig, North Central Texas Council of Governments
Ken Cervenka, North Central Texas Council of Governments

Introduction

The series of tornadoes which struck the Oklahoma City area on May 3, 1999 were the most damaging tornadoes in U.S. history, causing over 1 billion dollars in damage and completely destroying over 2500 structures. While loss of life was kept to a minimum due to advances in weather forecasting technology and the preparedness of the media, the impact of this tornadic event was augmented by the fact that the tornadoes struck a densely populated metropolitan area.



NOAA Photo Library, NOAA Central Library

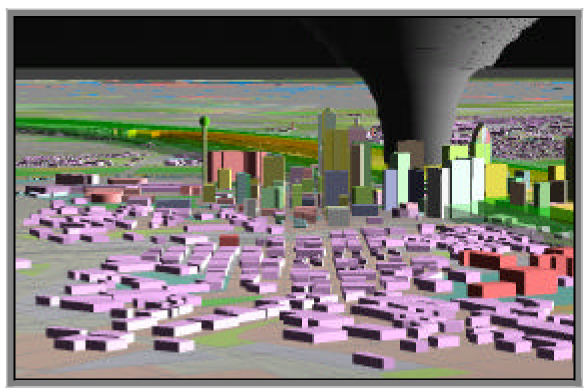
Dallas, Texas May 26, 1981

What if a tornado or outbreak of this magnitude struck the Dallas-Fort Worth Metroplex? With nearly 5 million people, 1.1 million houses, and 60,000 commercial structures, the effect would be devastating at best. Losses would likely exceed the cost impact to Oklahoma City by an order of magnitude. The climatology of Dallas-Fort Worth is prime for such weather systems, and it is only a matter of time before the odds bring one of these events to the heart of the Metroplex.

A joint research project between the North Central Texas Council of Governments (NCTCOG) and the National Weather Service Fort Worth (NWS) examines the potential impact such a weather event would have on the Metroplex. By utilizing many of the same tools and data sets typically used in regional urban planning for North Central Texas, the problem of tornado risk is demonstrated through demographic, environmental, and urban analysis.

NOAA Photo Library, NOAA Central Library

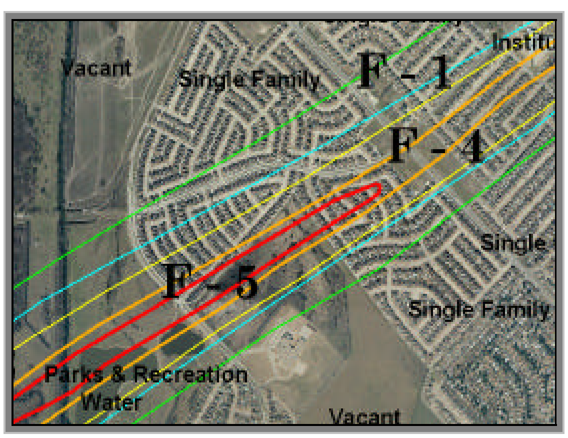
Above: *Wichita Falls, Texas F-4 Tornado of April 10, 1979.* This tornado, like the one in "Moore" Oklahoma, is the type of violent class tornado that would be extremely dangerous in a dense urban area like Dallas-Fort Worth.

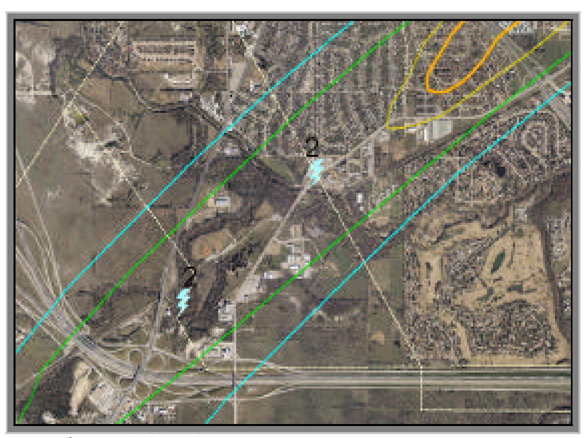


North Central Texas Council of Governments

Above: *Computer Model of Large Tornado* following Scenario Four path into Downtown Dallas. This scenario would likely impact over 30,000 structures and create estimated appraised structural losses of over $2.8 Billion.

Table of Contents





Aerial Image Maps Courtesy of VARGIS LLC

Study Overview

This study features the use of digitally mapped tornado path information from a real tornado outbreak laid atop Dallas-Fort Worth urban and demographic data. It uses some of the best regional geographic data available to help answer the unavoidable meteorological and emergency management questions that arise after a big storm event in a nearby geographical area:

- **What if it had happened here?**
- **What would have been our toll?**
- **Would we have been prepared?**

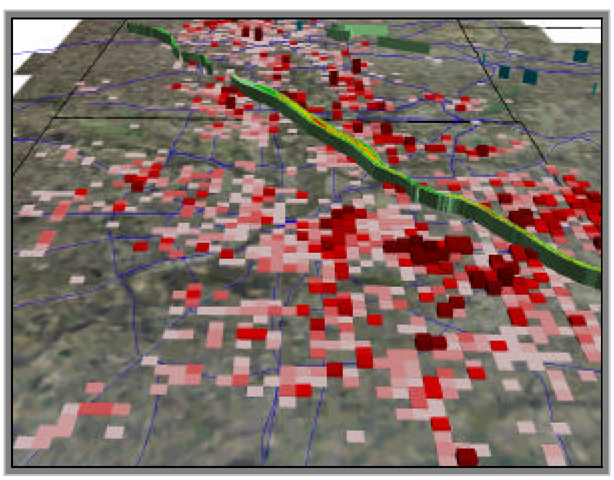
Modern computer technology can help estimate the magnitude that the tasks of warning, rescue, and recovery would require. If we make the very likely assumption that *Dallas-Fort Worth would see comparable damage in the same portions of the tornadoes that caused damage in Oklahoma*, we can then model this same event across the Dallas-Fort Worth Metroplex and assess how susceptible the area is to large tornado damage potential.

Five (5) separate distributions (scenarios) of the same Oklahoma tornado paths are modeled with the output including:

- The number of structures in the path
- Potential dollar damages to structures and contents
- Residents living in the path
- Employees working in the path
- Utility lines in the path
- The distribution of land use in the path
- Estimated roadway miles and vehicles travelling in the path

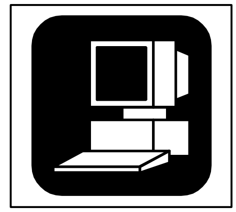
A second analysis looks at the largest tornado of the outbreak across 50 different paths through the Metroplex. Residents, structures, and values in the path are calculated and compared.

A tornadic outbreak like the one in Oklahoma would cover an amazing amount of North Central Texas territory, and this study will help identify and quantify the features that lie in the paths.



Right: *Tornado scenario five path through 3-D graphical representations of apartment complex density.* Dallas County is closest, with the view looking directly west towards Tarrant County.

Data Sources



- Dallas County Appraisal District Data – June 1999
- Tarrant County Appraisal District Data – June 1999
- Collin County Appraisal District Data – June 1999
- Denton County Appraisal District Data – June 1999

- North Central Texas Regional Population and Housing Estimates 1998
- North Central Texas Employment and Household Estimates 1995-1999
- Landiscor Aerial Photography 1999
- North Central Texas Regional Basemap
- Vargis 2 meter resolution Aerial Photography 1999
- North Texas GIS Consortium 0.5 meter resolution Aerial Photography 1997

* For this project, several databases were either utilized or constructed to provide the best-possible guess of what geographic features would be impacted by a specific alignment of one or more tornadoes. These included:

- A 400,000 record database identifying geographic distribution of:
  - Land use – Functional use of land areas
  - Structure Category - Commercial, Industrial, Single-Family, Apartment, and Mobile Home
  - Structure Density – The number of individual structures existing in an area
  - Structure Value – The appraised value of structures in an area

- A regional employment distribution data set showing the distribution of employees in relationship to their local transportation survey zone and land use.

- A regional data set showing the point location of major employers in the Dallas-Fort Worth Metroplex.

- A regional apartment complex distribution data set.

- A regional school distribution data set.

- An address-matched file of all commercial properties in the Metroplex.

- A regional transportation system data set.

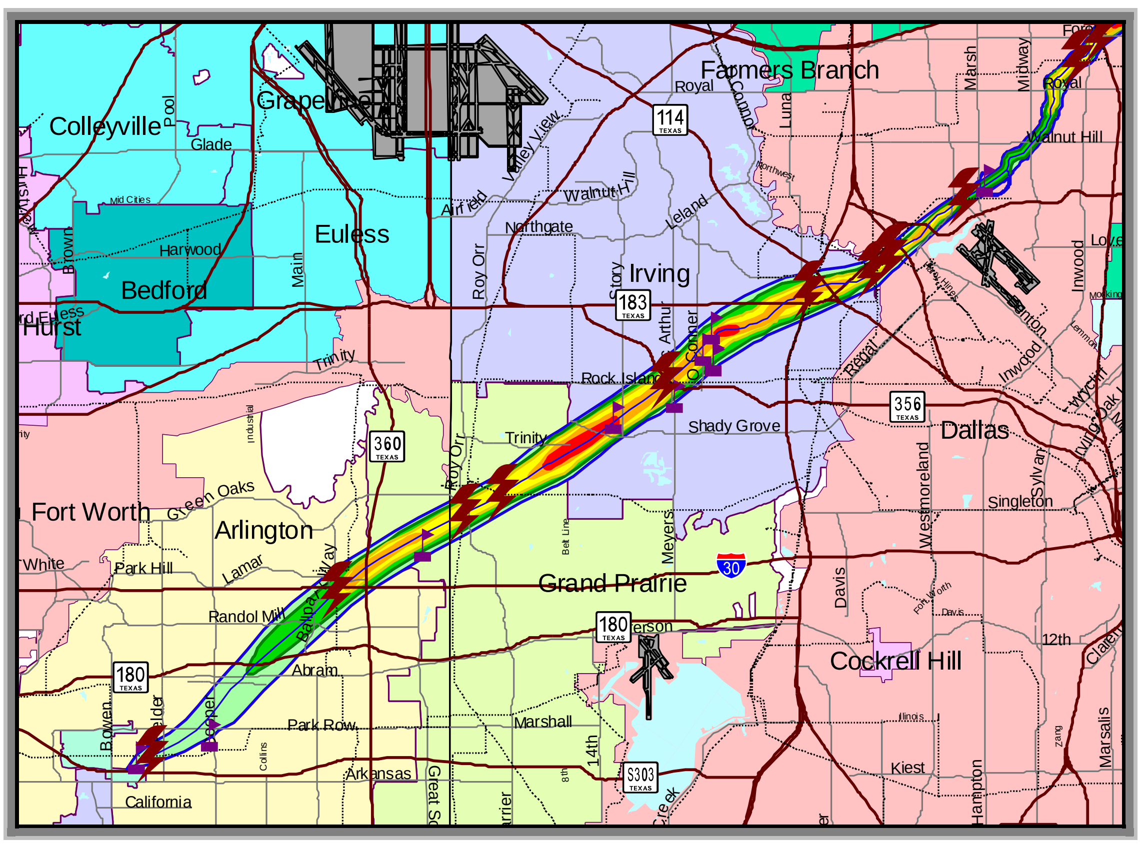
- Modeled roadway volume data sets for primary freeways, arterials, and collectors in the region.

- Distribution of major electrical power lines in Dallas, Tarrant, Collin, and Denton Counties.

- Detailed mapping of the May 3, 1999 tornado outbreak in Oklahoma. Mapping boundaries for the Moore, Oklahoma tornado were adapted from the damage survey performed by the National Severe Storms Laboratory (NSSL). Other tornadoes in the event were mapped using general mapping from the National Weather Service in Norman, Oklahoma and post-event damage survey descriptions. Widths and velocities were assigned from mapping and descriptions of each tornado provided by either the National Weather Service or the National Severe Storms Laboratory.

The 400,000 record database featured the merging of several data sets:

- 1995 North Central Texas Land Use
- North Central Texas City and County Jurisdiction Boundaries
- Census Block Group Boundaries
- MAPSCO Grid Cell Boundaries
- Trinity River Corridor Engineering Scale Mapping --76,000 Building Footprints
- Select City Parcel Mapping



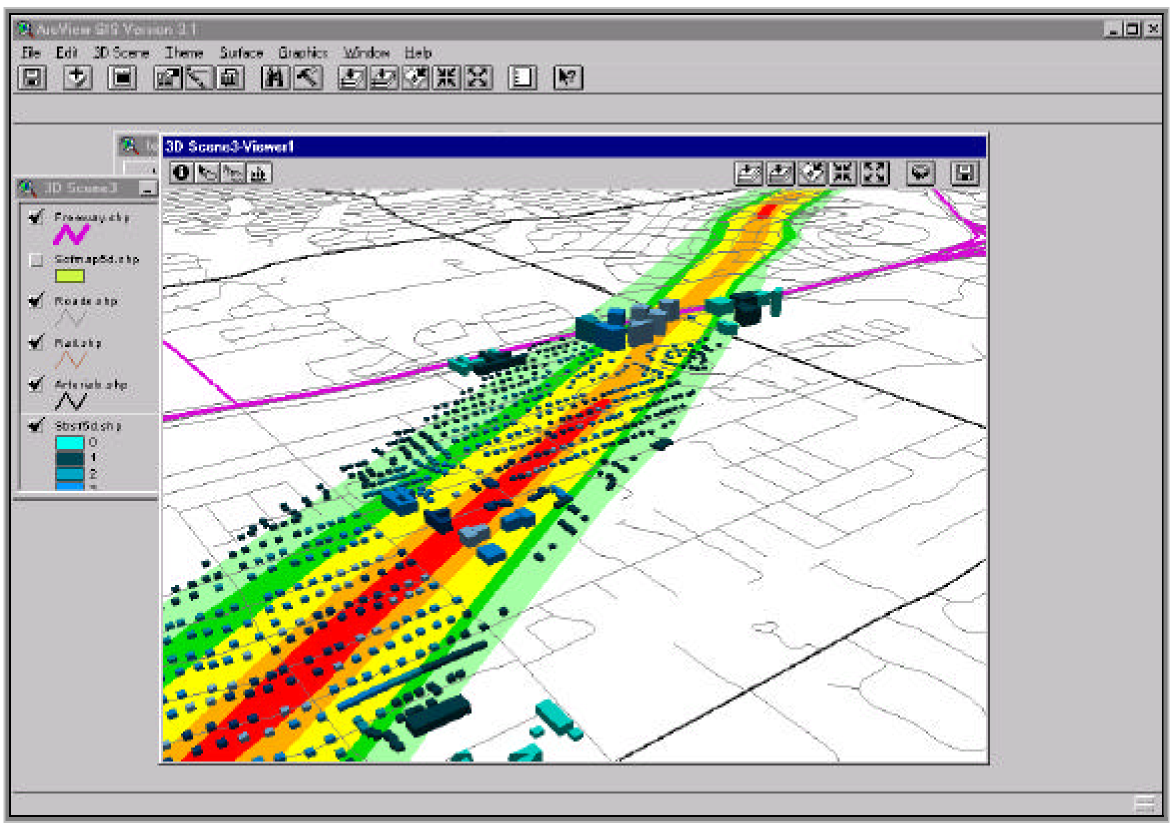
Above: *Schools and major electrical utility lines in the path of the biggest tornado of scenario five.* Overall, 43 utility line routes and 11 schools would be in the paths of tornadoes.

Oklahoma Moore Tornado Detailed Damage Delineation acknowledgement:

Provided by: Greg Stumpf, NSSL

Damage Survey Info:
Greg Stumpf, NSSL
Jim LaDue, NWS
Don Burgess, NWS
Mike Magsig, NWS
Mike Branick, NWS
Tim Marshall, Texas Tech U. and Haag Engineering

The delineation information provided was digitized into Arc/Info GIS by the North Central Texas Council of Governments using tiger mapping data in Oklahoma and translated to the Texas State Plane Coordinate System. Display maps were generated by Arcview GIS Version 3.1.



Above: *North Dallas Damage Path in Arcview GIS*

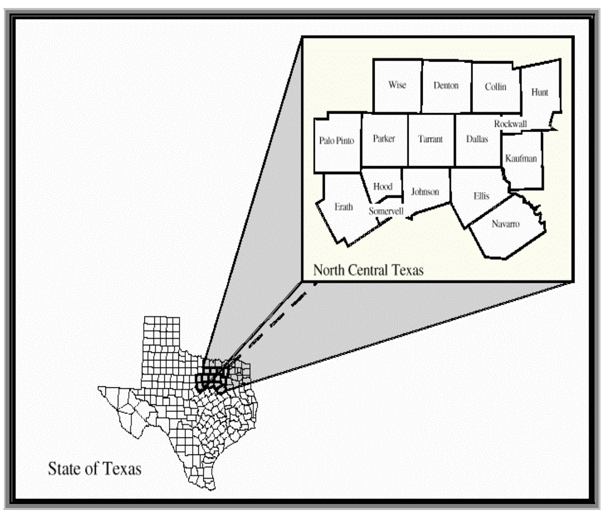
The Study Area

The North Central Texas region is made up of 16 counties and encompasses 12,797 square miles. The population of this area is estimated to be over 4.9 million (1999), and most of this population resides in the 1.14 million single family homes and 622,000 apartment units found in the region.

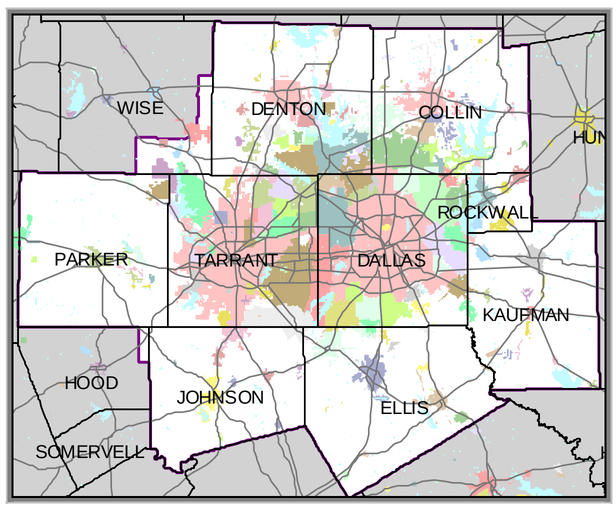
The analysis area specifically used in this study is a large subset of the North Central Texas region. The study area includes:

- All of Dallas, Tarrant, Denton, Collin, Rockwall and Parker Counties
- All of Johnson and Ellis Counties
- Portions of and Wise and Kaufman counties

Any tornadoes placed across these areas were analyzed using a detailed foundation of land use, population, housing, and employment data. Detailed appraisal data was available for Dallas, Tarrant, Denton, and Collin Counties. Tornadoes or portions of tornadoes falling outside of the analysis area did not have sufficient data available and calculations were not performed. Portions of tornadoes falling partially in the study area were analyzed, but only those included portions were calculated for damages.



North Central Texas Region
Graphic Courtesy of Sandy Blanchard, NCTCOG

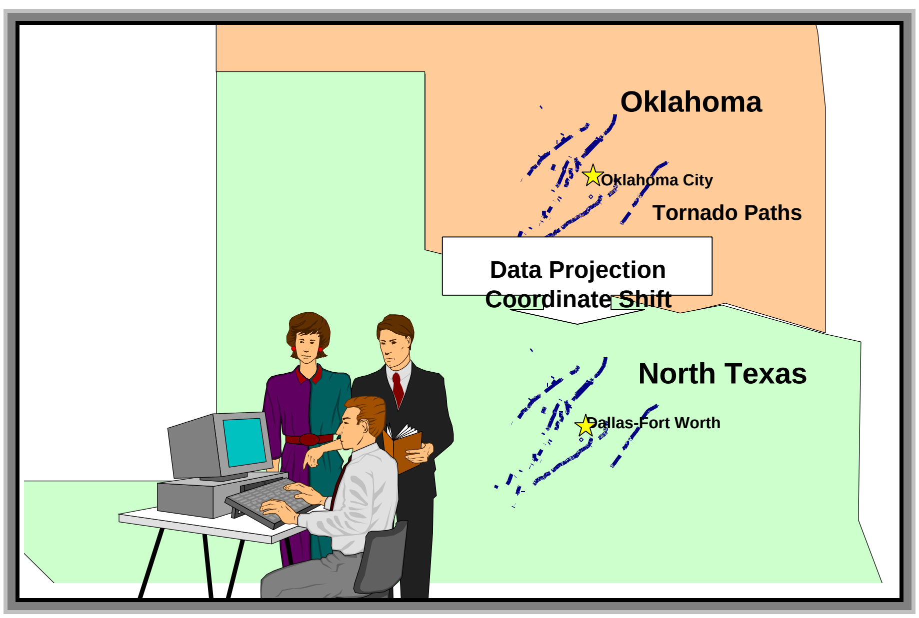


Tornado Study Area
(White Background)

Computer Application Methodology

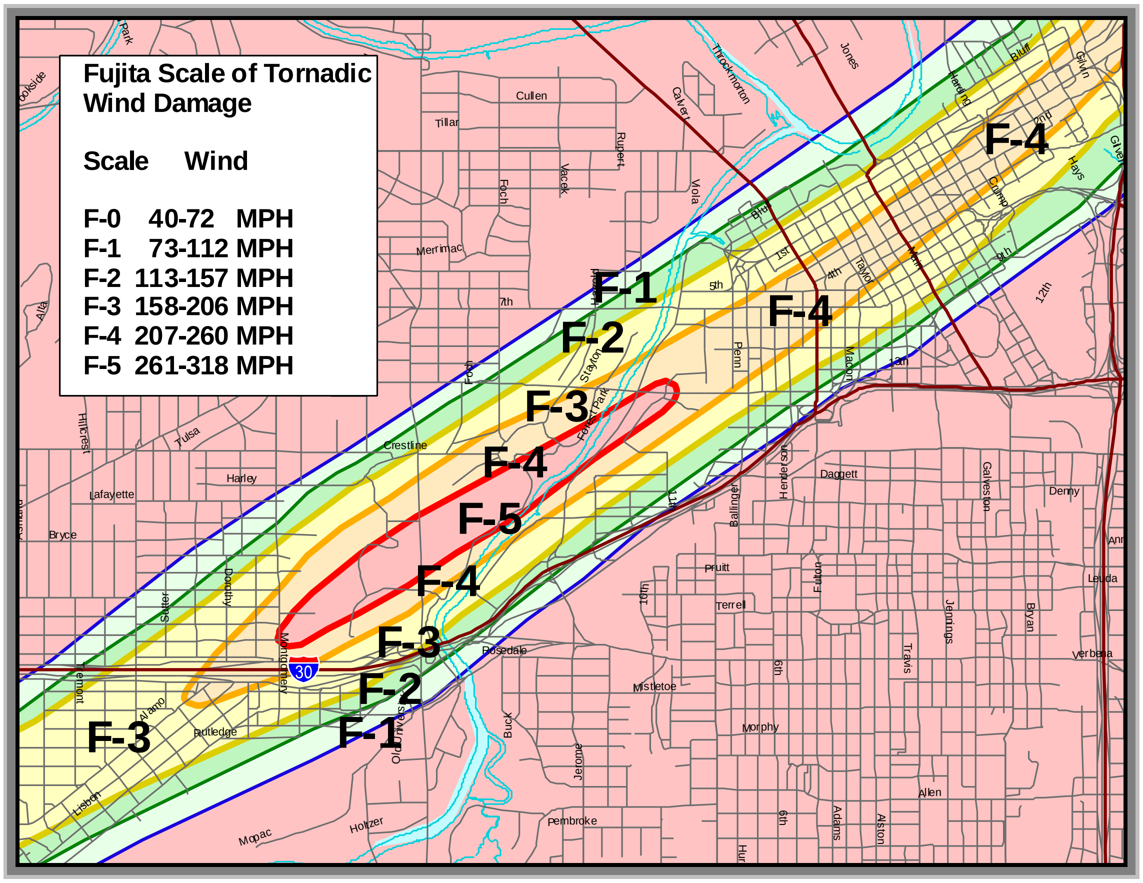
The goal of this study was to use urban analysis computer technology to estimate the threat to North Central Texas people and property that a major tornado outbreak could pose. The continuing growth and advancement of **Geographic Information System** (GIS) technology is making studies like this possible. GIS is utilized by the North Central Council of Governments and many North Central Texas cities as a primary tool to analyze, prioritize, and evaluate urban planning needs. It's role is prevalent in transportation, demographic, environmental, and emergency planning – and important geo-referenced databases continue to grow in detail and sophistication. The impact of a major tornado outbreak depends greatly on the characteristics of the area that it strikes, and GIS provides a way to analyze an area in detail.

In order to provide the most representative analysis, the actual tornado damage paths from the Oklahoma City tornado event were mapped and transposed across the North Central Texas geography. This mapping included 53 different tornadoes of varying size and strength. **Five(5) separate geographic scenarios** for the transposed tornadoes were chosen. The tornado paths maintained the precise size, length and direction of motion that they had in Oklahoma. The mid-point of the outbreak was shifted to North Texas and adjusted slightly North, South, East and West to make up the five scenarios. The scenarios were largely recommended by the National Weather Service Forecast Office in Fort Worth. The paths were chosen based upon both intuitive risk potential and apparent potential based on data trends. Note again that the relative geographical positioning of the various tornadoes and their direction of movement is the same as the Oklahoma outbreak. Thus, this is a real event transposed upon North Central Texas data.



Tornado Fujita Scale Damage Mapping

Boundaries of Expected Average Damage Losses



The Tornadoes used in this analysis were mapped using a distinct delineation of the Fujita Scale (F-Scale) damage regions as they occurred in Oklahoma. The F-Scale corresponds to the magnitude of damage occurring to structures. Information available from the Oklahoma event provided significant information on the tornado path widths, length, and F-Scale ratings and this information was used to re-construct aerial distributions and geographic extents of the tornadoes in the May 3rd outbreak. In cases where the data was too general, the tornado F-Scale boundaries were constructed by the computer using mathematical intervals. For the largest of the tornadoes, detailed damage path mapping was acquired from the National Severe Storms Laboratory, and the F-Scale boundaries were digitized into the Geographic Information System. In the Metroplex scenarios, the F-Scale regions represent areas where a *certain level of damage* is likely. In essence, it represents an **expectation**. Structures in a particular F-Scale zone in Oklahoma experienced a predominant category of damage that we are expecting would occur to Metroplex structures if subject to the same conditions in those zones. For this study, single family structures and apartment units were considered destroyed if in the F-2 level contour and mobile homes at F-1. The dollar values calculated for damages assumed an 80% loss of the appraised structure values at these levels. Commercial structures were expected, on average, to be more durable.

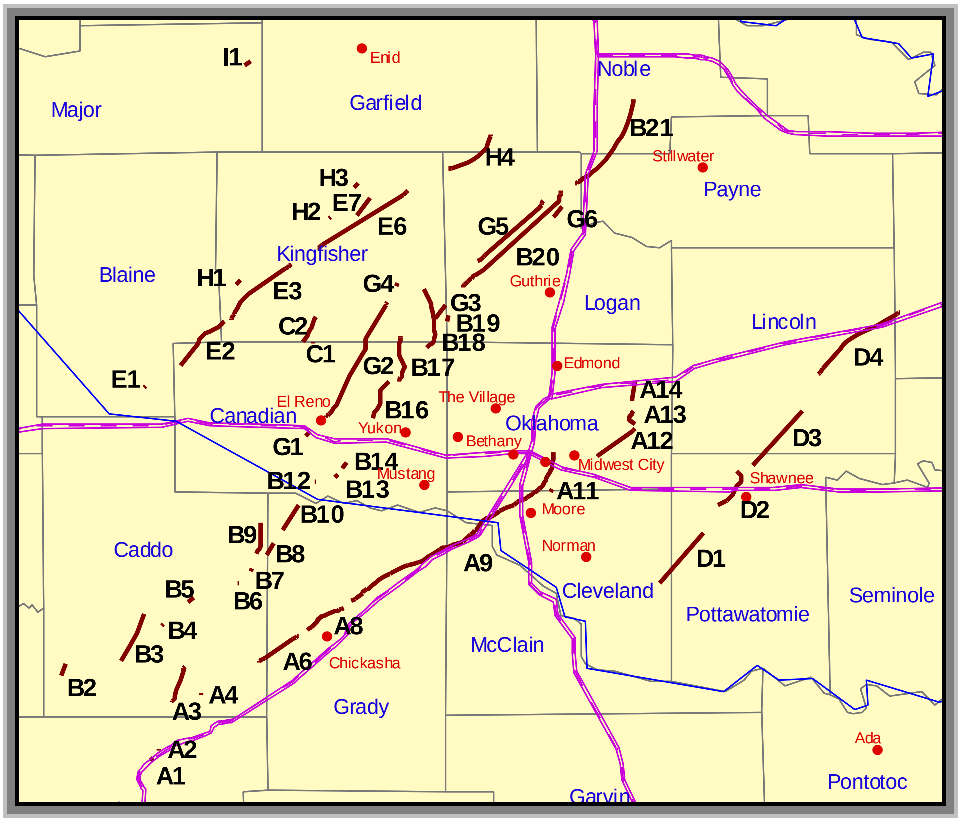
The Tornadoes

Fifty-three (53) tornado damage paths were mapped and included in this study. These ranged from very small and weak tornadoes, with paths as short as .1 mile and a Fujita rating of F-0, to very large tornadoes, with paths as long as 37.5 miles and a Fujita rating of F-5. The **prefix letter** in the tornado system (ie. A or B or C, etc…) refers to the **parent storm** producing the tornado. For instance, all of the tornadoes with A in the prefix (A1,A2,A3…A14) were all produced from the same tornadic thunderstorm at different times along the storm's path. These are referred to as tornado "families" and represent multiple stages in each thunderstorm's evolution and life. The family system codes were developed by damage surveyors with the National Weather Service in Norman, Oklahoma following the May 3 outbreak.

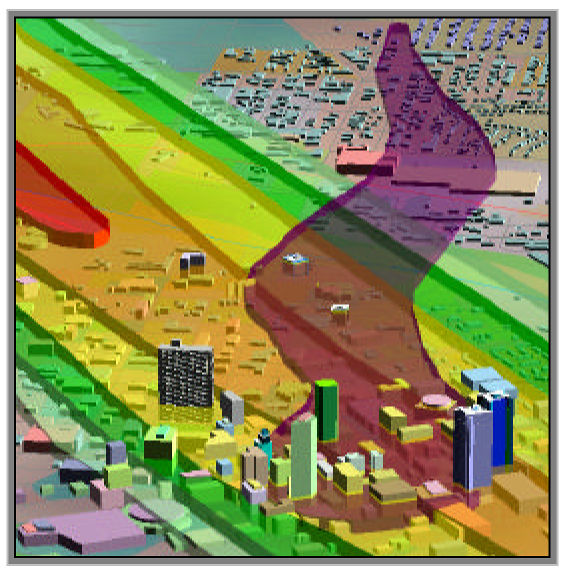
As the paths were together moved slightly east/west and north/south for each of the five North Central Texas scenarios, some of the tornadoes would shift to either intersect the outer study boundary or lie completely outside of it. In these cases, only the portion of the tornadoes that fit in the study area received calculations for damages. The chart below lists all of the tornadoes, their strength, size, hour of primary impact, and the proportion of each tornado's damage path that fell within the study area during each of the scenarios.

Tornado		Impacted Area				Time	Percentage of Tornado Path Falling in Study Area by Scenario				
System	Fujita Scale	Width (Feet)	Acres	Sq. Miles	Path Miles	Main Hour	One	Two	Three	Four	Five
A1	0	75	5.49	0.01	0.51	4 P.M.	0	0	0	100	100
A2	0	75	1.01	0.01	0.10	4 P.M.	0	0	0	100	100
A3	3	300	356.06	0.56	6.01	5 P.M.	21.30	0	0	100	100
A4	0	25	1.39	0.01	0.11	5 P.M.	100	0	0	99.95	99.95
A5	0	75	0.81	0.01	0.11	5 P.M.	100	0	100	100	100
A6	3	2640	1234.95	1.93	9.32	5 P.M.	100	100	62.37	100	100
A8	2	1500	366.78	0.57	4.33	6 P.M.	100	100	100	100	100
A9	5	5280	12242.4	19.12	37.52	7 P.M.	100	100	100	100	100
A11	0	180	7.44	0.01	0.32	7 P.M.	100	100	100	100	100
A12	2	660	344.94	0.54	6.32	7 P.M.	100	100	100	0	100
A13	0	150	44.77	0.07	2.53	8 P.M.	100	100	100	0	100
A14	1	150	48.36	0.08	3.05	8 P.M.	100	100	100	0	100
B2	0	75	40.78	0.06	2.01	6 P.M.	0	0	0	100	32
B3	1	450	374.92	0.59	7.95	6 P.M.	0	0	55	100	100
B4	0	75	1.68	0.00	0.24	6 P.M.	0	0	100	99.84	99.84
B5	0	75	16.92	0.03	1.02	7 P.M.	100	0	100	99.86	99.86
B6	0	75	1.47	0.01	0.16	7 P.M.	100	100	100	100	100
B7	0	75	15.91	0.02	0.52	7 P.M.	100	100	100	100	100
B8	1	900	245.12	0.38	2.11	7 P.M.	100	100	100	100	100
B9	1	150	88.32	0.14	4.94	7 P.M.	100	100	100	100	100

Chart Continued on Page 16

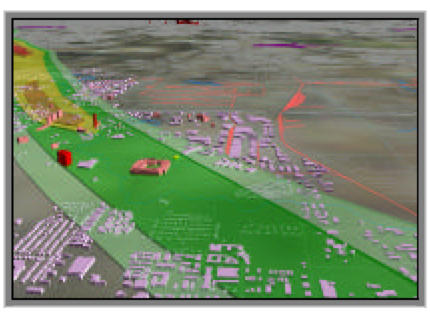


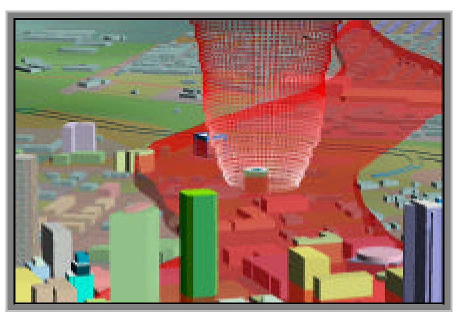
Above: *Tornadoes from the May 3 1999 Outbreak Included in this Study.* The map above shows the positions as they were mapped in central Oklahoma. This data set was moved south over the Dallas-Fort Worth Metroplex and merged with local data.

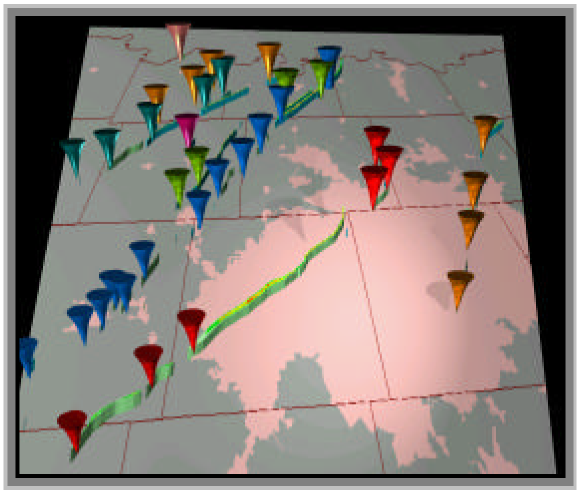


Above: Actual tornado damage in downtown Fort Worth due to a significant tornado on March 28, 2000. The right image shows the relative path sizes of the Fort Worth event (in purple) and the largest of the Oklahoma tornadoes through downtown (multi-contoured).

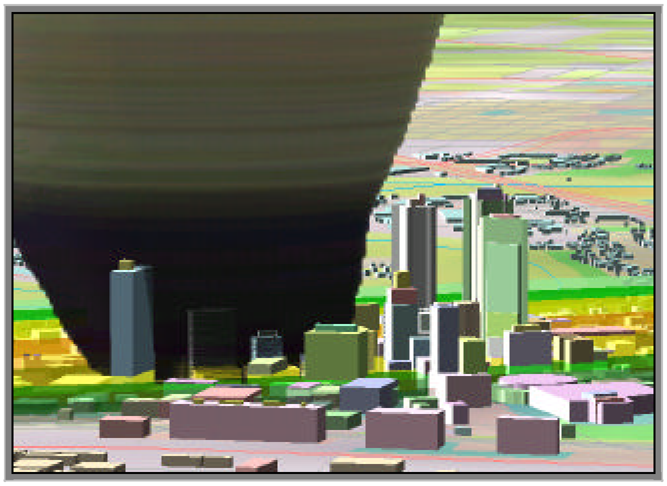
Tornado		Impacted Area				Time	Percentage of Tornado Path Falling in Study Area by Scenario				
System	Fujita Scale	Width (Feet)	Acres	Sq. Miles	Path Miles	Main Hour	One	Two	Three	Four	Five
B10	1	180	97.02	0.15	4.49	7 P.M.	100	100	100	100	100
B11	1	150	2.41	0.01	0.12	7 P.M.	100	100	100	100	100
B12	0	75	3.19	0.01	0.19	8 P.M.	100	100	100	100	100
B13	0	300	28.45	0.04	0.74	8 P.M.	100	100	100	100	100
B14	0	225	26.07	0.04	0.99	8 P.M.	100	100	100	100	100
B15	0	75	1.94	0.01	0.16	8 P.M.	100	100	100	100	100
B16	1	450	352.19	0.55	6.40	8 P.M.	100	100	60.45	100	100
B18	1	450	543.48	0.85	9.91	9 P.M.	100	100	100	77.06	87.61
B19	2	300	570.07	0.89	1.00	9 P.M.	100	100	100	100	100
B20	4	3960	9524.33	14.88	20.67	9 P.M.	98.83	77.73	19.05	0	0
B21	2	2640	5198.37	8.12	16.16	10 P.M.	0	0	0	0	0
C1	0	300	155.97	0.24	4.25	7 P.M.	100	100	0	100	100
C2	0	75	1.40	0.01	0.15	6 P.M.	100	100	0	100	100
D1	1	90	88.68	0.14	9.73	8 P.M.	100	100	100	87.67	100
D2	2	750	623.18	0.97	6.75	9 P.M.	100	100	100	0	9.09
D3	1	300	357.24	0.56	11.02	9 P.M.	60.90	73.10	100	0	0
D4	3	2250	4191.53	6.55	15.03	10 P.M.	0	0	80.39	0	0
E1	0	75	0.98	0.01	0.11	8 P.M.	100	0	0	100	0
E2	1	450	508.06	0.79	9.26	8 P.M.	88	0.12	0	100	0
E3	3	1350	2043.50	3.19	12.15	8 P.M.	51.49	0	0	37.57	12.78
E6	4	2640	4934.37	7.71	15.03	9 P.M.	100	66.58	0	0	0
E7	1	1320	595.34	0.93	3.52	9 P.M.	100	35.75	0	0	0
G1	0	150	17.30	0.03	1.00	9 P.M.	100	100	100	100	100
G2	3	1050	2587.08	4.04	20.34	10 P.M.	100	100	7.56	99.65	100
G3	0	450	142.44	0.22	2.55	10 P.M.	100	100	100	100	100
G4	0	150	9.11	0.01	0.51	10 P.M.	100	100	0	0	0
G5	3	2640	4203.04	6.57	12.92	11 P.M.	100	78.19	0	0	0
G6	2	1320	354.83	0.55	2.02	11 P.M.	100	0	0	0	0
H1	0	150	14.19	0.02	0.80	9 P.M.	0	0	0	0	0
H2	0	90	3.14	0.01	0.28	9 P.M.	100	100	0	0	0
H3	2	450	60.05	0.09	1.03	9 P.M.	70.43	0	0	0	0
H4	2	1320	1356.54	2.12	8.28	10 P.M.	0	0	0	0	0
I1	1	600	79.71	0.12	1.01	10 P.M.	0	0	0	0	0



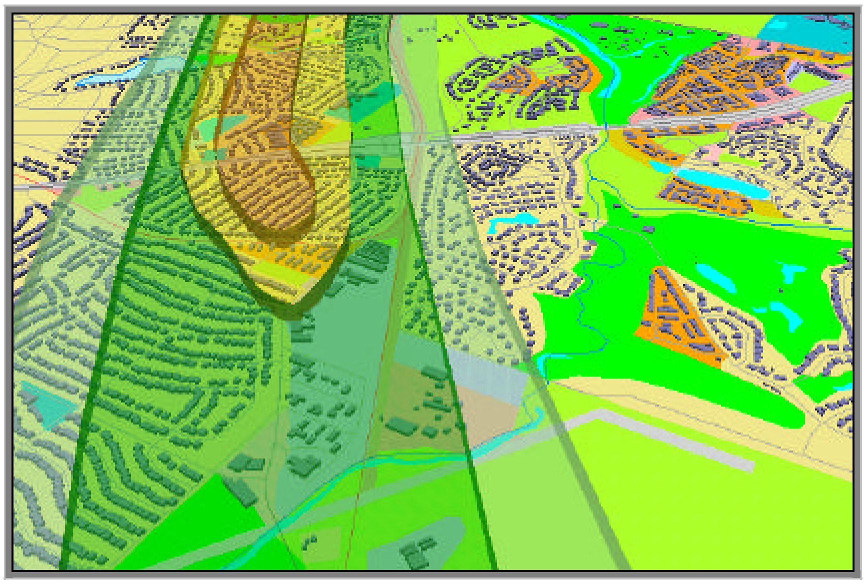




Above: *Thirty-Six (36) of the 53 tornadoes from the May 3, 1999 outbreak overlaid atop North Central Texas.* The tornadoes are positioned at the beginning of each of their ultimate damage paths. Similar colors represent tornadoes generated from the same thunderstorm.

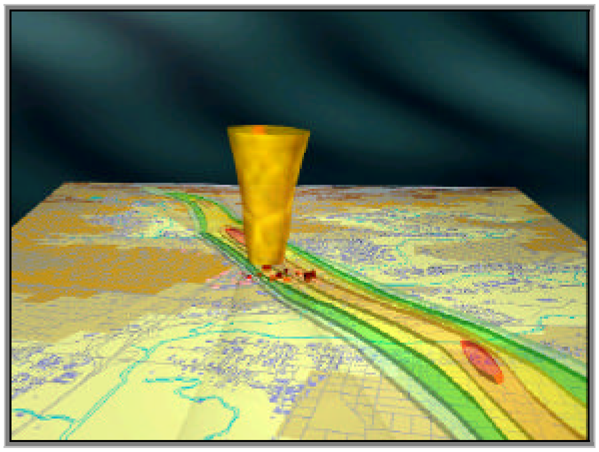


Above: *Computer representation of the largest of the tornadoes from the May 3, 1999 outbreak entering Downtown Fort Worth.* Simple GIS 3-Dimensional renderings allowed some basic visualization of the region's urban environment and its interaction with computer-generated phenomena.

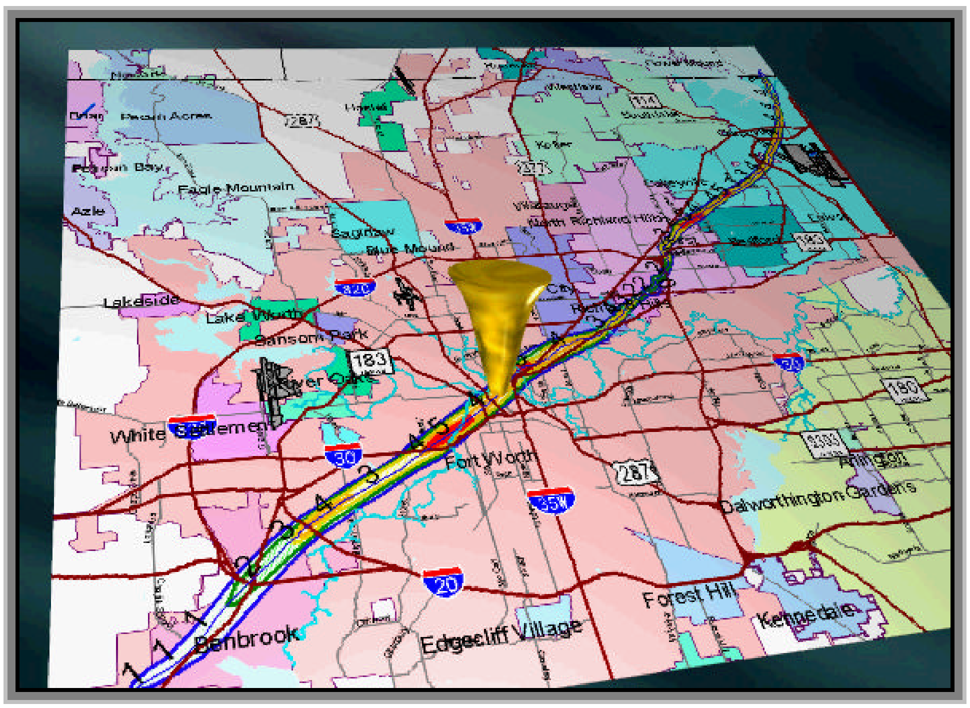


Tornado paths across Dallas-Fort Worth. GIS technology provided a means to estimate the number of structures and their appraised value beneath the tornado paths.

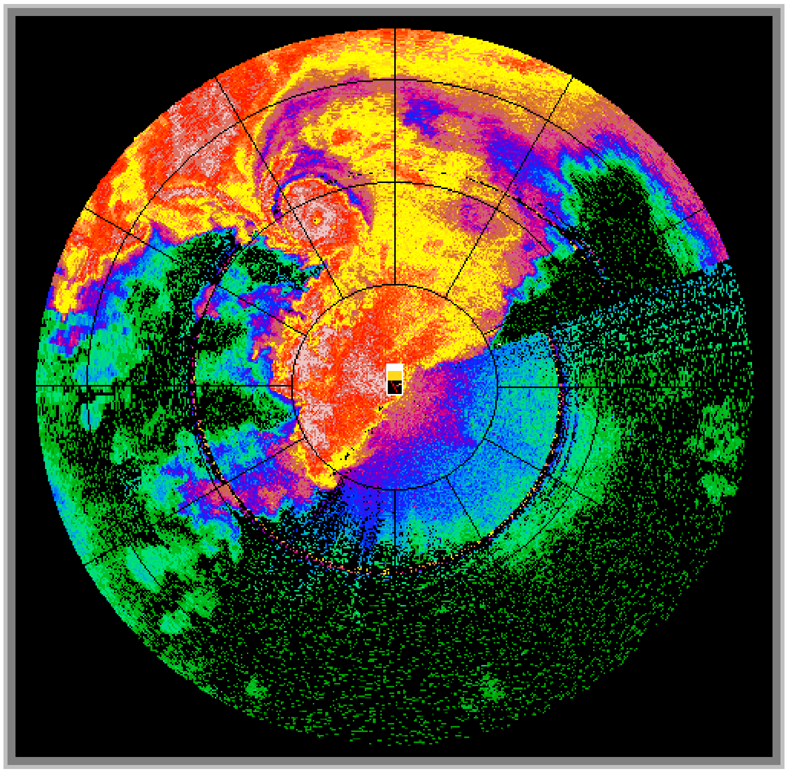
The Big Tornado "A9"



Tornado "A9" was arguably the largest of the outbreak. The trajectory of this large tornado into the Oklahoma City area certainly made it the most damaging. It is often referred to as the "Moore" tornado -- named after the southern suburb of Oklahoma City that received intense damage from the storm. It covered a 37 mile track and impacted almost 20 square miles of land. The study for North Central Texas uses this tornado as the focus for centering the entire outbreak. It is assumed to be the greatest threat to the metropolitan area. All of the scenarios include the entire length of this tornado in the study area, and most of its path impacts Tarrant or Dallas counties. This tornado also had the best mapping of its damage path through Oklahoma available. Fujita-scale damage contours for this storm were mapped in the Geographic Information System, and potential threats were identified with greater accuracy.

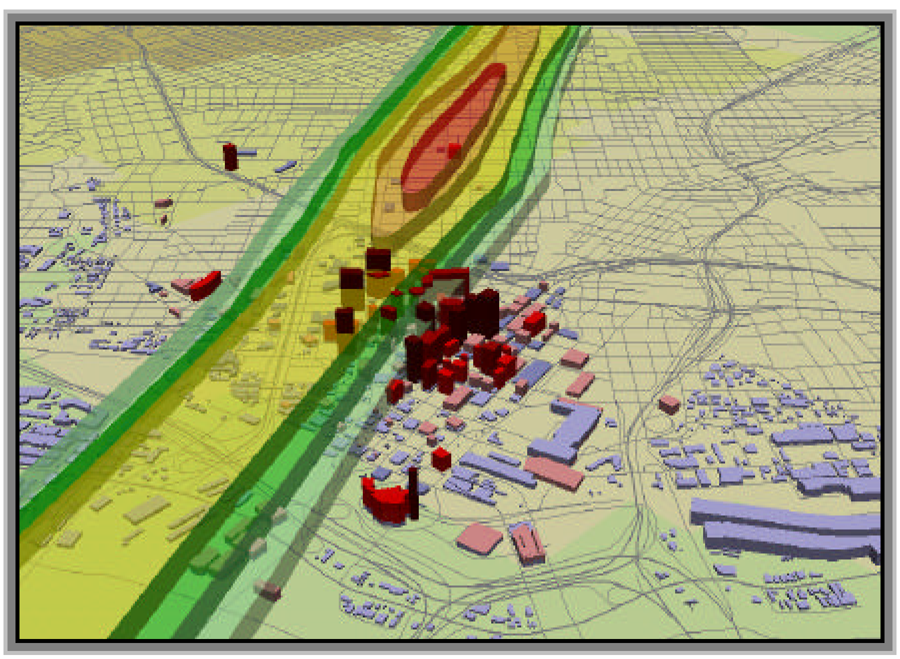


Above: *Computer simulated image of the path of tornado "A9" through the center of Tarrant County in scenario three.* The tornado passes through 8 different jurisdictions along this route.



Radar Image Courtesy of Joshua Wurman, University of Oklahoma

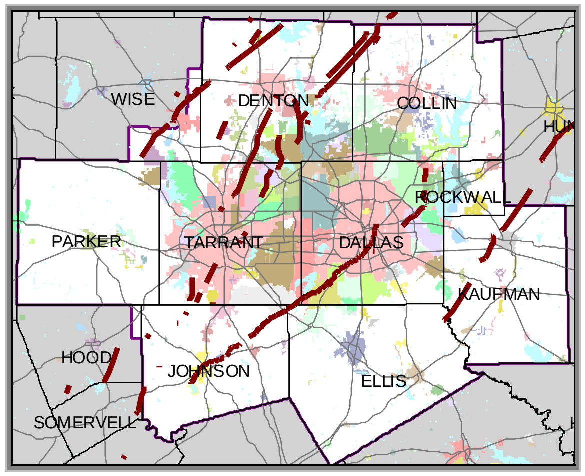
Above: *Radar Image of the Moore Tornado.* The storm was a mile wide at some points along its Oklahoma path. The "Doppler on Wheels" project collected the above radar data on the storm, and identified a wind velocity peak of over 300 miles per hour.



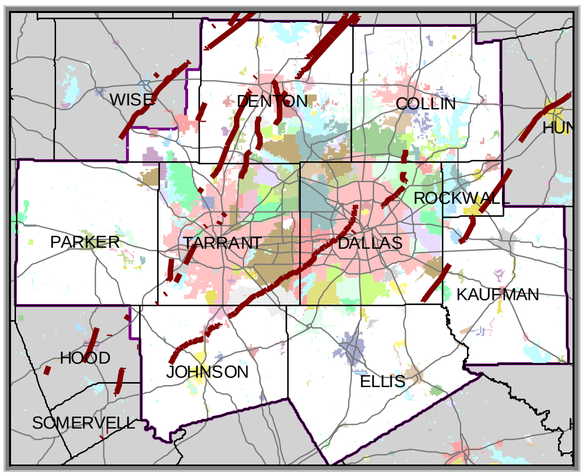
Above: *Projection of the Moore tornado path towards downtown Dallas in Scenario Four of the Study.* The storm was at a Fujita level of F-3 at this point, but quickly reaches F-5 beyond Central Expressway. The tornado would cause an estimated $2.8 billion in structural damage.

The Scenarios

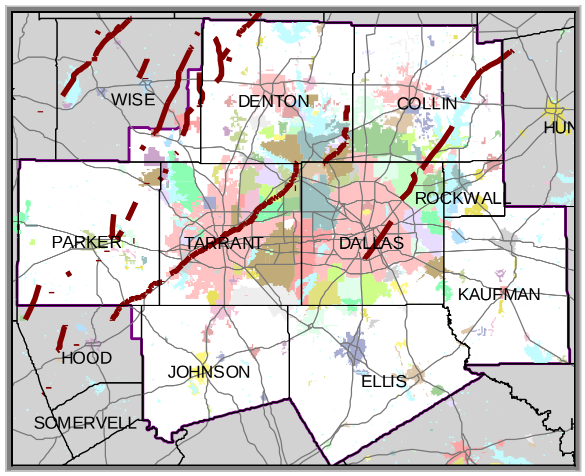
The 53 tornadoes that were mapped for this study were distributed across the Metroplex in 5 different alignment groups. All tornadoes maintained their exact length, width, and angle of direction. The variation in the scenarios was accomplished by moving the center point of the outbreak to 5 different locations. In all cases, the biggest tornado of the outbreak ("A9") took a path that was primarily over either Dallas or Tarrant counties.



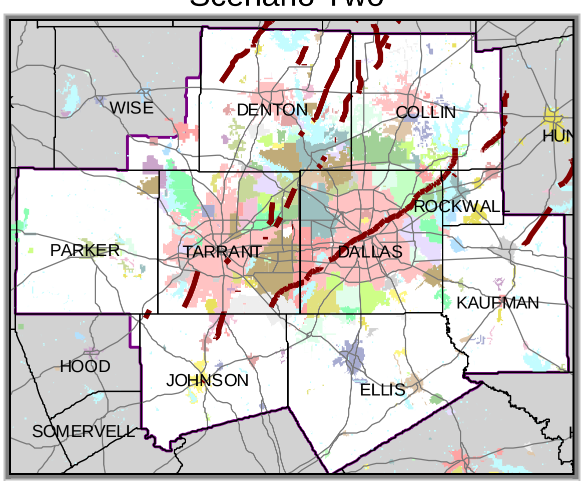
Scenario One



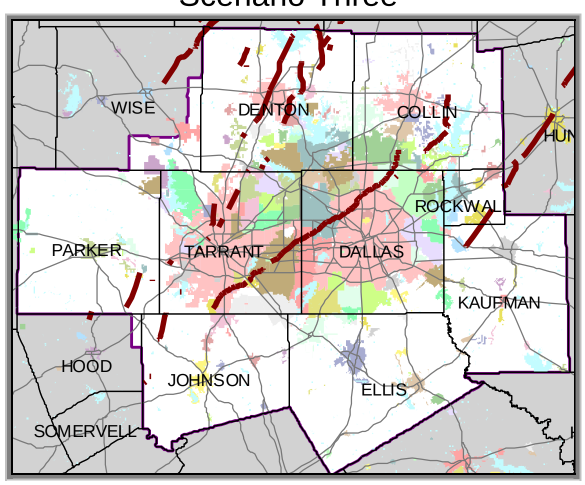
Scenario Two



Scenario Three



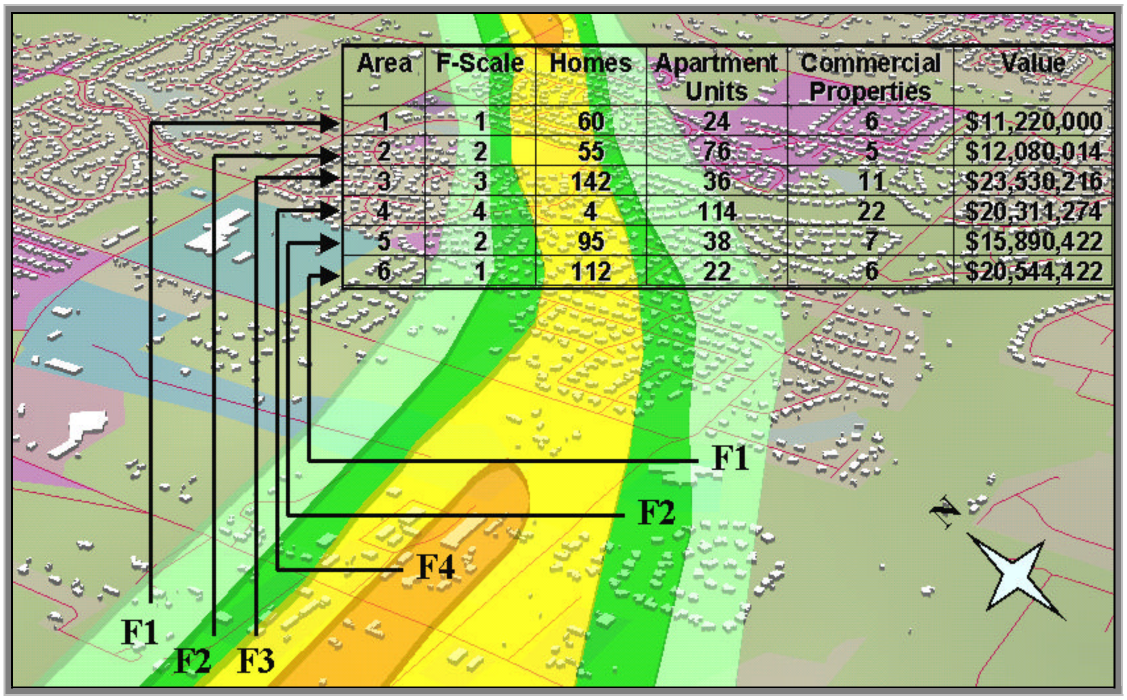
Scenario Four



Scenario Five

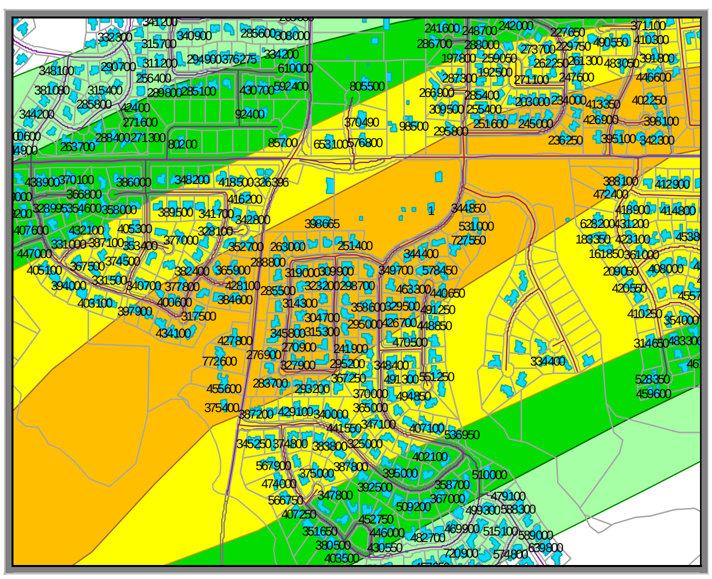
Summarizing Data By Fujita Damage Contour

Just How Much DFW Property Falls Inside of the Zones?



Area	F-Scale	Homes	Apartment Units	Commercial Properties	Value
1	1	60	24	6	$11,220,000
2	2	55	76	5	$12,080,014
3	3	142	36	11	$23,530,216
4	4	4	114	22	$20,311,274
5	2	95	38	7	$15,890,422
6	1	112	22	6	$20,544,422

GIS computer software allows databases to be summarized by the geographic positioning of their features. As the tornado path is directed across the DFW Metroplex geographic data, structures and attributes falling within the various Fujita mapping contours of the tornado can be identified and described. Although there is no direct correlation between how structures in Oklahoma reacted in these same zones and how DFW structures would react, there is little reason to suspect that DFW structures would fare significantly better. Over 90% of the structures falling in the paths in DFW are residential -- following similar building code, densities and neighborhood layouts.



Most of the data tables presented in this document are designed to provide a summary of property quantity, types, and total value located within the mapped Fujita contours. Similarly, residential population, employment, and traffic are summarized by these zones. In terms of individual damage ratings, not every structure in these zones in Oklahoma was rated with the Fujita scale of the contour, but the occurrence of that level of damage was significant and much repeated. The Fujita scale rating may vary somewhat, but the *average* dollar loss throughout the contour may not change much when applied to multiple structures. For every structure that fares better than expected within a contour, another may fare worse.

Summary of Study Findings

If the Oklahoma May 3, 1999 tornado outbreak had occurred over North Central Texas and followed the same direction of motion and produced comparable damages, the potential damages could have easily exceeded $3 billion. This estimate is based entirely on structures (buildings) and an estimate of contents of the buildings. This does not include other types of property such as cars, utilities, and infrastructure. Of the 5 distinct tornado path scenarios that were tested, 3 approached or exceeded the $3 billion damage mark. Two of those three scenarios hit downtown, but one followed a path directly through the center of the Metroplex without impacting downtown Dallas or Fort Worth. Ironically, despite missing the expensive high-rise real estate of downtown, that one scenario would match if not exceed the overall structural damages of the storms that passed through the downtown areas.

The two tornado scenarios that began the outbreak the greatest distance to the south (1,2) -- starting the "Moore" tornado in Johnson County -- would have resulted in the lowest damage totals, lowest overall traffic in the path, and smallest population impacted. This is due to a combination of fewer structures in the path and lower appraisal values for the structures that are in the path. The majority of the land hit by the tornadoes would qualify as "vacant" in these scenarios. None the less, the damage totals would likely be similar to those that occurred in the Oklahoma outbreak. The southerly positioning of the outbreaks would also be threatening to Denton County, bringing at least 12 separate tornado paths through the county in scenario one. Two of those tornadoes would have been classified as F-4.

In the three scenarios that occurred a greater distance to the north (3,4,5) – beginning the "Moore" tornado within either Dallas or Tarrant counties – the potential damages were extensive. At least 15,000 – 17,000 single family homes would have been damaged in each of the scenarios, with 9,000 – 10,000 of those destroyed. Scenarios four and five would have each surpassed $1 billion in damages to single family homes alone. The tornadoes in scenario five would have damaged over 19,000 apartment units – 11,500 of which would have been destroyed. Commercial property damages in all three of the scenarios would near or surpass $1.5 billion, with 1,200 – 1,700 structures in the path. The potential damage totals for each of the three scenarios ranged from 23,000 – 38,000 structures and $2.85 billion - $3.0 billion.

A lot of people could be in the way, either in residences, places of employment, or on the roadway. All scenarios would find at least 30,000 residents living in the path and 14,000 people working in the path. Of course, there is no guarantee how many of these people would actually be at their place of employment or at home during the time of the tornado impact. It is likely that people would be distributed in some combination of home, work and travel. In scenario five, 84,000 people live in the path of the tornadoes. In scenario four, 94,000 people work in the path of tornadoes. In the three more northerly scenarios, somewhere between 1700 and 7700 vehicles will likely be moving across the actual path of the tornadoes as they overtake freeways and arterial roadways. If those roadways were all congested (traffic jam), 60,000 – 87,000 cars could be sitting there in the path.

People and Traffic In Tornado Paths

Residents and Employees in Tornado Paths
(Estimate of everyone who lives or works in structures in Tornado Paths)

Scenario	Total Residents	Residents in F-2 or Greater	Total Employees	Employees in F-2 or Greater
1	34644	14178	10423	5722
2	34030	17706	19131	10062
3	51312	33378	64636	52242
4	69357	43203	94186	55992
5	84023	49795	65976	34620

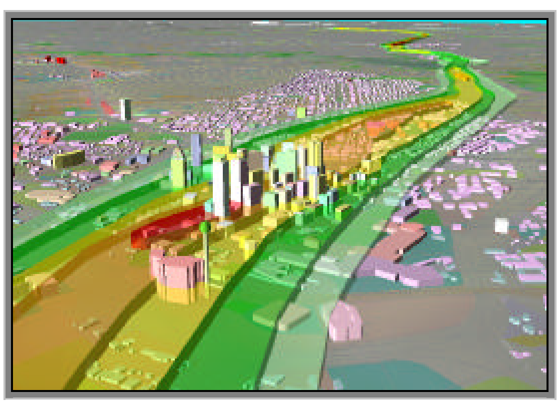
Miles of Transportation Routes in Tornado Paths
(Major Routes and Local Residential Routes – All Routes in the Database)

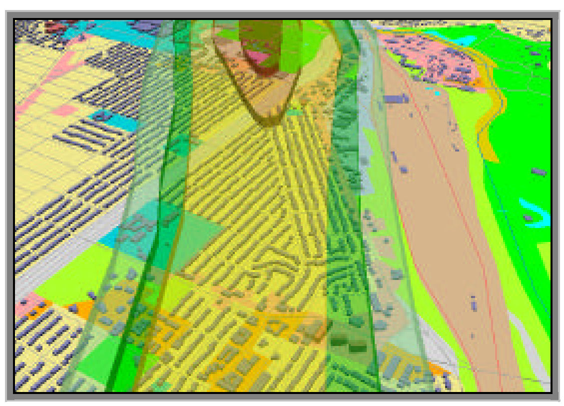
Scenario	Total Road Miles	Road Miles in F-2 or Greater	Total Railway Miles	Railway Miles in F-2 or Greater
1	294.91	155.80	10.52	6.02
2	270.11	144.05	24.70	14.26
3	400.30	256.21	20.39	10.12
4	344.34	211.48	18.06	12.66
5	344.90	186.07	16.29	8.06

Major Roadway Traffic in Tornado Path
(See the Following Pages for an Explanation of Terms)

Scenario	Hourly Traffic on Routes Crossed by Tornado	Cars Projected in Path if Traffic at Normal Roadway Vehicle Volumes	Cars Projected in Path if Roadways all Experiencing Traffic Jams
1	*104697	*635	44635
2	*101970	*643	39329
3	*169376	*1737	79581
4	*181933	*1833	87099
5	*213349	*2485	87044

* Estimated based on daily modeling totals and hourly multipliers





Other sensitive features would be in the path of these storms. Multiple schools would be hit in all of the scenarios. At least one would be in an F-4 or F-5 damage path. In scenario two, five schools would be in F-4 or F-5 categories. In scenario four, 27 schools would ultimately be located in F-1 or greater categories.

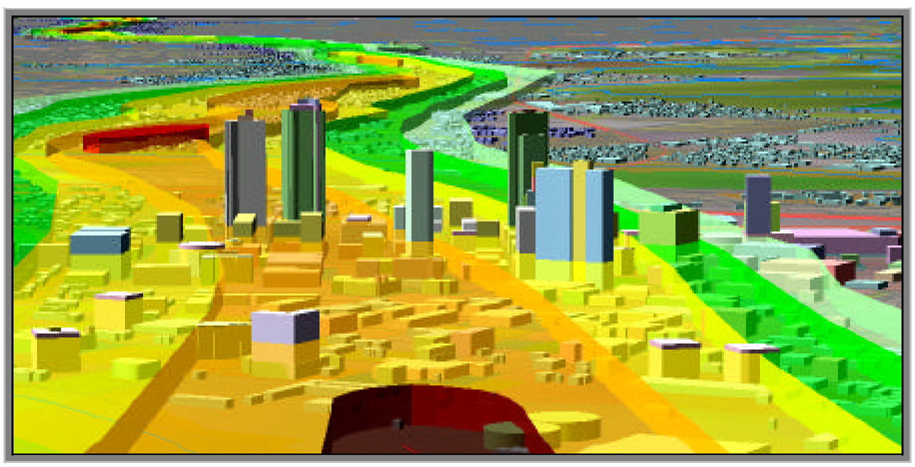
Across a large metro area like Dallas-Fort Worth, there would be many significant electrical utility lines in the path. No scenario saw less than 20 individual locations where a major utility line crossed an F-2 damage path. Thirty intersections could be identified in scenario five.

The miles of roads in the path would be very large. As many as 400 miles of roadways would be impacted by the tornadoes. In scenario three, nearly 45 miles of roads would be impacted by F-4 or F-5 level categories alone.

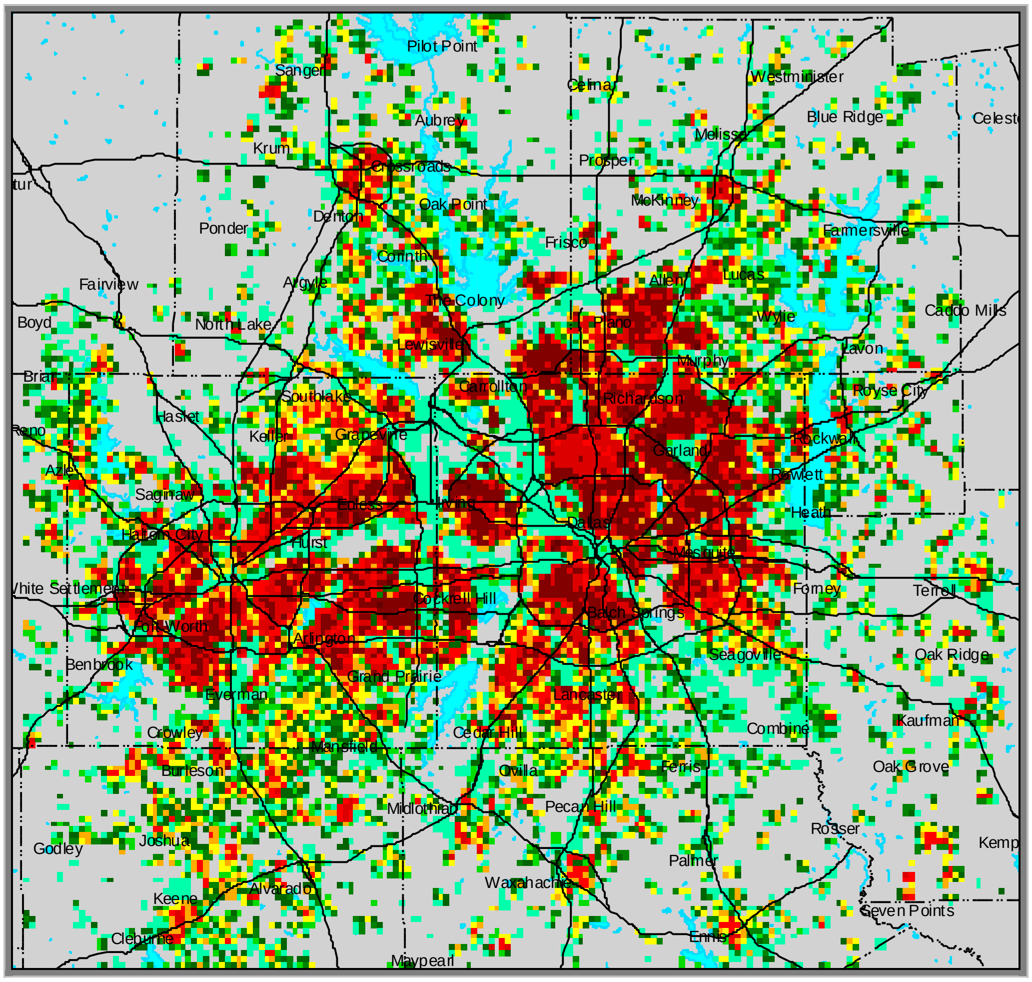
The impact of a tornado outbreak of this magnitude would be dramatic. A direct path through the Dallas-Fort Worth Metroplex would put a record number of structures, residents, and vehicles in the path. As the region grows, the target grows. It is hard to image the losses that could mount if the 84,000 residents in the path of the scenario five tornadoes, or the 94,000 employees in the path of the scenario four tornadoes were to ignore warnings or take the situation lightly.

Other Damages

The dollar numbers in this study only reflect an estimate of structural and content values in the path of the tornadoes. There will likely be a very significant collection of additional costs resulting from the outbreak. These will include, but are not limited to: city infrastructure damage, damage to vehicles, utility damages, communication systems failures, debris removal and disposal, repair and reconstruction crew overtime, city staff overtime, temporary housing costs, and lost income due to business interruption. There are some thoughts that these other costs could ultimately be equal to those incurred by the structural damages. If realized, the total cost of the urban core scenarios would likely be in the 5-6 billion dollar range.



Above: *Projection of the Moore tornado path towards downtown Fort Worth in scenario three of the Study.* This same portion of the storm caused F-4 damage in Oklahoma.

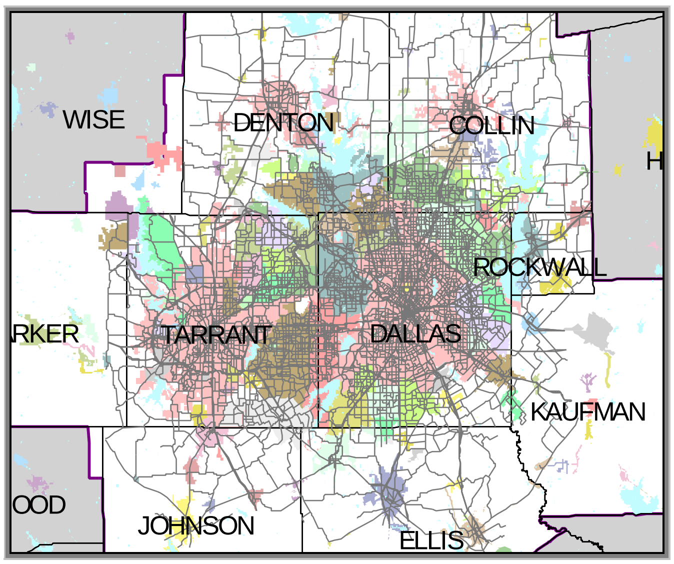


Legend	
Total Residents	
	0 - 20
	20 - 50
	50 - 100
	100 - 175
	175 - 300
	300 - 450
	450 - 700
	700 - 1000
	1000 - 2500
	> 1000

Above: *Total estimated residents living in the Dallas-Fort Worth area as distributed in uniform 2400x2400 foot grid cells.* The total resident population in each grid is a function of the number of structures, the type of structure, the average household size for the local jurisdiction, and the average occupancy rate in that jurisdiction. High density residential areas, such as apartments, will tend to feature many more residents for unit area than single family houses, even though the average number of people living in a typical house is larger than a typical apartment unit.

Estimating Traffic in the Path of Tornadoes

Traffic figures for vehicles in the path of the tornadoes are based on NCTCOG transportation modeling for major thoroughfares in the region. The data is an estimate of road volumes and capacities across more than 21,000 links throughout the Metroplex, many of them calibrated to actual traffic count data. The models include estimates for freeways, arterials, and collectors, but do not include local residential streets. For each scenario, we estimate the number of vehicles that, as a function of volume, speed, time, and distance, should be located on the actual roadway pavement in the tornado's path at the time the tornado overtakes the route. **Hourly traffic** numbers provide an estimate of how many vehicles would actually cross the path during the hour of the tornado's primary impact. **Vehicles trapped** numbers are estimates of how many vehicles should theoretically be on the roadway in the tornado path when the tornado strikes (under varying traffic levels).



NCTCOG Transportation Modeling Network

During a day, a certain number of vehicles are expected to travel between 2 points on a specific road segment (link) in the region. The transportation model yields a good assessment of how many cars (volume) should travel on each link during the day. A table of specific multipliers is used to determine how much of that daily traffic is expected to cross the segment during each hour of the day. From that data, a snapshot is taken. If 2000 cars are expected to pass through a 100 yard section of the road (the eventual tornado impact area) during a given hour, mathematically, a certain number will likely be there at any given instant during the hour. This is a function of the length of road segment, the number of cars passing through over a given period of time, and the speed at which they travel through.

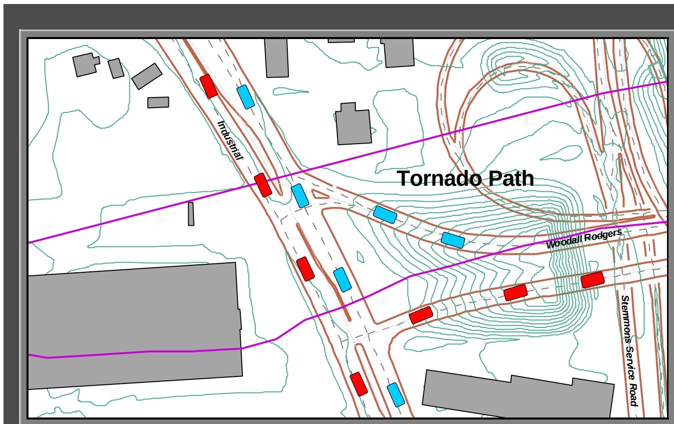
Thus, the math boils down to a couple of pretty simple conclusions:

- If the length of the road segment hit by the tornado is short, only a few vehicles pass through it, and the vehicles pass quickly through it, then few if any vehicles will be there at the instant the tornado overtakes the road segment.

- If the length of the road segment hit by the tornado is long, a lot of vehicles pass through it, and the vehicles move slowly (they are there for a long time), the odds are high that vehicles will be there at the instant the tornado overtakes the road segment.

There are, of course, many variations in between.

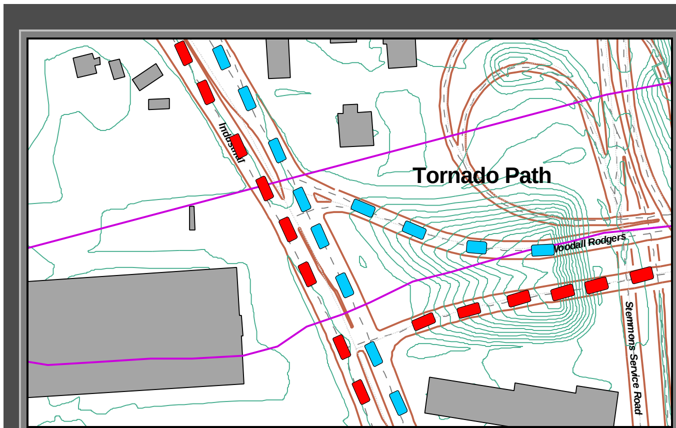
The numbers derived for this summary are based on daily information that has been broken down from daily modeling totals to an instant in time. The best bet for planning purposes is to use the range of figures provided -- traffic will probably fall somewhere in between normal and congested. Traffic behavior can not expected to be “normal” when drivers encounter a mile-wide F-5 tornado approaching the freeway. The worst case scenario is complete congestion or a “traffic jam”.



Above: 6 vehicles trapped in the path

Normal Daily Volume

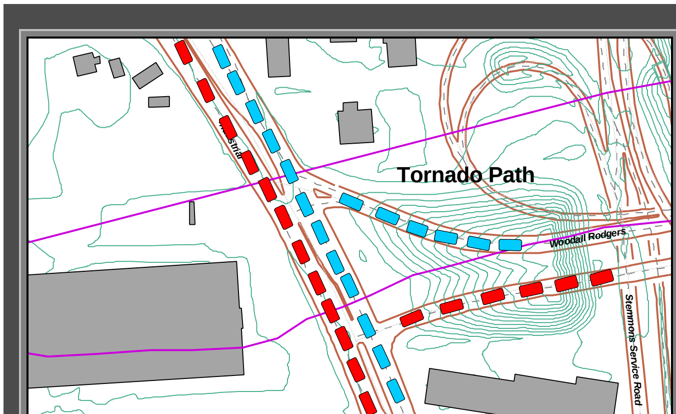
Imagine a typical weekday in Dallas-Fort Worth during the hour of the tornado strike. The modeled normal daily volume data provides an estimate of how many cars should pass across a given link during that hour. By spreading that traffic out uniformly though out the hour, we estimate the number of cars that should be in the path at that time when traffic is <u>normal.</u>



Above: 10 vehicles trapped in the path

Capacity Volume

At roadway capacity, the road segment is passing as many vehicles as it is can from one point to the next. Traffic moves slower and spacing between vehicles decreases. Traditionally, the capacity volume is higher than the normal daily volume. By spreading that traffic out uniformly though out the hour, we estimate the number of cars that should be in the path at that time when roadway is filled to <u>capacity</u>.



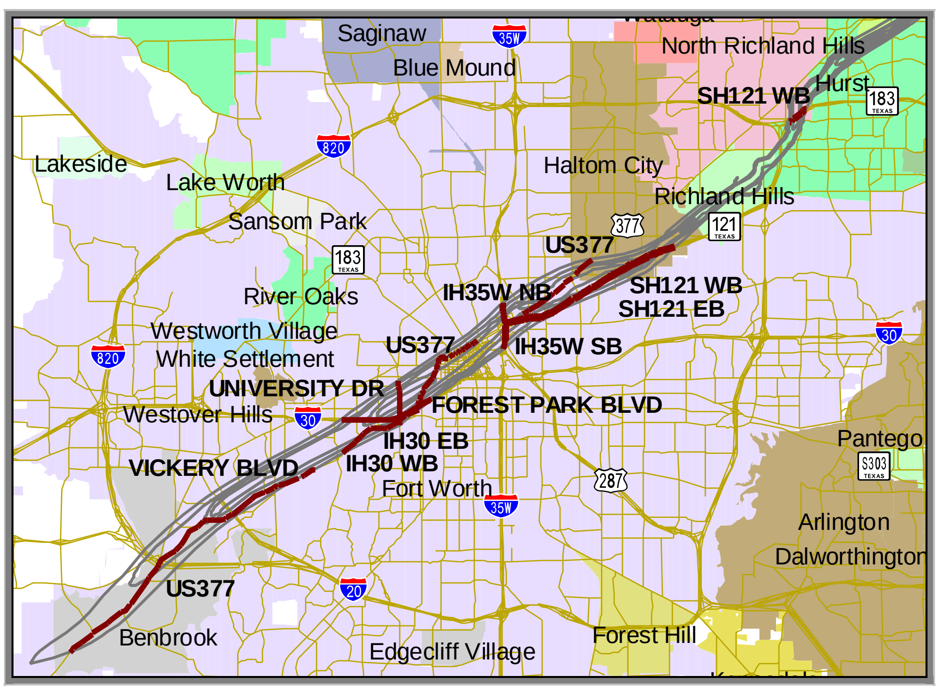
Above: 16 vehicles trapped in the path

Traffic Jam

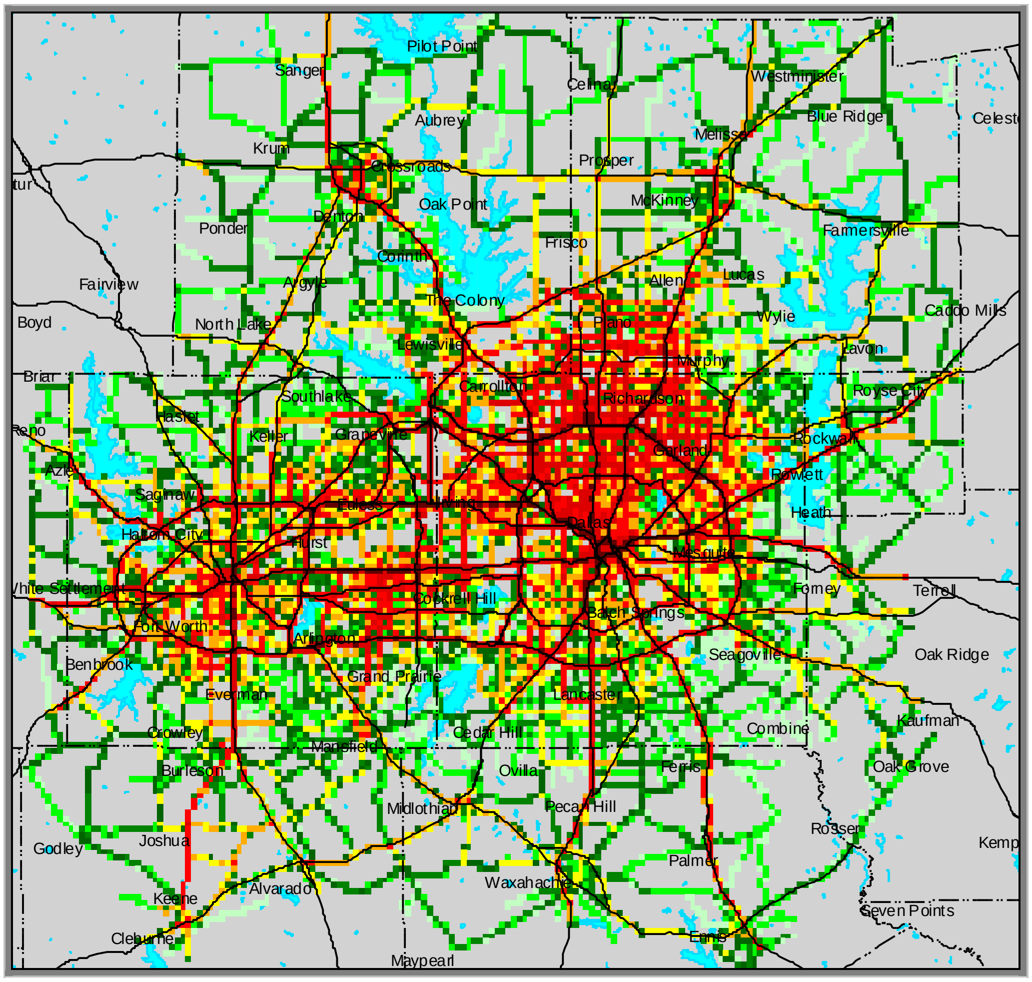
The roadway volume has exceeded capacity. Speeds slow and roadways become congested. The distance between cars decreases. For this calculation, volume is not considered. Instead, the length of the road segment and the number of lanes is used. A spacing of one vehicle per 25 feet or so is used to estimate the density. Huge car numbers would be in the path.

Roadways with the Largest Estimated Number of Vehicles Threatened in Tornado Paths under Normal Volume Conditions

Roadway Name	Scenario	Maximum Fujita Scale on Route	Miles in Path	Road Lanes	Vehicles Threatened in Tornado Path
SH121 West Bound	3	4	4.89	4	162
SH121 East Bound	3	3	4.23	4	154
US377	3	4	5.87	4	118
SH183 West Bound	2	4	2.10	3	111
SH183 East Bound	2	4	2.07	3	105
IH30 East Bound	3	4	2.18	5	98
US75 North Bound	2	4	1.51	4	93
IH30 West Bound	3	4	2.22	5	95
US75 South Bound	2	4	1.37	4	86
IH30 West Bound	4	4	1.66	3	79
VICKERY BLVD	3	3	6.35	4	79
FORT WORTH AVE	4	4	3.32	6	77
IH30 East Bound	4	4	1.61	3	75
WOODALL ROGERS West Bound	4	3	1.43	5	69
WOODALL ROGERS East Bound	4	3	1.31	4	66
SH78	4	4	1.85	6	60
IH35E North Bound	4	3	0.72	5	60
GREENVILLE AVE	2	4	1.88	6	60



Above: Scenario Three: *Transportation freeways and arterials with potentially 25 or more vehicles in tornado paths under normal traffic weekday volumes.* Over 5 ½ miles of routes US 377 and Vickery Boulevard would be in a tornado path rated F-1 or greater.

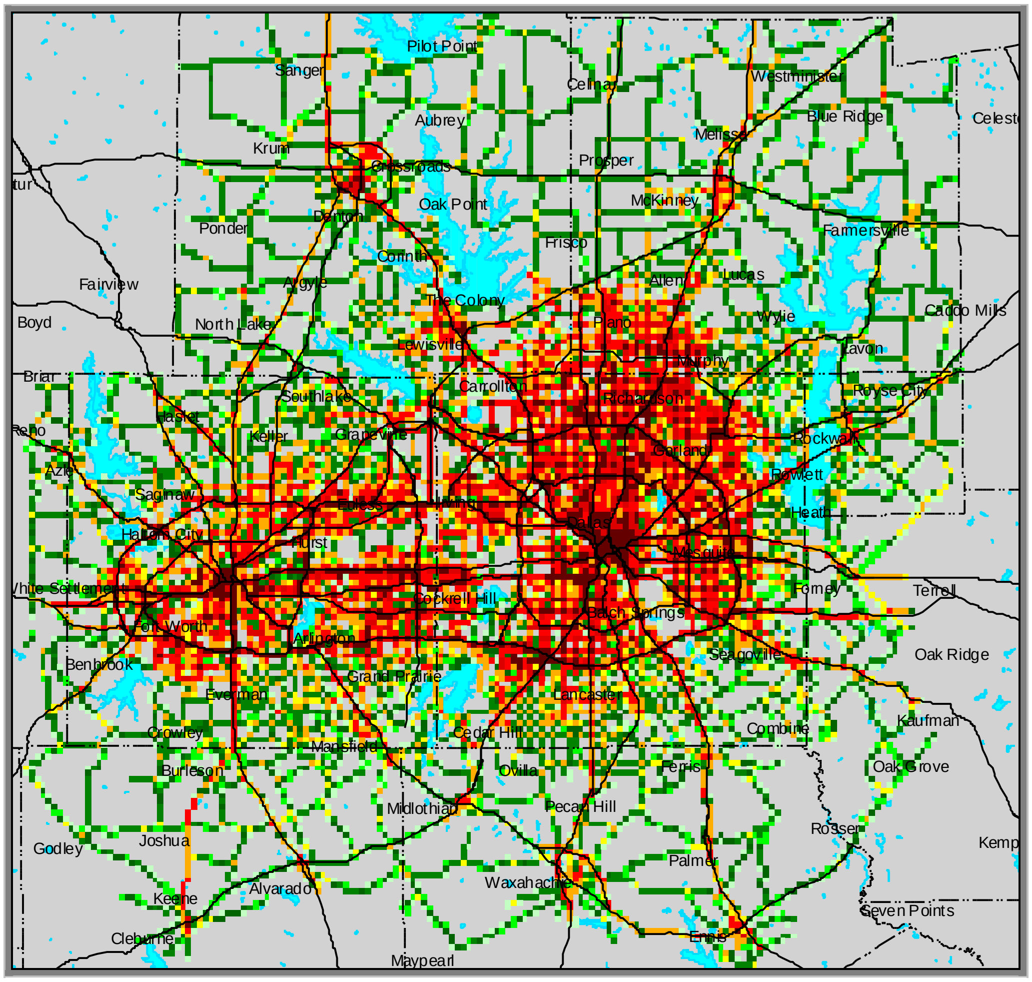


Legend

Number of Vehicles

- 0
- 1
- 2 - 3
- 4 - 6
- 7 - 11
- 12 - 20
- 21 - 38
- 39 - 100
- > 100

Above: *Normal traffic density at 6:00 P.M. on major thoroughfares in the Dallas-Fort Worth area as distributed in uniform 2400x2400 foot grid cells.* The above numbers apply for a typical weekday and only include routes designed for handling significant urban traffic flow – not residential streets. The use of a density allows us to assume how many vehicles should be located on those roadways in any given grid cell at any instance in time during the 6:00 hour. Since the numbers represent typical daily conditions at that hour, it is assumed that those vehicles will have either have to alter their travel plans at the time of the tornado strike, or be caught in the tornado itself. Either way, some impact is likely for those drivers.



Legend

Number of Vehicles

- 3 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 500
- 500 - 800
- 800 - 1000
- > 1000

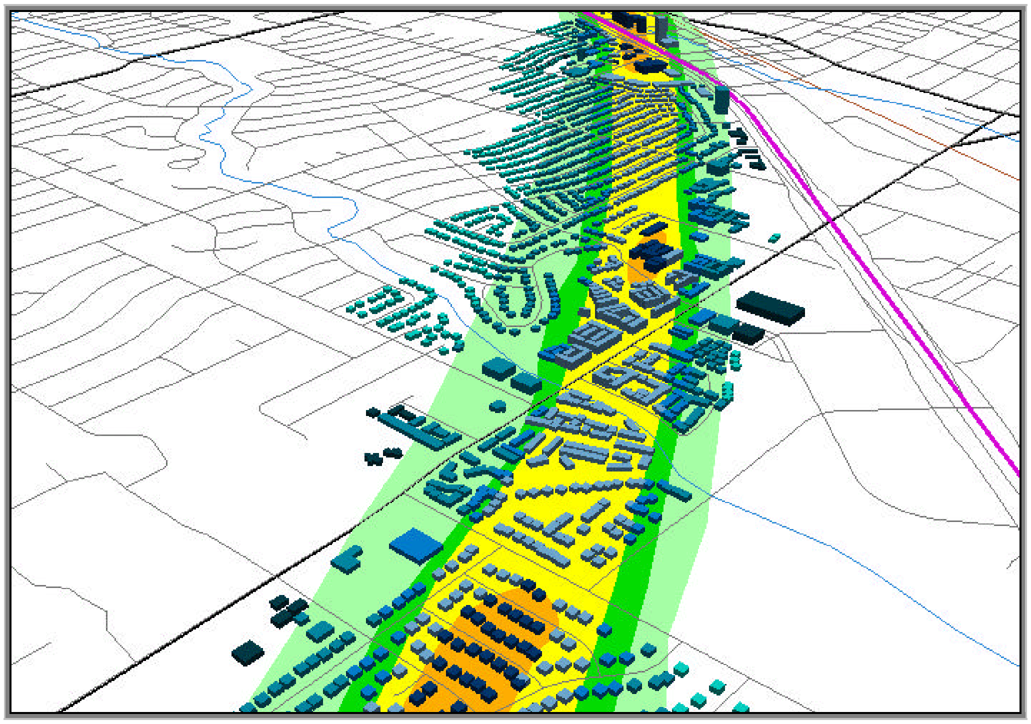
Above: *Traffic density on major thoroughfares in the Dallas-Fort Worth area under conditions of complete grid-lock as distributed in uniform 2400x2400 foot grid cells.* The values represent a basic assumption that the carrying capacity of the roadway lanes has been reached and there is little or no flow. The values represent a density of one car per each 25 feet of roadway lane. This condition is very likely in a chaotic or panic situation. Vehicles looking for protection under a bridge can easy block other vehicles on a congested roadway behind them. The number of vehicles is naturally a function of both roadway length and the number of lanes.

Roadways with the Largest Estimated Number of Vehicles Threatened in Tornado Paths under Congested (Traffic Jam) Conditions

Roadway Name	Scenario	Maximum Fujita Scale on Route	Miles in Path	Road Lanes	Vehicles Threatened in Tornado Path
US377	3	4	5.87	4	3540
VICKERY BLVD	3	3	6.35	4	3043
FORT WORTH AVE	4	4	3.32	6	3009
SH121 West Bound	3	4	4.89	4	2469
LIVE OAK ST	4	5	2.67	7	2373
ROSS AVE	4	4	3.43	6	2162
SH121 East Bound	3	3	4.23	4	2149
GASTON AVE	4	4	3.30	4	1993
GREENVILLE AVE	5	4	1.88	6	1702
SH78	4	4	1.85	6	1496
COMMERCE ST	4	4	2.31	6	1403
JEFFERSON BLVD	4	2	1.72	6	1325
IH30 West Bound	3	4	2.22	5	1208
IH30 East Bound	3	4	2.18	5	1164
BALLPARK WAY	5	2	1.37	6	1143
SH5	5	4	1.52	6	1056
BELT LINE RD	5	5	1.50	6	1042
KIEST BLVD	1	4	1.20	6	1030

Above: Scenario Four: *Transportation freeways and arterials with potentially 750 or more vehicles in tornado paths under congested (traffic jam) conditions*. Four separate routes could see 2000-3000 vehicles in the path at the time of the tornado strike.

Structural Damage Estimates



Damage Path of Scenario 5 North of I-635 and East of 75 in North Dallas.

Total Damage Estimates By Scenario

Scenario	*Structures Impacted	**Property Value in Path	***Potential Damages
1	17,070	$1,630,613,000	$811,000,000
2	14,363	$1,652,263,000	$790,000,000
3	23,380	$4,188,993,000	$2,652,000,000
4	30,887	$5,013,443,000	$2,808,000,000
5	38,463	$5,064,222,000	$2,859,000,000

* An Individual Apartment Unit is Considered a Single Impacted Structure in the Summary
** Property Value in Path is the total structure and content value located within the tornado paths.
*** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.

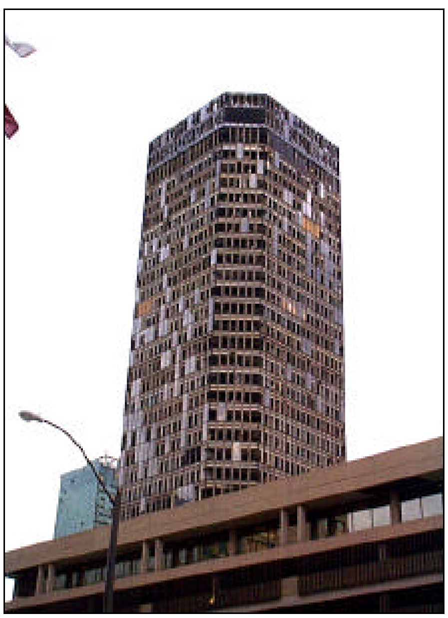
Estimation of Potential Damage Dollar Losses

Structural *"Potential Losses"* calculations represent an attempt to scale down the total structural property value based upon each structure type and the Fujita Scale contour containing the structure. In this way, the Fujita Scale contours used in the mapping are treated as *zones of expected average losses*. This calculation is more appropriate for residential structures than it is to commercial structures. Commercial structures experience a wide variety of construction methods, materials, and designs. Only broad assumptions are made.

Structure Category	Fujita Contour Containing Structure	Percentage of Appraised Structure Value Considered Lost Due to Damages
Single Family Home	1	(0-20%) 10.00%
Single Family Home	2	(60-100%) 80.00%
Single Family Home	3	(80-100%) 90.00%
Single Family Home	4	100.00%
Single Family Home	5	100.00%
Apartment Unit	1	(0-20%) 10.00%
Apartment Unit	2	(60-100%) 80.00%
Apartment Unit	3	(80-100%) 90.00%
Apartment Unit	4	100.00%
Apartment Unit	5	100.00%
Mobile Home	1	50.00%
Mobile Home	2	100.00%
Mobile Home	3	100.00%
Mobile Home	4	100.00%
Mobile Home	5	100.00%

Damage Calculation Methodologies for Residential Structures (Actual Range) and Final Average Value Used for Calculations

Single family structures are largely considered a loss (80%) at a Fujita scale of F-2 or greater. The roof is commonly removed at this level. At this level, the study also considers structure contents. Contents are considered to be worth a fraction of the value of the structure they are in.



Above: Tornado-damaged Bank One building in downtown Fort Worth. Window replacement alone is expected to cost over 50% of the structure's appraised value.

Commercial structures are more complicated. There are very few if any instances in which a glass high-rise office building has been hit by a tornado rated at the F-4 category. Recent experiences in downtown Fort Worth with F-2 damages have provided some indications, but expectations are speculative and would require specific engineering evaluations. For the scope of this study, commercial structures are *expected to be more durable*. On average, no structure in this study is considered to have losses equal to its appraised value at a category below F-4.

Estimated values for Metroplex structures were determined from property appraisal data for Dallas, Tarrant, Denton, and Collin Counties. These data sets allow for small area estimates of property values. Value is incorporated for each structure on a land parcel.

Common Study Damage Categories

In all of the scenarios, damage estimates are described with some common terminology. Below are some brief descriptions of those terms:

Single Family Homes in Tornado Path: Single family residential structures are designed to hold one family.

Apartment Units in Tornado Path: An apartment unit is treated as a structure itself, even though most share one or more walls with adjacent units. Each apartment unit is a place holding one household. It is subject to the same damage impacts as is a single family home – generally approaching a total loss in the F-2 range. Because of their compact nature, many more households can be threatened per unit area when an apartment building is struck by a tornado.

Mobile Homes in Tornado Path: Each mobile home is one structure and is home to one household. Mobile homes are much more susceptible to damage, and a 50% loss is assumed for any located in the F-1 Fujita contour.

Commercial Properties in Path: A commercial property is composed of office structures, retail, governmental buildings, hospitals and schools.

Industrial Properties in Path: An industrial property is a structure housing a workforce or equipment related to industrial activities.

Residents in Tornado Path: Residential estimates identify the number of residents that would be impacted if they were all at home at the time of the tornado strike. In short, people are placed in the single family homes, apartment units, and mobile homes in the path of a tornado. The calculations consider:

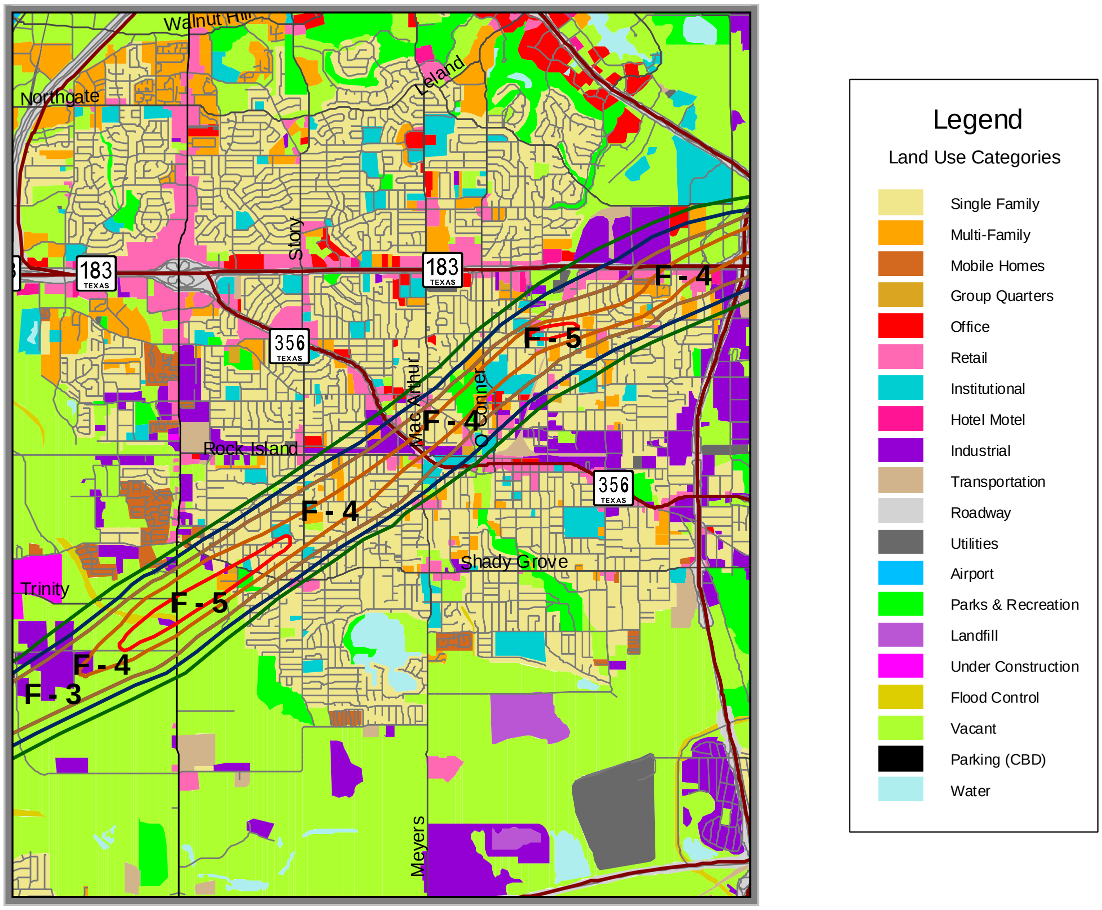
- The Number of Structures Damaged
- The Average Persons per Household (1998) for the Particular City in the Path
- The Rate of Occupancy (Occupied vs. Vacant) (1998) for the Particular City in the Path

Employees in Tornado Path: Employee data reflects an estimate of how many employees work at the locations within the tornado damage paths. It utilizes data distributed within traffic survey zones, commercial land uses, and specific points containing major North Central Texas employers.

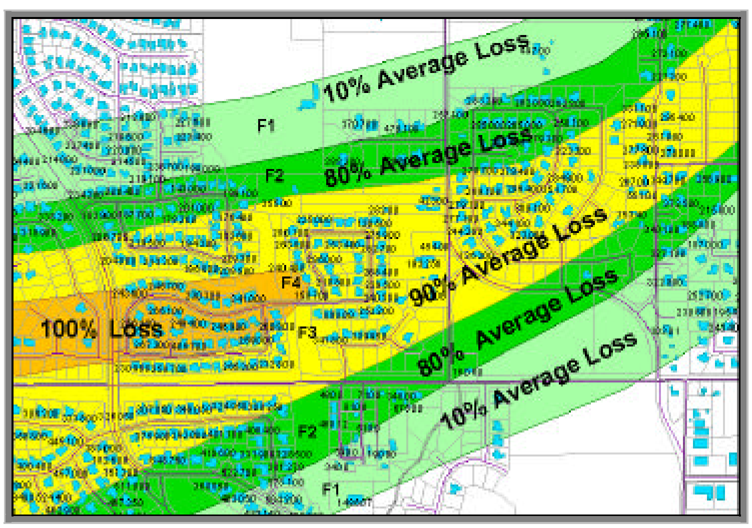
Transportation Routes in Tornado Path: The miles of both roads and railways are estimated based upon the centerline miles of each falling within tornado paths.

Schools in Tornado Path: Point locations of schools in the Metroplex are grouped together based upon how many fall within tornado paths and specific Fujita scale contours.

Major Electrical Utility Lines Intersected by Tornadoes: The majority of major electrical utility lines have been mapped for the Metroplex. These are the large regional distribution lines, not the smaller local distribution lines. The number of utility intersections with F-2 and greater tornado path centerlines of are provided for each scenario.



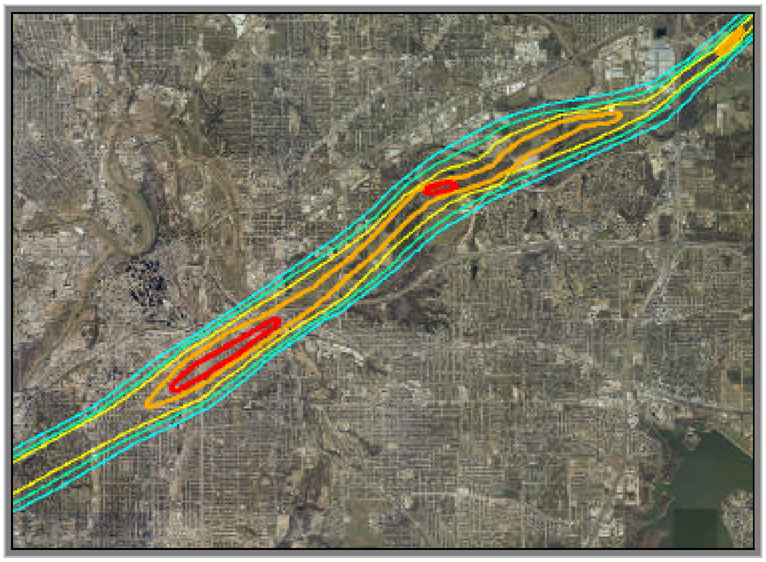
Land use mapping for central Irving in scenario five. Land use data covers the entire study area and was a vital tool to help categorize structures in the tornado paths.



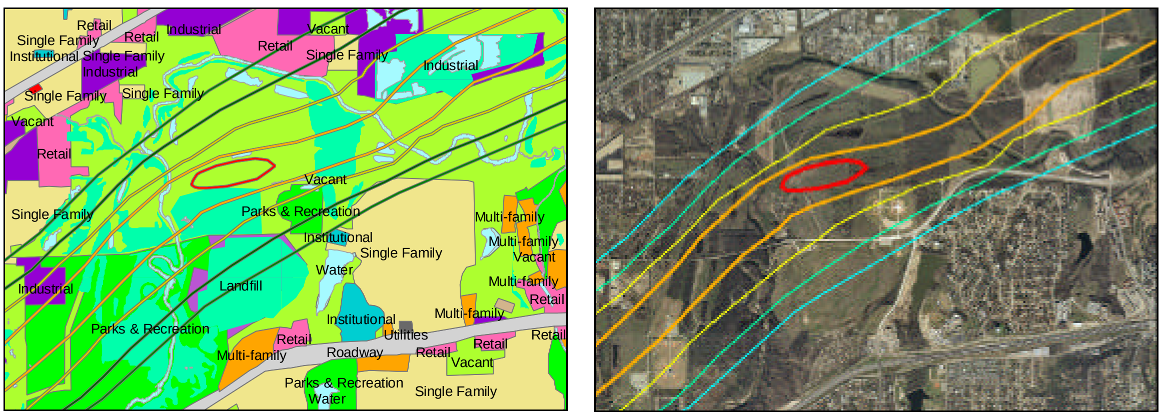
Potential dollar damage losses are calculated to provide a better indication of where structures and property values are located in reference to the main damage core of the tornado paths. For each of the residential buildings mapped in the left image, appraisal information is available to provide a good indication of the structure value that ultimately could be subject to a dollar loss in a tornado. The percentage average loss represents the *average* expected portion of each structure's appraised value that this study credits as a loss in that specific Fujita zone of the tornado.

Structures in the F-1 zone are expected *on average* to survive with minimal (10%) losses, while structures in the F-3 to F-4 zones are expected to require an investment near or equal to the structure's appraised value to repair or rebuild.

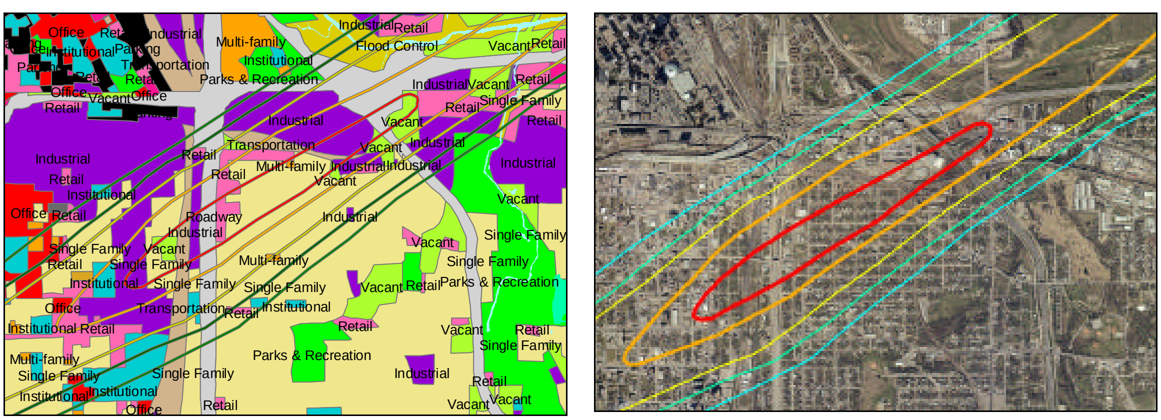
Modeling the Landscape -- Example of Computer Damage Calculations



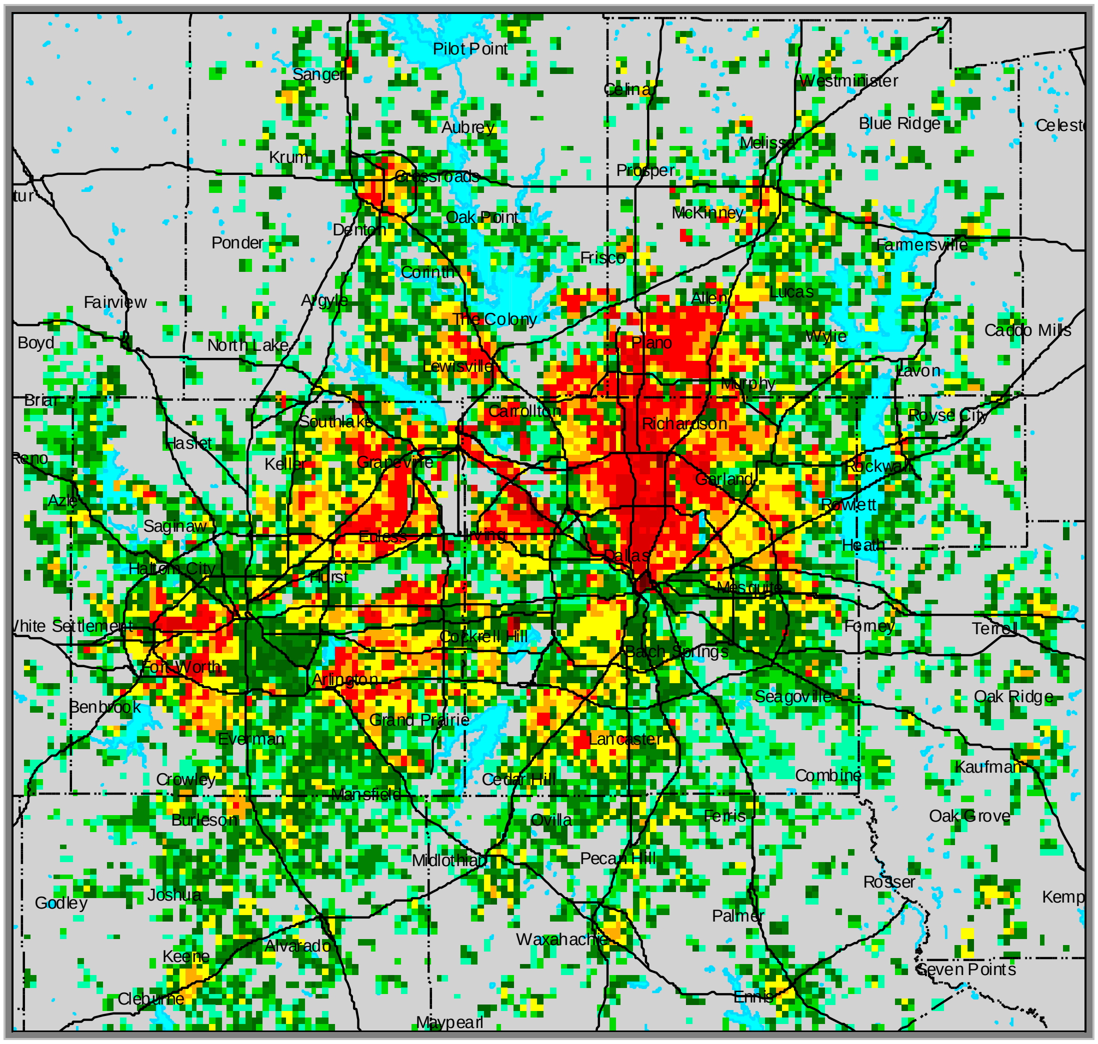
The calculation of estimated structures and values in the path of a given tornado is dependent upon quality GIS data for any given area. The tornado path to the left is estimated to be a $1.5 billion dollar damage path. The path features a wide variety of structures and land uses. The damage calculations fluxuate significantly along the path before arriving at the final estimate. Damage expectations are truly a function of both the tornado and the structure categories.

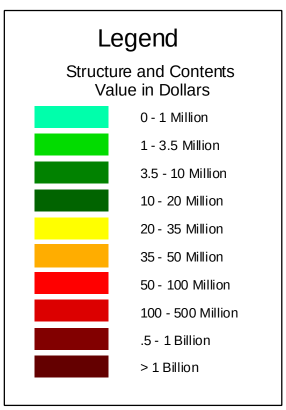


Above: *An area with LOW estimated damage calculations.* Although the tornado is violent and very dangerous at this point, the land beneath it is largely vacant. The computer recognizes this and produces damage estimates far below many of the areas along the rest of the path.

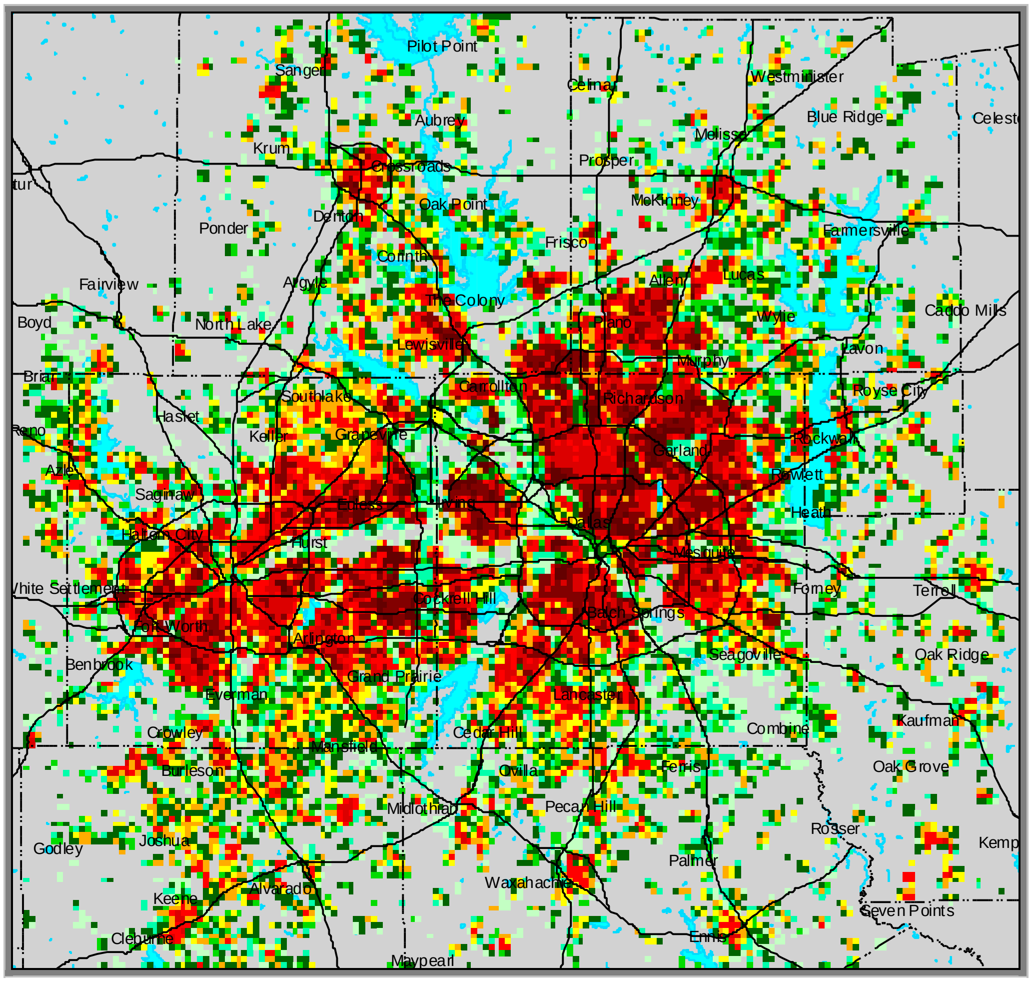


Above: *An area with HIGH estimated damage calculations.* The tornado is violent and very dangerous at this location and the land beneath it is heavily developed with houses and industrial uses. The computer recognizes this and produces damage estimates based on the appraisal data linked to these structures.





Above: *Total estimated structure and contents value for Dallas-Fort Worth as distributed in uniform 2400x2400 foot grid cells.* The total value in each grid is a function of the number of structures and the value of the structures. Contents are calculated for each structure as a function of the structure type and value. A select group of areas feature over $500 million of estimated structure and content value contained within an individual cell. In such cases, the grid cell usually contains multiple commercial structures of high value – such as near a downtown or near a major economic corridor. Grid cells dividing a large property will tend to distribute portions of the value to each of the grid cells involved.



Legend

Number of Structures and/or Apartment Units

- 0 - 2
- 2 - 8
- 8 - 20
- 20 - 40
- 40 - 65
- 65 - 100
- 100 - 175
- 175 - 300
- 300 - 425
- 425 - 700
- > 700

Above: *Total estimated structures and/or apartment units for Dallas-Fort Worth as distributed in uniform 2400x2400 foot grid cells.* The total value in each grid represents the total number of appraised property structures or individual apartment units estimated to be located within that grid. Grid cells displayed in darker reds can contain over 500 separate structures or apartment units. As might be expected, any areas with a dense number of apartment units can quickly see a rise in total structure values. Also, single family areas with small lot sizes will lead to higher structure numbers per area. Note that the downtown areas do not contain particularly high numbers of structures, although the size and value of those structures are often significantly large.

Scenario Summary by Structure Category

Single Family Homes In Tornado Paths

Scenario	Damaged	In F-2 or Greater	Property Value in Path	Potential Damages
1	11944	6512	$1,232,998,903	$643,821,000
2	8790	4258	$1,073,925,068	$499,778,000
3	14480	9350	$1,311,323,302	$753,579,000
4	17064	9917	$1,765,098,694	$1,063,995,000
5	17287	10003	$2,039,340,760	$1,170,205,000

Apartment Units In Tornado Paths

Scenario	Damaged	In F-2 or Greater	Property Value in Path	Potential Damages
1	3728	1729	$83,528,277	$32,652,000
2	3900	2496	$168,480,134	$92,655,000
3	6200	4575	$237,749,649	$172,914,000
4	10953	7725	$333,734,132	$210,124,000
5	19053	11678	$534,207,672	$305,435,000

Mobile Homes In Tornado Paths

Scenario	Damaged	In F-2 or Greater	Property Value in Path	Potential Damages
1	818	695	$18,946,847	$6,233,035
2	1214	1040	$22,700,605	$14,326,741
3	31	31	$488,506	$267,313
4	616	616	$7,655,328	$6,612,407
5	582	537	$9,109,008	$5,330,938

Commercial Properties in Tornado Paths

Scenario	Damaged	In F-3 or Greater	Property Value in Path	Potential Damages
1	505	163	$249,161,535	$96,426,015
2	361	107	$300,175,530	$139,967,564
3	1408	745	$2,204,693,573	$1,464,295,345
4	1263	424	$2,820,373,600	$1,469,457,831
5	1718	417	$2,291,954,031	$1,269,344,214

Industrial Properties in Tornado Paths

Scenario	Damaged	In F-3 or Greater	Property Value in Path	Potential Damages
1	64	28	$45,977,820	$32,028,440
2	85	20	$86,982,069	$43,370,115
3	478	164	$434,738,177	$261,241,264
4	319	174	$86,582,016	$59,050,148
5	165	63	$189,611,183	$108,993,692

Analysis by Structure Category and Fujita Scale

Scenario One

Fujita Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	4703	$490,794,981	$38,562,493
2	Single Family Homes	2611	$277,177,987	$221,742,390
3	Single Family Homes	2577	$231,406,696	$231,406,696
4	Single Family Homes	1241	$138,465,851	$138,465,851
5	Single Family Homes	83	$9,030,070	$9,030,070
Total		11218	$1,146,875,588	$639,207,514
1	Apartment Units	1819	$45,841,070	$3,151,570
2	Apartment Units	672	$18,815,336	$15,052,268
3	Apartment Units	718	$9,936,925	$9,936,925
4	Apartment Units	339	$4,294,084	$4,294,084
Total		3549	$78,887,417	$32,434,851
1	Mobile Homes	621	$14,509,805	$4,560,224
2	Mobile Homes	41	$970,269	$970,269
3	Mobile Homes	10	$238,546	$238,546
4	Mobile Homes	23	$340,224	$340,224
Total		696.81	$16,058,846	$6,109,264
1	Commercial Buildings	212	$105,553,268	$8,007,487
2	Commercial Buildings	93	$53,436,778	$25,797,071
3	Commercial Buildings	114	$48,475,060	$38,780,053
4	Commercial Buildings	39	$19,187,903	$19,187,903
5	Commercial Buildings	10	$4,015,823	$4,015,823
Total		471	$230,668,833	$95,788,335
1	Industrial Buildings	18	$11,753,914	$861,948
2	Industrial Buildings	17	$12,532,872	$10,026,296
3	Industrial Buildings	19	$14,642,484	$14,642,484
4	Industrial Buildings	9	$6,468,720	$6,468,725
Total		65	$45,397,991	$31,999,450

* Total Value in Path is the total structure and content value located within the tornado paths.
** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.

Scenario Two

Fujita-Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	4214	$531,886,231	$41,791,063
2	Single Family Homes	2125	$275,746,988	$220,597,578
3	Single Family Homes	1437	$155,054,399	$155,054,399
4	Single Family Homes	660	$75,954,977	$75,954,977
5	Single Family Homes	36	$4,744,777	$4,744,777
Total		8474	$1,043,387,374	$498,142,786
1	Apartment Units	1365	$71,555,192	$4,919,417
2	Apartment Units	925	$38,347,498	$30,677,990
3	Apartment Units	865	$32,510,055	$32,510,053
4	Apartment Units	706	$24,472,949	$24,472,949
Total		3862	$166,885,696	$92,580,411
1	Mobile Homes	398	$7,866,091	$2,472,193.00
2	Mobile Homes	239	$4,055,381	$4,055,382.00
3	Mobile Homes	241	$4,091,864	$4,091,865
4	Mobile Homes	162	$3,573,871	$3,573,871
Total		1042	$19,587,208	$14,193,316
1	Commercial Buildings	153	$104,356,050	$7,916,650
2	Commercial Buildings	79	$71,171,454	$34,358,637
3	Commercial Buildings	72	$70,914,617	$56,731,700
4	Commercial Buildings	32	$38,443,984	$38,443,984
5	Commercial Buildings	3	$1,825,365	$1,825,365
Total		340	$286,711,473	$139,276,333
1	Industrial Buildings	39	$41,131,911	$3,016,341
2	Industrial Buildings	23	$25,138,295	$20,110,640
3	Industrial Buildings	15	$15,163,331	$15,163,331
4	Industrial Buildings	5	$5,055,129	$5,055,129
Total		84	$86,488,667	$43,345,436

* Total Value in Path is the total structure and content value located within the tornado paths.
** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.

Scenario Three

Fujita-Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	5391	$529,888,481	$41,634,095
2	Single Family Homes	3894	$318,434,331	$254,747,468
3	Single Family Homes	3887	$331,479,600	$331,479,600
4	Single Family Homes	1077	$112,508,905	$112,508,905
5	Single Family Homes	102	$12,880,732	$12,880,732.00
Total		14353	$1,305,192,051	$753,250,804
1	Apartment Units	1639	$48,511,859	$3,335,190
2	Apartment Units	2068	$98,293,161	$78,634,530
3	Apartment Units	2644	$85,825,077	$85,825,077
4	Apartment Units	205	$5,119,551	$5,119,551
Total		6556	$237,749,649	$172,914,350
1	Mobile Homes	21	$322,573	$101,380.00
2	Mobile Homes	10	$165,409	$165,409.00
Total		31	$488,506	$266,789
1	Commercial Buildings	337	$339,372,076	$25,745,467
2	Commercial Buildings	320	$452,933,421	$218,657,510
3	Commercial Buildings	464	$953,328,237	$762,662,590
4	Commercial Buildings	268	$454,144,660	$454,144,660
5	Commercial Buildings	12	$3,019,743	$3,019,743
Total		1403	$2,202,798,140	$1,464,229,985
1	Industrial Buildings	160	$155,779,174	$11,423,806
2	Industrial Buildings	153	$144,963,422	$115,970,730
3	Industrial Buildings	123	$101,153,215	$101,153,215
4	Industrial Buildings	36	$29,324,023	$29,324,023
5	Industrial Buildings	4	$3,361,654	$3,361,654
Total		477	$434,581,490	$261,233,430

* Total Value in Path is the total structure and content value located within the tornado paths.
** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.

Scenario Four

Fujita-Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	7083	$661,170,614	$51,949,133
2	Single Family Homes	4652	$422,848,711	$338,278,955
3	Single Family Homes	3401	$382,192,383	$382,192,354
4	Single Family Homes	1656	$256,898,273	$256,898,273
5	Single Family Homes	208	$34,262,544	$34,262,544
Total		17002	$1,757,372,527	$1,063,581,231
1	Apartment Units	3220	$109,414,340	$7,522,238
2	Apartment Units	3371	$109,367,097	$87,493,671
3	Apartment Units	2169	$63,396,413	$63,396,413
4	Apartment Units	2185	$44,099,966	$44,099,966
5	Apartment Units	675	$7,290,975	$7,290,975
Total		11607	$333,568,794	$209,803,263
1	Mobile Homes	144	$1,520,932	$478,004
2	Mobile Homes	362	$4,779,554	$4,779,554
3	Mobile Homes	104	$1,260,514	$1,260,514
4	Mobile Homes	6	$94,326	$94,326
Total		617	$7,655,328	$6,612,409
1	Commercial Buildings	513	$790,672,024	$59,982,008
2	Commercial Buildings	323	$724,908,936	$349,956,043
3	Commercial Buildings	305	$1,221,671,814	$977,337,449
4	Commercial Buildings	91	$56,969,045	$56,969,045
5	Commercial Buildings	28	$25,179,775	$25,179,775
Total		1263	$2,819,401,596	$1,469,424,313
1	Industrial Buildings	58	$24,171,983	$1,772,597
2	Industrial Buildings	87	$25,662,603	$20,530,097
3	Industrial Buildings	136	$32,142,478	$32,142,478
4	Industrial Buildings	38	$4,604,949	$4,604,949
Total		320	$86,582,016	$59,050,145

* Total Value in Path is the total structure and content value located within the tornado paths.
** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.

Scenario Five

Fujita-Scale 1 and Greater

Fujita Scale Contour Within	Category	Impacted	*Total Value in Path	**Potential Damages
1	Single Family Homes	7010	$811,926,619	$63,794,230
2	Single Family Homes	3880	$452,734,790	$362,187,809
3	Single Family Homes	4304	$563,241,022	$563,241,019
4	Single Family Homes	1593	$148,975,509	$148,975,510
5	Single Family Homes	226	$30,282,563	$30,282,565
Total		17016	$2,007,160,505	$1,168,481,133
1	Apartment Units	7175	$202,998,193	$13,956,134
2	Apartment Units	5160	$136,655,725	$109,324,570
3	Apartment Units	4422	$130,963,433	$130,963,433
4	Apartment Units	1762	$45,064,056	$45,064,056
5	Apartment Units	334	$5,517,287	$5,517,287
Total		18856	$521,198,696	$304,825,486
1	Mobile Homes	292	$4,601,614	$1,446,232
2	Mobile Homes	84	$1,488,235	$1,488,235
3	Mobile Homes	143	$2,268,258	$2,268,258
4	Mobile Homes	18	$100,336	$100,336
Total		538	$8,458,444	$5,303,060
1	Commercial Buildings	727	$595,066,222	$45,142,968
2	Commercial Buildings	269	$676,879,715	$326,769,529
3	Commercial Buildings	247	$558,029,534	$446,423,618
4	Commercial Buildings	126	$440,850,614	$440,850,614
5	Commercial Buildings	12	$9,765,683	$9,765,683
Total		1383	$2,280,591,770	$1,268,952,417
1	Industrial Buildings	63	$77,798,843	$5,705,260
2	Industrial Buildings	39	$41,959,085	$33,567,266
3	Industrial Buildings	49	$53,530,341	$53,530,341
4	Industrial Buildings	13	$15,196,030	$15,196,030
5	Industrial Buildings	1	$987,834	$987,834
Total		165	$189,472,134	$108,986,737

* Total Value in Path is the total structure and content value located within the tornado paths.
** Potential Damages represents an estimate of property value damage based on the proportion of property value falling within different Fujita Scales.