Native Earth Consulting

Rebecca Whitton – Project Manager
Cameron Howitt – Assistant Manager
Justin Briseno – GIS Analyst
Michael Stanley – Web Designer

Flash Flood Fatality Frequency in Texas Counties

Prepared by:

Native Earth Consulting

TABLE OF CONTENTS

INTRODUCTION

Flooding is a global phenomenon and is one of the most dangerous weather-related natural disasters in the world. Floods have the potential to cause extreme loss to property, economic and agricultural production, and impact the general welfare of the community. However, the most serious and irreversible consequence attributed to flood events is the loss of human life (Jonkman 2005). More deaths are attributed to flash floods than any other weather-related disasters that occur in the United States and the Federal Emergency Management Agency (FEMA) estimates that these events are responsible for more than 10,000 deaths since 1900 (National Severe Storms Laboratory 2009). Texas accounts for more flash flood-related deaths and damages reported than any other state and the Central Texas region has been identified as the most flash flood prone area in the U.S. (French 1983). Flash flooding is defined by the National Weather Service (NWS) as a "flood that rises and falls quite rapidly, usually as a result of intense rainfall over a small area, in a short amount of time" (2009). These events most often occur with little warning and their dangers are often underestimated.

The anticipated effects of climate change, and increased population growth and development in flood-prone areas are expected to result in future increase of flood risk (Jonkman 2005). As flooding occurs more and more frequently, the considerable amount of economic and social losses will also increase. Therefore, flood events are of major concern, illustrating an explicit need for a better understanding and knowledge about the magnitude, pattern, and circumstances surrounding fatalities caused by floods and in particular, flash floods.

To address these issues, the International Flash Flood Laboratory (IFFL) is currently being developed under the James and Marilyn Lovell Center for Geographic Education and Hazards Research at Texas State University. The IFFL will function as a center of learning to improve flash flood research and knowledge, information dissemination, and risk communication. More importantly, the work conducted by the IFFL has the potential to reduce the fatalities, injuries, and damage caused by flash flood disasters. Managers and planners will be able to utilize this information and ultimately have the ability to improve emergency response times to flash flood vulnerable areas, as well as design and construct efficient and effective public warning and evacuation procedures.

PROBLEM STATEMENT

The objective of this project is to utilize a geographic information system (GIS) to analyze the spatial and temporal distribution of historically-recorded flash flood fatalities in Texas counties and identify any existing patterns, areas of vulnerability and correlation to event damages and population growth. The circumstances contributing to flood fatalities are also examined to ascertain possible relationships between factors and determine the variables that characterize those most likely to be at risk. Furthermore, this project seeks to play an integral role in enhancing the establishment of the IFFL. Texas is very prone to flash flood disasters and has recently been experiencing exponential population growth, serving as an ideal region of study.

Due to the global nature of flooding, studies similar in nature to this particular project have been conducted to address the dynamics of flooding and their impacts. However, the geographic distribution of these events has not been a central component in analysis and studies utilizing GIS are limited in number. GIS provides a unique basis for the analysis of flood fatality distribution. By applying GIS to solve problems that are generally spatial in nature, information can be easily managed and organized. In addition, non-spatial information from a variety of different data sources can be linked to spatial information. Furthermore, possibly the greatest advantage lies in the visual nature of GIS. It has the capacity to discover and clearly display spatial relationships and the results of complex analysis effectively. Communicating such information visually in the form of static and interactive mapping has the capacity to enhance public awareness, improve organizational management at a variety of levels and empower those involved through participation. Other methods of presentation that solely include tables or detailed text would have fallen short in achieving current objectives and goals of this study.

Results of this project are expected to reveal a high concentration of flash flood fatality in the Central Texas region, primarily because of the area's high propensity to experience flash flood event. In addition, areas that have experienced high population growth, particularly within close proximity to major urban areas, are expected to be identified as high-risk for flash flood fatality.

The following final project report is organized in five sections. First, the data that is utilized during project implementation is presented. Second, the methodology and research design is discussed, including compilation of the flash flood fatality database and procedures for statistical and GIS analysis. The results of data analysis are presented in the third section. Presented fourth is discussion of the results derived, including project limitations and implications, and areas for future research. Finally, the conclusions of the project regarding opinions and lessons learned are described.

DATA

Flood Fatality Database

The flood fatality database was compiled by utilizing essential flood event information collected from two distinct networks that provide the most comprehensive information available regarding flood events. First, the Spatial Hazard Events and Losses Database for the United States (SHELDUS) at the Hazard Research Laboratory, University of South Carolina contains a collection of information organized at the county level on eighteen natural hazards types, such as floods, hurricanes, and wildfires. Event records include a start and end date, the number of injuries and deaths, and estimated total dollar amounts of property and crop damages. SHELDUS data are primarily derived from the National Oceanic Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) Storm Data report publications. Therefore, qualitative and quantitative information regarding the flood fatalities has been obtained through the NCDC Storm Events Database. Both databases have been consistently monitoring hazard events that cause significant loss of life, injuries, and monetary damages since the 1950s.

Information included in the Storm Data reports is predominately received from the National Weather Service (NWS). However, some data is provided by other sources, such as the media, law enforcement, or other organizations. In the cases where information has been collected from other sources, this data may not have been verified by the NWS. Therefore, the quality and accuracy cannot be guaranteed. In addition, inaccuracies may exist due to underreporting of events and level of detail included within the reports. This may produce a conservative estimate of flash flood fatalities. Nevertheless, both SHELDUS and NCDC Storm Events databases contain the best sources for obtaining the information necessary for this analysis.

GIS Data Layers

The Mapping Website of the Texas Water Development Board (TWDB) provided data layers for the major rivers and terrain for the state of Texas. The United States Geological Survey (USGS) is the primary source from which the TWDB has collected the datasets. The county data layer was obtained from Texas Natural Resource Information System (TNRIS), part of the TWDB, which was derived from various sources such as the Texas Department of Transportation and other agencies in order to create the most comprehensive data available. In addition, comparison maps of population growth in PDF format were acquired through the Texas State Data Center (TSDC). All data layers will be implemented in ArcGIS, a computer software program instrumental in producing static maps and performing both spatial and statistical analysis.

METHODOLOGY

The risk associated with flash flood fatality is dependant on a number of factors (Maples 2006). The geographic location, including the nature of the physical environment and topology, the social characteristics of a population, such as age and/or gender, and the human interaction with such events may contribute to flash flood fatality. The comprehensive analyses of these factors were investigated in two phases. The first phase consisted of compiling the flash flood fatality database and included generating descriptive statistics for non-environmental variables. The second phase employed various GIS techniques in order to complete spatial analysis of flood fatality distribution and creating static maps. Therefore, these phases are presented separately.

Flood Fatality Database

The scope of the current study focuses on data aggregated at the county level as a result of two factors. First, data from both SHELDUS and the Storm Event reports is only available at the county scale, primarily to protect the identities of the victims and, secondly, flood events generally tend to affect multiple counties simultaneously.

To determine the number of fatalities and obtain details about these events, a search was first conducted in SHELDUS from 1950 to 2007 for all flood events that occurred in Texas counties. The events that resulted in at least one fatality were then cross-referenced against the NCDC Storm Events Database. Only events that appeared in both databases were considered and used in analysis. Fatalities were compiled in an excel spreadsheet and organized by date and included the county of occurrence, number of fatalities, and the total dollar amount reported on damages to both property and crops.

The reports from the NCDC database often are accompanied by a description of the details of the flood event including information on the circumstances surrounding the flash flood fatality. These reports were then reviewed to determine further qualitative and quantitative data for each of the flood fatalities included in the final dataset. Copies of these reports were saved in digital format and printed copies were compiled into a single binder. If provided, the following additional variables were recorded in the database for each fatality:

1. Demographic information, such as gender and age,
2. Type of incident death,
3. Latitude and longitude coordinates of the incident or other descriptive information identifying fatality location

Flood fatalities were classified by each variable in the dataset and descriptive statistics were derived for each variable. Ultimately, this method of analysis allowed the circumstances contributing to flash flood fatality to be enumerated, revealing the characteristics of those most vulnerable to flash flood fatality.

GIS Analysis

A more in depth analysis of flash flood fatalities was conducted by employing various GIS techniques to investigate temporal and spatial distribution of the fatality incidents. Data layers for Texas counties, rivers, and terrain were first imported into ArcGIS, a computer software program created by the Environmental Systems Research Institute (ESRI).

The aggregated fatality data that was compiled in the flash flood fatality database were attached to the county data layer utilizing keyboard entry. Fields were then created in the attribute table of the county layer for total fatalities (FAT_TOT), fatalities that occurred during each decade (FAT_1990 and FAT_2000), property damage total (PROP_TOT), and crop damage total (CROP_TOT). The newly created fields were edited to input attribute data values.

Finally, a number of graduated color maps were created based on their individual attribute values and include the following:

1. Total Flash Flood Fatality
2. Flash Flood Fatality by County by Decade
3. Flash Flood Property and Crop Damages

In addition, a reference map of Texas counties, rivers, and terrain were also generated. To conclude the GIS analysis of the temporal and spatial distribution of flash flood fatality frequency, these maps have been visually interpreted to reveal existing patterns and the areas most susceptible to this type of fatality and describe the geography of these areas. Furthermore, correlations between fatality patterns and event damages or population growth have been determined.

RESULTS

Flash Flood Fatality Statistics

Based on the available data from SHELDUS and NCDC Databases, the final database includes a total of 182 fatalities across 56 counties during the period under study. Bexar County represented the highest total fatality frequency and also contained the highest frequency in the 2000s with a total of 11. However, during the 1990s, Dallas county has the most fatalities with 21. Property damage is reported most often with 71 of the 112 events reporting a total of over $225 million in damages. Crop damage reported only about $31.7 million in damages as a result of 14 flood events. The most significant values of property and crop damages were reported by counties with very few fatalities. Burnet County reported

$137 million in property damages and Tarrant County reported $30 million in crop damages. However, the number of deaths in Burnet and Tarrant counties was only 2 and 8, respectively. Table 1 summarizes in detail the totals flood fatality and damages by county and by decade.

The 182 fatalities, occurring in 112 separate events, range temporally from 1993 to 2007 (Table 2). The number of flood events has nearly doubled in the last two decades. However, frequency of fatality incidents only slightly increased, resulting in a decreased number of deaths per flood event. The number of flood events does not indicate a correlation to the number of fatalities during the 1990s. The highest number of flood event resulted in 15 fatalities while the years that accounted for the greatest numbers of fatalities were 1995 with 24 fatalities and 1998 with 23 fatalities. However, during the 2000s, fatalities increased as the number of event occurrences increased. 2007 accounted for the greatest amount of both flash flood events and fatalities with 28 and 43, respectively. Furthermore, no statistically significant trend in fatalities over the period of years is evident.

Descriptive statistics derived for the variables contained in the Storm Data reports are summarized in Table 3. Nearly all event records included some sort of descriptive information about location, such as the identifying the river or creek. Unfortunately, exact geographic coordinates and water-crossings were less frequently reported. Only 18 of the records had fatality location latitude and longitude. Of all the deaths reported, 74% included information regarding the setting of fatality occurrence. Most flood fatalities are vehicle related, representing nearly 77% or 80 deaths. Mobile home and outside/open area fatality location represented the fewest number of fatalities and accounted for only about 3%.

Outside/open areas can either be the result of a person accidentally being swept into flood waters or the result of a person intentionally walking into flooded areas. In addition, there is no real significant difference in age. However, the most common ages reported were under 20 years of age, representing 34%. Victims over the age of 60 accounted for nearly 22%. The least reported age group ranged from forty-one and sixty, with only 18%. Males represented 60% of fatalities that reported gender, with a total of 81 out of the 135 fatalities.

GIS Analysis

To investigate the spatial distribution of flash flood fatalities, a series of maps have been created. By examining total flood fatality map (Figure 1) and fatality by decade map (Figure 2), counties with the highest fatalities are located primarily in the Central Texas region. Both flood events and fatalities cluster spatially in this area. Other areas with high fatality frequency are randomly distributed among various counties. There were 198 counties with zero fatalities reported.

By comparing decadal fatality maps (Figure 2) to population growth maps (Figure 3), it is evident that a direct correlation exists between population growth and number of fatalities. Counties that have experienced high population growth also experienced high number of flood related deaths. In addition, many of these counties with high flash flood fatalities also represented the locations of highly-populated urban centers. However, high fatality frequency does not necessarily indicate high levels of property and crop damage (Figure 4).

A number of physical environment factors can also be determined. In addition, comparison to the map of Texas counties, river and terrain (Figure 5), reveal that counties located within close proximity of major rivers account for the vast majority of flood related fatalities. This area of high fatality frequency also coincides with the edge of the Balcones Escarpment, where higher elevation descends rapidly into the lower elevations of the coastal plains region. Many of the deaths reported are found in counties along the Interstate-Highway 35 corridor between San Antonio and Dallas, an area that has been identified as "Flash Flood Alley" (Frech 2005).

DISCUSSION

Results & Variables Identifying High Risk

Flood events are of major concern and there is an explicit need for a better understanding about the magnitude, pattern, and circumstances surrounding fatalities caused by flash floods. The use of the SHELDUS and NCDC databases provided for the study and analysis of flood fatality frequency, geographic distribution and the circumstances and associated factors that contributed to flood fatality.

Although the number of fatalities varies from year to year, fatality frequency per event has decreased. This may be in part due to improved warning systems or public awareness on the dangers and risks associated with flash flood events. At the same time, a lack of public awareness may also be suggested due to an existing increase in the number of flash flood fatalities. The variables that describe those most likely to be at risk are males under the age of 20 and over the age of 60 traveling by automobile in flooded areas. Examining fatality frequency totals and by age group reveal that improved public awareness programs should be targeted at specific groups, such as children and teens, parents and the elderly.

Those most likely at risk are located in areas of close proximity to rivers and elevation changes along the Balcones Escarpment of the Central Texas region. In addition, areas of high fatality frequency are also areas with high population density and high population growth rates. This may be a direct result of the increased amount of impervious cover resulting from development. The extensive road system in Texas may be another possible contributor to high flash flood fatality. Texas has the largest road system of any other state (Texas Department of Transportation 2009). More roadways may directly increase areas that water can cross the roads, increasing the risk of flash flood fatality.

Many of the results reflect the initial project expectations. However, an interesting result found during the reading of individual event reports was revealed. Although fatalities tended to cluster around areas of high population, a vast majority actually occurred in the rural areas surrounding these major urban centers. This level of precision was not feasible by mapping fatalities at the county level and only evident through close examination of individual Storm Event records. In addition, it was surprising that the number of fatalities had increased between decades. The technological advances experienced in past years were thought to have had a significant impact on reducing fatalities. This directly reflects the need for a continued commitment to improve public awareness and reduce flash flood fatalities.

Limitations

The results of this study are subject to limitations. First, there is a limited amount of accurate and complete data for all fatalities. Previous research suggests that a lack of accurate data and incomplete methods for collecting and publishing such data lead to inconclusive results that are not representative of the entire population (French 1983). Although flood fatality data does exist, efforts to collect and publish this information have not been thorough or consistent (Frech 2005). Better qualitative and quantitative data, especially with regards to exact geographic location, will provide insight into the causes and factors associated with flood fatalities. It is imperative that this information be made more readily available for areas at risk can properly implement mitigating and preventative measures. In addition, there is a need for the development of a standardized method for reporting the location and circumstances of flood fatalities.

Secondly and most importantly, the results of the study are seriously limited by time constraints. There was simply not enough time to comprehensively acquire the necessary information for answering the important questions regarding flash flood fatalities. In particular, the exact geographic location of fatalities could not be identified. The lack of point-specific data would not allow for mapping at any scale other than at the county level. If an attempt had been made to map the fatalities that contained such information, the results would not have been representative of all flash flood fatalities and conclusive results could not have been determined.

In part, lack of time has hindered the confidence level of the project results. Many of the decisions in regards to the approach taken were made out of necessity from constraints in time. For example, a larger database was created in the initial project stages and included over five-hundred fatalities. However, the opportunity to determine exact locations other than at the county scale led the project to limit the number of incidents included in analysis. It was later determined at too late a stage in project implementation that exact location could not be accurately determined for a sufficient amount of incidents. Given additional time to accurately identify specific geographic location of flash flood fatality and other social characteristics, this project would be more effective in identifying the variables surrounding such fatalities. In addition, if the time constraints had been identified in the earlier stages of project implementations, more time would have been devoted to constructing static maps, statistical analysis, and web construction.

Implications & Future Research

Despite the existing limitations, the comprehensive analysis has provided unique insight into flash flood fatalities and has a number of profound implications. Results can be sued to facilitate improved means of public education on flood safety and assist in reducing the number of flash flood fatalities. Furthermore, results of this study will prove to be an integral part of the International Flash Flood Laboratory to be interpreted by people in the academic, hazards, and planning communities.

The results may be used to allow for responsible, safe, and sustainable development in lower water areas, and high growth areas. This study, serving as a foundation, may also be built upon by others in the future to map out the vulnerability of other geographic areas to the hazards posed by flash floods. Findings from this research may provide insight into the patterns of flood related events and can be used as predictors for future loss of life associated with such events. A better understanding of where these deaths are occurring can lead to better mitigating efforts so that mortality at low water crossings can be reduced, if not eliminated.

Although this study offers some important insight into the circumstances and distribution of flash flood fatality, it is only a single small step that should serve as a foundation to be built upon. Flash flood fatality and the circumstances that attribute to such events is a complex problem that presents a number of challenges on a global scale. There are many avenues for which future research should be developed and conducted to answer the hard questions surrounding flash flood fatality.

First and foremost, a more comprehensive and detailed database should be developed regarding flash flood fatalities and circumstances. By employing the two databases used in this project, as well as historical records, such as newspaper archives, more research should be conducted in order to identify the exact locations and more detailed information regarding a number of variables. In addition, the variables examined should also be expanded to include a number of other factors, such as ethnicity and income levels. More information, across a larger time scale and with a higher level of detail with regards to location and the other associated variables, would help to better establish the relationships between the circumstances and distribution of fatalities.

Another possible avenue for future research lies in examining the role of specific infrastructure and development. For example, transportation networks in relation to river networks might reveal areas of low-water crossings most susceptible for flash flood fatality so that efforts could be directed at reducing the risk. Other variables to consider in evaluating flash flood fatality frequency might include stream density, floodplain overlap and flood control structures. In addition, it would be beneficial to investigate public perception of flood dangers and risk and examine the effectiveness of local policy regarding mitigation, public awareness, and mitigating efforts. This type of research would have serious implications in planning and development arenas.

CONCLUSIONS

Project Opinions

As previously discussed, this project was seriously limited and hindered because of time constraints. Given an opportunity to approach the project a second time, many of the issues presented within the limitations and future research sections of this report would be addressed in more detail. For example, more time would be spent developing the fatality database and other sources would have been investigated and better time management would be utilized. Interpretation of critically flooded locations and the circumstances surrounding fatalities could have been better understood given the availability of more time to develop the data utilized in analysis. Given a higher level of detail in which the data could have been obtained the overall results would have been more conclusive, providing to be more powerful in assisting the development of mitigation, education, and protection projects.

This study is extremely important, since there are a large number of fatalities created due to flash floods in the Central Texas region. There is a lack of education programs, citizen awareness, and proper development of protection measures that exist in the region. This study serves as the first step in making the significant changes necessary to address such issues and it has been an honor to be involved and play such a pivotal role in establishing such an important program as the International Flash Flood Laboratory.

Lessons Learned

This project did not necessarily teach any of the team members anything that was not already known about the functions and techniques used in GIS analysis. However, lessons have been learned with regard to successful implementation of professional projects and dealing with potential clients. This project also provided experience with conducting research and data intensive studies. In addition, this project presented a unique opportunity to collaborate with team members and set individual deadlines that had to be met for successful project implementation. Many times, the projects during college courses are completed individually and are not dependant on teamwork. All team members not only benefited from the project but also enjoyed the course and project.

CONTRIBUTION TO FINAL REPORT & PRESENTATION

Rebecca Whitton, the Project Manager, completed all of the technical writing of the final report and constructed the final PowerPoint presentation. Team member contributions by Cameron Howitt, Justin Briseno, and Michael Stanley were made in the limitations, future research, project opinions, and lessons learned sections of the final report. In addition, team members helped with the proofing and revision of the final report.

REFERENCES

Frech, Marshall. 2005. Flood Risk Outreach and the Public's Need to Know. *Journal of Contemporary Water Research and Education*. 130 (61-69).

French, Jean, R. Ing, S. Von Allmen, and R. Wood. 1983. Mortality from Flash Floods: a Review of National Weather Service Reports, 1969-81. *Public Heath Reports.* 98.6 (584-588).

Jonkman, S.N. 2005. Global Perspectives on Loss of Human Life Caused by Floods. *Natural Hazards*. 34 (151-175).

Maples, Luaren Zappone (2006). *A Historical Geographic Assessment of Drowning Incidents in Automobiles During Texas Floods, 1950-2004*. Masters Thesis. Texas State University – San Marcos.

National Climatic Data Center. "Storm Event Database." http://www4.ncdc.noaa.gov/cgi-in/wwcgi.dll?wwEvent~Storms. (Last accessed 3.22.09).

National Severe Storms Laboratory. "Understanding Damage and Impacts." http://www.nssl.noaa.gov/primer/flood/fld_damage.html (Last accessed 4.25.09).

National Weather Service. "Definition of Flood and Flash Flood." http://www.srh.noaa.gov/mrx/hydro/flooddef.php (Last accessed 3.22.09)

Texas Natural Resource Information Systems. "Data Search and Download." http://www.tnris.org/datadownload/download.jsp (Last accessed 2.18.09).

Texas State Data Center. "Texas Population Growth Maps." http://txsdc.utsa.edu/maps/thematic/txpopmap_large_2008.pdf (Last accessed 4.22.09)

Texas Water Development Board. "Mapping & GIS Data Website." http://www.twdb.state.tx.us/mapping/gisdata.asp, (Last accessed 2.18.09).

Spatial Hazard Events and Losses Database for the United States, s.v. "Flooding, 01/01/1950 – 12/31/2007, United States," http://webra.cas.sc.edu/hvriapps/sheldus_setup/sheldus_results.aspx. (last accessed 2.18.09).

Unknown Author. 1998. Storm-Related Mortality – Central Texas, October 17-31, 1998. *MMWR Weekly*. 49(07) (133-135).

APPENDIX I: TABLES

Table 1: Flood Fatality and Damage by County by Decade

County	Total	1990s	2000s	Property	Crop
Austin	2	0	2	8,000	-
Bandera	3	2	1	5,020,000	1,000,000
Bastrop	2	0	2	100,000	-
Bell	9	2	7	467,500	-
Bexar	27	16	11	23,000,000	105,000
Blanco	2	0	2	100,000	-
Brown	1	1	0	250,000	50,000
Burnet	2	0	2	137,000,000	-
Chambers	1	1	0	50,000	5,000
Comal	1	0	1	-	-
Comanche	3	0	3	42,500	-
Cooke	3	0	3	28,000,000	-
Coryell	4	0	4	75,000	-
Dallas	23	21	2	350,000	-
Denton	4	4	0	-	-
Ector	1	1	0	300,000	-
Edwards	2	1	1	85,000	-
El Paso	4	3	1	250,000	-
Ellis	2	0	2	20,000	-
Fort Bend	2	1	1	35,000	-
Freestone	1	0	1	12,000	-
Gillespie	3	0	3	20,000	-
Goliad	1	1	0	-	-
Grayson	3	1	2	20,000,000	-
Grimes	3	0	3	50,000	5,000
Guadalupe	6	4	2	5,080,000	100,000
Hardeman	1	1	0	-	-
Harris	7	1	6	3,812,000	-
Hays	3	2	1	2,500,000	50,000
Howard	2	0	2	10,000	-
Jefferson	2	0	2	5,010,000	-
Kendall	5	0	5	300,000	-
Kerr	2	1	1	25,000	-
Lavaca	1	1	0	1,000,000	50,000
Liberty	1	0	1	10,000	-
Mason	1	0	1	15,000	-
McLennan	2	1	1	20,000	-
Medina	1	1	0	13,000,000	100,000
Milam	1	0	1	10,000	-
Navarro	2	0	2	10,000	-
Nueces	2	2	0	-	-
Palo Pinto	1	0	1	10,000	-
Parker	2	1	1	5,000	-
Potter	2	0	2	73,000	-
Real	4	4	0	1,066,667	20,000
Scurry	1	1	0	50,000	-
Shackelford	1	0	1	3,000,000	-
Shelby	1	1	0	-	-
Somervell	2	0	2	-	-
Starr	1	1	0	50,000	-
Tarrant	8	2	6	265,000	30,000,000
Taylor	1	0	1	30,000	-
Travis	4	2	2	3,050,000	150,000
Uvalde	2	1	1	30,000	90,000
Webb	1	0	1	1,000,000	-
Williamson	3	0	3	500,000	-
Totals	**182**	**82**	**100**	**$ 255,166,667**	**$ 31,725,000**

Table 2: Fatality Totals by Year

Year	Events	Fatalities	%
1990s Total	40	84	46.2
1993	3	5	2.7
1994	6	8	4.4
1995	6	24	13.2
1996	5	7	3.8
1997	11	15	8.2
1998	7	23	12.6
1999	2	2	1.1
2000s Total	72	98	53.8
2000	7	9	4.9
2001	7	8	4.4
2002	10	13	7.1
2003	2	2	1.1
2004	8	10	5.5
2005	3	5	2.7
2006	7	8	4.4
2007	28	43	23.6
Total	112	182	100.0

Table 3: Reported Flood Fatality Variables

Variable	Fatalities	%
Gender	**135**	**74.2**
Male	81	60.0
Female	54	40.0
Fatality Location	**105**	**57.7**
VE (Vehicle)	80	76.2
OU (Outside)	5	4.8
OT (Other)	1	1.0
IW (In Water)	16	15.2
MH (Mobile Home)	3	2.9
Age	**97**	**53.3**
0 - 20 years	33	34.0
21 - 40 years	25	25.8
41 - 60 years	18	18.6
60 + years	21	21.6
Lat/Long	**18**	**9.9**
Descriptive Data	107	95.5
Injuries Reported	26	23.2

APPENDIX II: FIGURES

Figure 1: Total Flash Flood Fatalities in Texas Counties

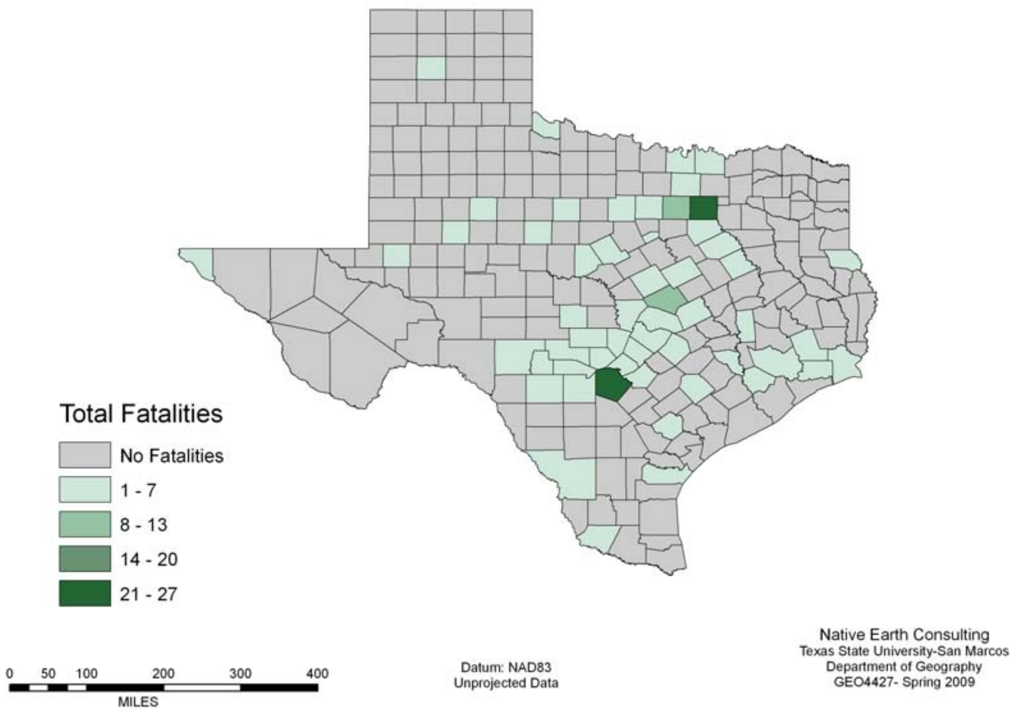


Figure 2: Flash Flood Fatality by Decade

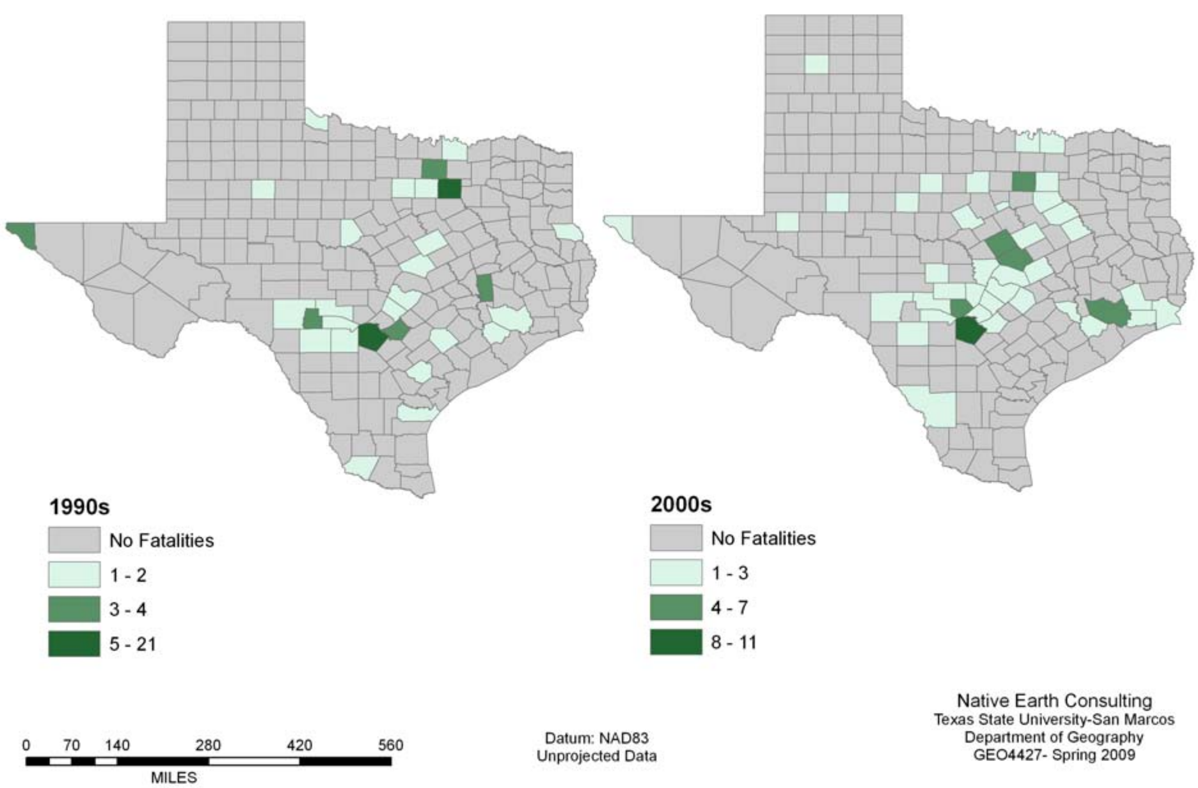
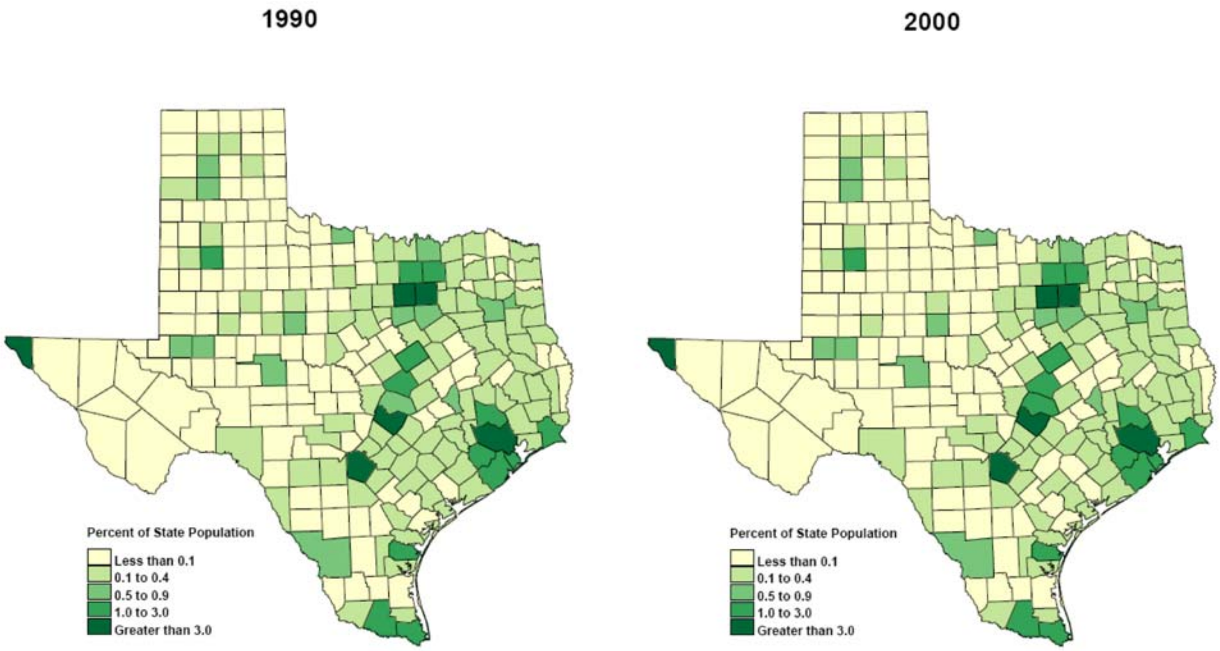


Figure 3: Population Growth of Texas Counties



Maps Produced by the Texas State Data Center

Figure 4: Flash Flood Fatality Crop and Property Damages

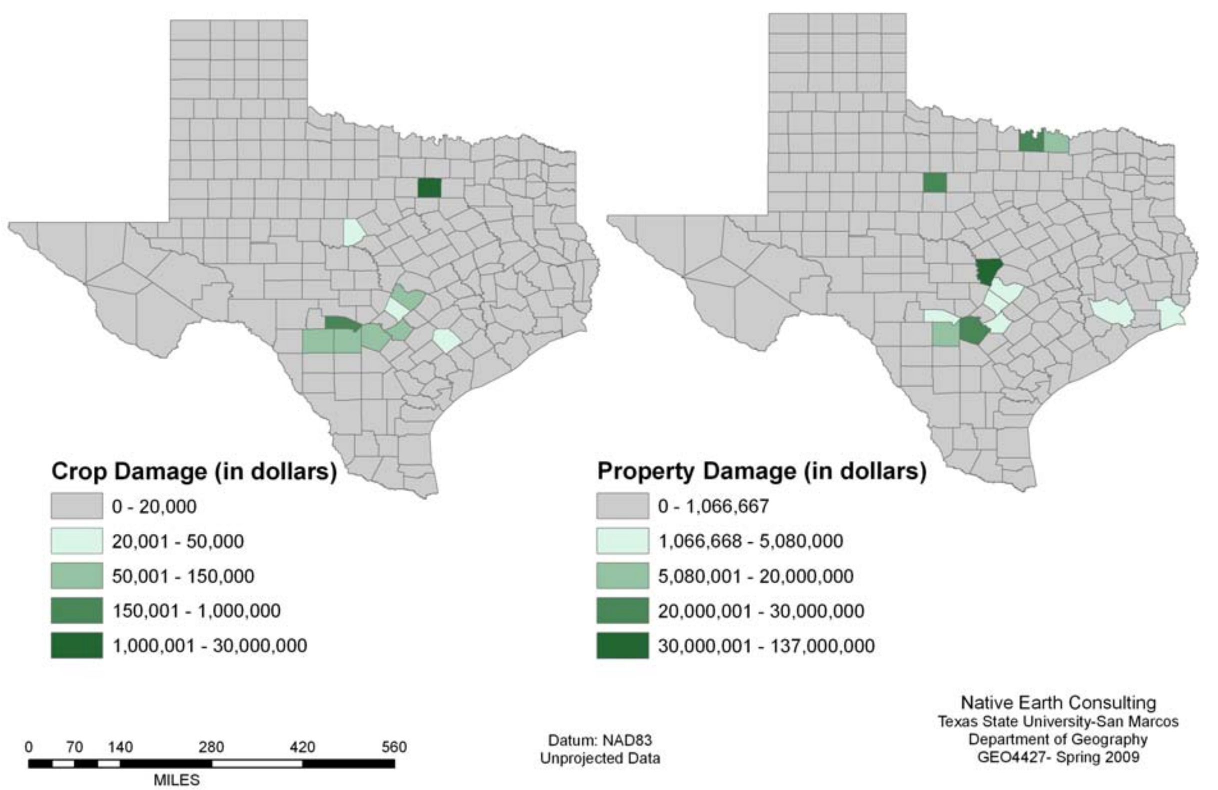
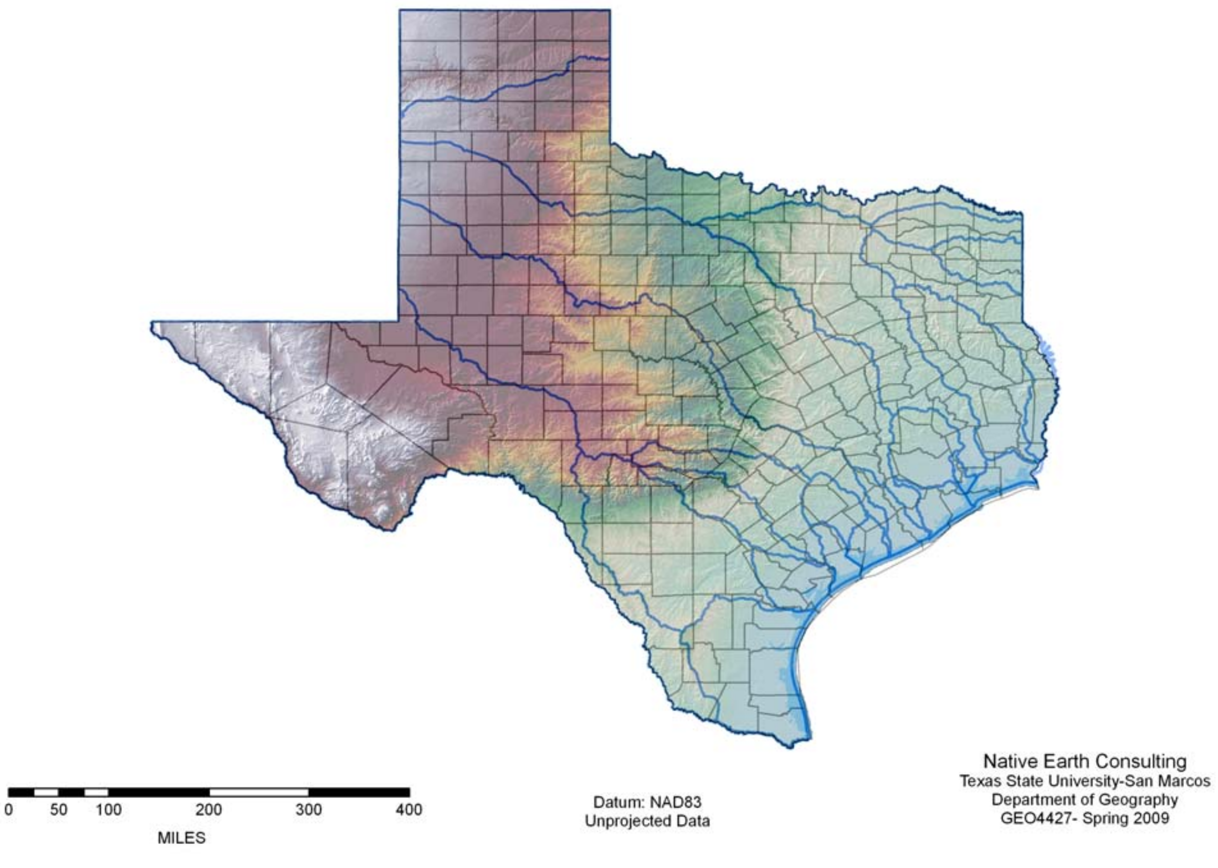


Figure 5: Texas Counties, Major Rivers & Terrain



APPENDIX IIII: METADATA FOR COUNTY LAYER

Identification_Information:
  Citation:
    Citation_Information:
      Originator: TNRIS
      Publication_Date: 1995
      Publication_Time: Unknown
      Title: Counties
      Geospatial_Data_Presentation_Form: vector digital data
      Series_Information:
        Series_Name: Boundary Data
        Issue_Identification: Version 1
      Publication_Information:
        Publication_Place: TNRIS
        Publisher: State of Texas
      Online_Linkage: \\GEO-305591\E\Flash Flood Project\Data for project\Counties.shp
      Larger_Work_Citation:
        Citation_Information:
          Originator: TNRIS
          Publication_Date: 1995
          Publication_Time: Unknown
          Title: Boundary
          Edition: 1
          Geospatial_Data_Presentation_Form: vector digital data
          Series_Information:
            Series_Name: Boundary
            Issue_Identification: 1
          Publication_Information:
            Publication_Place: TNRIS
            Publisher: State of Texas
  Description:
    Abstract: StratMap Boundaries show political jurisdictions including city, county, state, national boundaries, and cultural boundaries i.e., airports, universities, wildlife refuges, and military bases. StratMap Boundaries are useful in right-of-way determination, highway planning and maintenance, real estate, public services, jurisdiction maintenance, and numerous administrative assignments.

    Purpose: The Texas Strategic Mapping Program, known as StratMap, is a multi-year, cost-sharing program that has built mission-critical GIS base data statewide. The federal government and the State of Texas are contributing up to 75% of the development costs of the data, making StratMap a great opportunity for Texans to develop low cost, accurate, and up-to-date GIS base data for their part of the state. It is StratMaps goal to create the best integrated statewide transportation layer possible. The transportation layer is designed to be a transportation layer that can be integrated into many GIS applications.

Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date: January 2004
      Beginning_Time: 12:01am
      Ending_Date: December 2004
      Ending_Time: 11:59 pm
  Currentness_Reference: publication date
Status:
  Progress: Complete
  Maintenance_and_Update_Frequency: As needed
Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -106.646220
    East_Bounding_Coordinate: -93.507800
    North_Bounding_Coordinate: 36.500380
    South_Bounding_Coordinate: 25.837220
Keywords:
  Theme:
    Theme_Keyword_Thesaurus: County
    Theme_Keyword: Boundary
  Theme:
    Theme_Keyword_Thesaurus: TxDOT Districts
  Theme:
    Theme_Keyword_Thesaurus: Council of Governments
  Place:
    Place_Keyword: Texas

Access_Constraints: Trans data is organized by county in both ESRI 9.x Personal GeoDatabase and Shapefile formats. The data is available for free on the internet or can be purchased on CD.

Use_Constraints: StratMap does not warrant this data for any particular use and is not responsible for any damages resulting from the use of the data. Users of these files should be aware that (1) StratMap data are not authoritative representations of boundaries, (2) StratMap boundary lines are subject to change and corrections, (3) StratMap boundaries was generated from the best available data which is subject to change, and (4) StratMap is updating the boundary data and has a process for collecting and noting boundary changes. Contact StratMap for more details. Acknowledgement of the StratMap program appreciated in products derived and used from the data.

Point_of_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: TNRIS
Contact_Person: StratMap
Contact_Address:
Address_Type: mailing address
Address: P.O. BOX 13231
City: Austin
State_or_Province: Texas
Postal_Code: 78701
Country: USA
Contact_Voice_Telephone: 512-463-8337
Contact_Facsimile_Telephone: 512-463-7274
Contact_Electronic_Mail_Address: stratmap@tnris.state.tx.us
Hours_of_Service: 8:00-5:00
Browse_Graphic:
Security_Information:
Security_Classification_System: None
Security_Classification: Unclassified
Security_Handling_Description: None
Native_Data_Set_Environment: Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 3; ESRI ArcCatalog 9.3.1.1850
Cross_Reference:
Citation_Information:
Originator: TNRIS
Publication_Date: 1995
Publication_Time: Unknown
Title: Boundaries
Edition: 1
Geospatial_Data_Presentation_Form: vector digital data
Series_Information:
Series_Name: Boundaries
Issue_Identification: 1
Publication_Information:
Publication_Place: State of Texas
Publisher: TNRIS
Data_Quality_Information:
Positional_Accuracy:
Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: Trans features digitized to much 1995-1997 State of Texas Aerial Photography. Hornizontal positional accuracy is +/- 4 meters. The boundary layer was visually inspected and compared to source maps by a second technician to ensure horizontal position accuracy met standards. Accuracy is limited to the validity of available data.

Quantitative_Horizontal_Positional_Accuracy_Assessment:

Horizontal_Positional_Accuracy_Value: +/- 4 meters

Horizontal_Positional_Accuracy_Explanation: Data photorevised to the DOQQs: +/-4 meters. Data revised to the DRGs: +/- 4 meters. The accuracy of the DOQQs is better than the DRGs.

Vertical_Positional_Accuracy:

Lineage:

Source_Information:

Source_Citation:

Citation_Information:

Originator: TNRIS

Publication_Date: 1995

Publication_Time: Unknown

Title: Boundary

Edition: 1

Geospatial_Data_Presentation_Form: vector digital data

Series_Information:

Series_Name: Boundary

Issue_Identification: 1

Publication_Information:

Publication_Place: State of Texas

Publisher: TNRIS

Source_Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: 1995

Source_Currentness_Reference: publication date

Source_Information:

Source_Citation:

Citation_Information:

Originator: Texas Department of Transportation, Transporation Planning and Programming

Publication_Date: 1995

Publication_Time: Unknown

Title: Boundary

Edition: 1

Geospatial_Data_Presentation_Form: vector digital data

Series_Information:
Series_Name: Boundary
Issue_Identification: 1
Publication_Information:
Publication_Place: State of Texas
Publisher: Department of Transportation
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: D:\DOCUME~1\rmitche\LOCALS~1\Temp\xml4.tmp
Process_Step:
Process_Description: Metadata imported.
Source_Used_Citation_Abbreviation: C:\DOCUME~1\rmitchel\LOCALS~1\Temp\xml46.tmp
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation: Server=Huan; Service=5151; Database=IS_PG; User=rmitchell; Version=sde.DEFAULT
Process_Step:
Process_Description: Dataset copied.
Source_Used_Citation_Abbreviation: \\TNRISFS\InProgress\Vector\Boundaries\StratMapv2\pgdb\StratMap_Boundaries_v150.mdb
Spatial_Data_Organization_Information:
Direct_Spatial_Reference_Method: Vector
Point_and_Vector_Object_Information:
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: G-polygon
Point_and_Vector_Object_Count: 254
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Label point
Point_and_Vector_Object_Count: 1056
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: GT-polygon composed of chains
Point_and_Vector_Object_Count: 1055
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Node, planar graph
Point_and_Vector_Object_Count: 2089
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Point
Point_and_Vector_Object_Count: 4
SDTS_Terms_Description:

SDTS_Point_and_Vector_Object_Type: Label point
Point_and_Vector_Object_Count: 0
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 273
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 255
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 31
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 26
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 2
SDTS_Terms_Description:
SDTS_Point_and_Vector_Object_Type: Composite object
Point_and_Vector_Object_Count: 2
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution: 0.000000
Longitude_Resolution: 0.000000
Geographic_Coordinate_Units: Decimal degrees
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Resolution: 1.000000
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates
Entity_and_Attribute_Information:
Detailed_Description:
Entity_Type:
Entity_Type_Label: Counties

Entity_Type_Definition: GeoDataBase Feature Class
Entity_Type_Definition_Source: TNRIS
Attribute:
Attribute_Label: SOURCE
Attribute_Definition: Source of Data
Attribute_Definition_Source: TNRIS
Attribute:
Attribute_Label: NAME
Attribute_Definition: Name
Attribute_Definition_Source: TNRIS
Attribute:
Attribute_Label: COG_ABBR
Attribute_Definition: Council of Governments Abbr
Attribute_Definition_Source: TARC
Attribute:
Attribute_Label: FID
Attribute_Definition: Internal feature number.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Sequential unique whole numbers that are automatically generated.
Attribute:
Attribute_Label: SHAPE
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: Shape
Attribute_Definition: Feature geometry.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Coordinates defining the features.
Attribute:
Attribute_Label: LOCAL_ID
Attribute_Definition: Local Unique Number
Attribute_Definition_Source: Local
Attribute:
Attribute_Label: TXDOT_ABBR
Attribute_Definition: TxDOT District Abbr

Attribute_Definition_Source: TxDOT
Attribute:
Attribute_Label: STRATMAP_I
Attribute:
Attribute_Label: FIPS_CODE
Attribute_Definition: FIPS Code
Attribute_Definition_Source: US Census Bureau
Attribute:
Attribute_Label: DATE_CREAT
Attribute:
Attribute_Label: DATE_RETIR
Attribute:
Attribute_Label: SHAPE_Leng
Attribute_Definition: Area of feature in internal units squared.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: 2000
Attribute_Definition: Flash flood fatalities occuring in 2000's
Attribute_Definition_Source: National Oceanic and Atmospheric Admisitration
Attribute:
Attribute_Label: Crop
Attribute_Definition: Total crop damage caused by flash floods
Attribute_Definition_Source: National Oceanic and Atmospheric Admisitration
Attribute:
Attribute_Label: Prop
Attribute_Definition: Total property damage caused by flash floods
Attribute_Definition_Source: National Oceanic and Atmospheric Admisitration
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: SHAPE_Area
Attribute_Definition: Area of feature in internal units squared.
Attribute_Definition_Source: ESRI
Attribute_Domain_Values:
Unrepresentable_Domain: Positive real numbers that are automatically generated.
Attribute:
Attribute_Label: 1990
Attribute_Definition: Flash flood fatalities occuring in 1990's

Attribute_Definition_Source: National Oceanic and Atmospheric Admisitration
Distribution_Information:
Distributor:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: Texas Department of Transportation
Contact_Person: Information Systems Division - GIS
Contact_Voice_Telephone: 512-465-3618
Contact_Facsimile_Telephone: 512-465-7668
Contact_Electronic_Mail_Address: ISD-GIS-Support@dot.state.tx.us
Hours_of_Service: 8:00-5:00
Resource_Description: Downloadable Data
Standard_Order_Process:
Digital_Form:
Digital_Transfer_Information:
Transfer_Size: 3.070
Available_Time_Period:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: January
Ending_Date: December
Metadata_Reference_Information:
Metadata_Date: 20090507
Metadata_Review_Date: 20021231
Metadata_Future_Review_Date: 20031231
Metadata_Contact:
Contact_Information:
Contact_Organization_Primary:
Contact_Organization: TNRIS
Contact_Person: StratMap Analyst
Contact_Address:
Address_Type: mailing address
Address: P O Box 13231
City: Austin
State_or_Province: Texas
Postal_Code: 78701
Country: USA
Contact_Voice_Telephone: 512-463-8337
Contact_Facsimile_Telephone: 512-463-7274
Contact_Electronic_Mail_Address: data@tnris.state.tx.us

Hours_of_Service: 8:00-5:00
Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
Metadata_Standard_Version: FGDC-STD-001-1998
Metadata_Time_Convention: local time
Metadata_Access_Constraints: This data has been prepared for internal use within the Texas Department of Transportation. Accuracy is limited to the validity of available data.
Metadata_Use_Constraints: This data is for mapping and planning purposes only. It is not to be used to develop any engineering products.
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile
Metadata_Extensions:
Online_Linkage: http://www.esri.com/metadata/esriprof80.html
Profile_Name: ESRI Metadata Profile

APPENDIX IV: TEAM MEMBER CONTRIBUTION

Preliminaries

- All team members worked collaboratively in locating data sources for flash flood fatalities, journal articles, and lists of variables and data layers
- All team members designed a group name and logo and collectively decided on Native Earth Consulting and Earth Logo

Proposal

- Sections split between group members
  - Michael: Summary, Scope and Budget
  - Cameron: Purpose and Implications
  - Justin: Data and Methodology
  - Rebecca: Literature Review, Timetable, Final Deliverables, Conclusion and Participation
- Rebecca organized proposal sections, completed technical writing and revision, and had final version spiral bound for submittal to client.

Proposal Presentation

- Each group member created slides for their own sections of the proposal
- Cameron: Completed proposal presentation
- Cameron & Rebecca: Revised proposal presentations based on class comments

Flash Flood Fatality Database Compilation

- All team members worked collaboratively:
  - Compiling the flash flood fatality database
  - Conducting searches in SHELDUS and the NCDC Storm Data reports.
- Counties were split alphabetically between the team to search the NCDC reports for more detailed information regarding statistics
- Michael: Reviewed Storm Data reports, continued to search for more detailed data, and compiled information into final database
- Cameron and Justin: Continued to search for more detailed data
- Rebecca & Cameron: printed out NCDC Storm Data Reports
- Rebecca: Compiled reports into binder and created a cover sheet

Tables & Statistical Analysis of Flash Flood Fatality Database

- Cameron: Generated totals, percentages and statistics from the FFF Database
- Rebecca: Compiled everything into excel spreadsheets and created tables used in the poster and final report

Progress Report & Presentation

- Rebecca: Completed progress report and presentation

GIS Analysis/Static Maps

- Justin: Added fields within the county layer attribute table, calculated values for counties to be edited, and utilized keyboard entry to input values with help from Rebecca and Cameron
- Justin: Created all static maps with input and help from Rebecca and Cameron
- Cameron: Updated metadata for the counties layers and newly created attribute fields

Website and IMS

- Michael: Created both the Website and IMS/Manifold with input from all team members
- Rebecca: Provided text to be used on the website

Poster

- Rebecca: Constructed/Organized the Poster and completed technical writing for various sections
- Cameron: Helped in writing the results and conclusion
- Justin: Provided all maps for the poster
- Michael: Helped with revision and proof-reading

Final Report & Presentation & CD

- Rebecca: Completed organization and all technical writing of final report, constructed the final presentation and compiled all necessary documents provided from all team members onto a CD and created labels for CD, and compiled all final deliverables for submittal to the client
- Cameron, Justin & Michael: Provided input for the limitations, future research, project opinions, and lessons learned sections and proof-read final report

Section	Word Count
Introduction	374
Problem Statement	442
Data	391
Methodology	647
Results	756
Discussion	1,313
Conclusions	336
Contributions	63
Totals	4,322