DISCOVERING SPATIAL AND TEMPORAL PATTERNS OF TRAFFIC ACCIDENTS IN STILLWATER, OKLAHOMA

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CHAPTER I

INTRODUCTION

Conquering the Landscape

Automobiles dominate urban landscapes. A majority of people choose the automobile as their primary mode of transport over other alternative modes such as pedestrian, bicycle, and mass transit (subways, buses). Society enjoys the luxury that personal automobiles offer. They offer freedom and convenience to drivers, allowing one to rapidly transport to various destinations. The driver chooses when and where to depart and arrive. While in motion, drivers enjoy the luxury of personal climate controlled environments along with one's choice of a variety of music. This machine is American society's preferred mode of travel; the demand and dependence of the automobile has determined the fabric of urban cityscapes. The design of the landscape, from drive-thru restaurants to indoor car garages, is forced to satisfy the demand of the personal vehicle by becoming automobile-oriented.

Automobile-Oriented Society

In the United States, society and cityscapes are increasingly becoming automobile-oriented. In the post WWII economy, the user-friendly automobile flourished. Vehicles are mass produced at a price that allows the consumer the ability to have a trendy and affordable automobile. Society has continued to become more dependent upon this convenient mode of personal transportation. Worldwide, U.S. cities show extreme dependence upon the automobile, along with cities in Canada and Australia (Kenworthy and Laube 1999). The distribution of automobile use is not the same worldwide. European and Asian cities are not as dependent on the automobile, with much of their population using different modes of transportation. These cities use mass transit and are dependent upon pedestrian modes such as walking and bicycling (Kenworthy and Laube 1999). The design of the city is influenced by the heavy reliance upon the automobile.

The American urban landscape sprawls outward and stretches out; such as Los Angeles, California. The automobile allows movement along far ranging distances and destinations. Parking lots and garages are created to house the automobile when not in use. Drive-thru restaurants flourish, delivering fast food directly into the windows of automobiles. Automobile dependence shapes cityscapes into automobile-oriented urban societies. With society choosing this mode of transport, problems of traffic congestion and accidents are made known through our increasing use and dependence upon automobiles.

Congestion and Accidents

As society continues to use the automobile as a major mode of transportation, traffic congestion and accidents are inevitable. The benefits of the automobile are offset by congested cities during rush hour traffic. The convenient and comfortable automobile slowly travels along congested roadways. Congestion and traffic accidents increase in occurrence as motorists increase usage and dependence on the automobile. The congestion is due to about 160 million drivers in the U.S. freely using roadways (Li et al. 2007). High levels of traffic and congestion greatly influence the production of automobile accidents (Levine et al. 1995c). Accidents continue to occur as more cities modernize and develop to appease the desire for motorization (Hijar et al. 2004). Although congestion is an issue, it is not immediately life threatening. Traffic accidents are the real hazard to human health, and there are several social factors associated with automobile accidents.

Social Issue of Traffic Accidents

Traffic accidents occur because of several factors. They are products of driver behavior, roadway condition, traffic characteristics, and environmental factors (Li et al. 2007). Accidents are also influenced by social patterns. Concentrated social activities such as shopping, entertainment, and employment explain driver behavior (Levine et al. 1995c). Levine describes that accidents involve an interaction of traffic volume, weather, holidays, and weekly patterning of social activities (1995a). The behavior of daily travel patterns of the entire fleet of automobiles on roadways is dynamic in process (Axhausen et al. 2002). Different age cohorts of the population have different travel patterns.

The Baby Boomer generation refers to the cohort of the population in the U.S. of people born between 1946 and 1964. This size cohort increases the proportion of drivers and traffic on roads in the U.S. (McKnight 2003). Boomers lead to an increase of traffic and daily travel patterns such as leisure, social, and shopping activities (Moreno and Gosselin 2008). Levine suggests that human activities can help to predict traffic accidents (Flahaut 2004). The Boomer cohort contributes to more daily travel patterns on roads, influencing an increase in traffic accidents. Drivers are involved in accidents while experiencing everyday social activities, allowing accidents to be considered at the social level. To help remedy this social phenomenon, safety has become a primary goal for transportation planners and city officials.

Importance of Safety

Transportation safety became center stage with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 (Kim et al. 1995a). With ISTEA, increased awareness and attention is continually devoted to traffic congestion and safety at preventing accidents (Jun et al. 2007). Transportation planners and engineers continue to research and seek ways to make roadways safe for drivers. The goal of safety research is to better understand the complex influences associated with traffic accidents to implement corrective measures and remedy the problem (Brijs et al. 2008). This thesis will show that by mapping traffic accidents, the phenomena can be better understood through various visualization techniques.

Mapping and Location Identification

One of the most important aspects of researching traffic accidents is studying specific locations where accidents occur. This makes "crash mapping" (Kaufman 2008) an essential part of reducing traffic accidents. By visualizing traffic accidents, one is able to observe spatial relationships to gain a greater understanding of where and when they occur. Maps become a compass that can help direct police and transportation planners to specific urban areas for safety improvements. As "visual stimuli," a map shows geographic relationships to viewers (Monmonier 1991). Maps allow many aspects of real space to be represented to a viewer without having to go out into the real-world. Using maps, the viewer can comprehend spaces and patterns by a visual representation of the real-world (Lloyd and Bunch 2009). A map is an important method at which to view spatial-temporal patterns of traffic accidents. Different visual representations can act as tools to provide users with gained knowledge of accidents. Geographic visualization becomes a powerful tool. Geovisualization involves using visual representations to make spatial problems visible to one of the human body's most powerful senses—vision (Slocum et al. 2009). Geovisualization allows viewers to easily see and understand accidents in urban areas. Viewing the locations of accidents helps to identify areas of urban cities needing reform.

Once specific locations are identified, solutions such as new road design and better signage can help reduce accidents. The most common method is black spot or hot spot detection. A hot spot is a concentration of traffic accidents occurring at or close to a specific location (Kaufman 2008). Usually, crashes form these clusters, or hot spots, in geographic space (Xie and Yan 2008). The terms black spot and hot spot are often used interchangeably. Hot spot identification is a tool for safety as it helps prioritize specific areas on a road network (Kaufman 2008). Finding and reforming intersections and road areas with unusually high amounts of accidents, these so called hot spots, improves road safety (Geurts and Wets 2003). Identifying hot spots is a widely accepted and effective approach to the safety of accident prevention. Western Australia uses the National and State Black Spot Program for reducing the accidents at these locations, making roads safer for users (Meuleners et al. 2008). Solutions can be implemented onto existing road networks once hot spots are identified through crash mapping.

Using crash mapping is significant; as it acts as a compass for finding solutions to accidents. Formulating solutions is the next step once a hot spot is identified. Roundabouts are a choice solution for intersection hot spots (Figure 1). The benefits to roundabouts include safety and mobility. As a safety solution, roundabouts are becoming increasingly popular in the U.S., and reduce injury due to traffic accidents (Hels and

Bekkevold 2007). Other solutions such as traffic calming are implemented at hot spots. Examples of traffic calming include parabolic speed humps and chicanes (Figure 2).

Transportation planners have used traffic calming to also encourage alternative modes of travel such as pedestrian movement (Randall et al. 2005). Awareness from ISTEA and the 1998 Transportation Equity Act for the 21st Century (TEA-21) has caused a shift from automobile-oriented planning to accommodating pedestrian travel. Walking and bicycling are now seen as valid modes of travel. The goal of this new urban design of "walkable cities" helps to reduce traffic congestion and accidents, and is viewed as an important safety solution (Southworth 2005). As hot spots for traffic accidents are identified, many solutions aid in increasing the safety of society and its use of road networks for travel.

Figure 1. An example of a roundabout in Cecil County, MD (Persaud et al. 2000).

Figure 2. Chicanes in Saint-Sulpice, France are used to reduce speed (Larsen 2007).

Statement of the Problem

Traffic accident research is important and necessary to gain greater understanding of accidents. According to the National Highway Traffic Safety Administration (NHTSA), the primary mode of travel in the U.S. is the automobile. In 1951, the U.S. recorded its millionth death from traffic accidents. In the 1980s, deaths from traffic accidents averaged 50,000 annually (Whitelegg 1987). In 2007 there were over 6 million traffic accidents reported by police, and over 41,000 people died as a result of those crashes (NHTSA 2009). On average, that is 112 people each day—one every 13 minutes. In 2005, traffic accidents were the leading cause of death for every age from 3 through 6 and 8 through 34 (NHTSA 2009). Traffic accident research is worth studying, in hopes of creating safer roads for an automobile-oriented society. Geography brings unique aspects to the research of traffic accident safety through crash mapping and geovisualization techniques.

Traffic accident research benefits from knowledge gained by studying geographic relationships within the phenomena. Geography allows accidents to be studied spatially. This study seeks to gain understanding of traffic accidents through various visual and cartographic representations. Traffic accident data can be rearranged to reveal spatial-temporal patterns. In this study, maps are used as methods in which to descriptively analyze accidents. These methods incorporate various visual representations as tools. New knowledge and patterns of traffic accidents can be gained from studying crashes geographically. Traffic accidents are not simply random events occurring on the landscape. There exist patterns in the occurrence of accidents, and the benefits of incorporating geography better the research (Levine et al. 1995b). Traffic accident research has benefited from using geographic information systems (GIS) to map and visually represent traffic accidents.

Crash mapping determines the geographic locations of traffic accidents. Mapping traffic accidents using GIS allows police, planners, and the public to visualize where traffic safety improvements can be implemented (Kaufman 2008). GIS is a vital tool for traffic safety, it identifies safety "deficient" locations to help decrease accidents (Erdogan et al. 2008). This study seeks to discover patterns within traffic accidents in order to navigate police and city planners to specific locations. Using GIS to cartographically represent the accidents improves the safety of a city's road network. Individual cities benefit from crash mapping and identifying hot spots to create safer roads.

To my knowledge, there has been no research dealing with crash mapping in Stillwater, Oklahoma. This study searches within the data to find crash patterns associated with social activities. Greater understanding is gained by using maps as a method of communication. Traffic accident data is "sliced and diced" to reveal distinct spatial-temporal patterns. By isolating specific days and times, patterns are visually represented to gain a better understanding of accidents in the city of Stillwater. This study acts as a powerful navigation tool to direct police and city planners to highlighted locations within the city. The study also acts as a staging checkpoint in the process of increasing driver and road safety. The city benefits from this study by gaining insight through visually represented patterns of traffic accidents within Stillwater, Oklahoma.

Area of Study

The study area incorporates Stillwater, Oklahoma, located in Payne County, and has a population of approximately 50,000. The city hosts a major university, Oklahoma State University (OSU). Both Oklahoma City and Tulsa are within approximately a one hour driving distance from Stillwater. This short distance makes it easy for drivers to make trips interchangeably between the major cities of Oklahoma for desired goods, services, and activities. Traffic and congestion are often experienced in the city as a result of the influx and outflux flows of automobiles. Sporting events, holidays, and OSU students create patterns of congestion within the city. With OSU's presence, the proportion of college aged drivers is most likely higher than a similar city without a major university. Residents of the city from ages 20 to 24 make up 29% of the overall population (U.S. Census Bureau 2000). Stillwater also experiences the normal patterns of traffic in a city such as rush hour at 5 p.m., the end of a workday. Traffic accidents are highly concentrated in developed urban areas such as Stillwater; locations of accidents usually overlap with urban concentrated areas (Kim et al. 1995a). Stillwater's urban area offers an interesting pattern of traffic and accidents between the city and university.

Stillwater's transportation network influences traffic flow, congestion, and accidents. The city's two main arterial collector streets are state or federal highways (6th Avenue - SH51 and Perkins Road - US177). Much of the traffic flow within the city utilizes the two streets (Figure 3). Seasonal patterns of traffic and accidents occur in conjunction with OSU's activities. The student population leaves the city for holidays and summer seasons. Traffic accidents are influenced by the city's social activities tied to the university.

Patterns associated with Stillwater's traffic accidents are the spatial and temporal characteristics behind the crashes. Stillwater's social activities, seasonal patterns, sporting events, and weather events reveal distinct patterns of when and where accidents are occurring within the city. Of the many factors influencing accidents, part of the issue

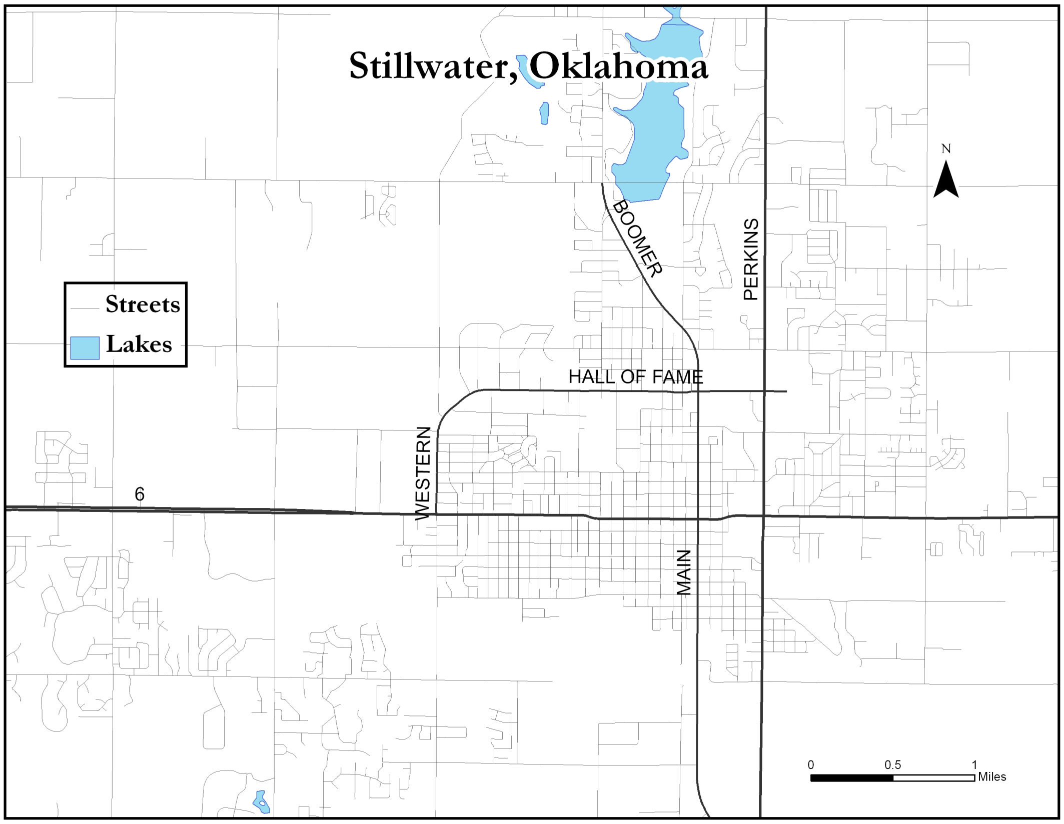

Figure 3. The city uses the darker shaded streets as arterial collectors for traffic flow.

is related to the lifestyles and behaviors of drivers—activities such as work, school, and socializing (Kim and Yamashita 2001). These social activities influence the spatial and temporal arrangement of the accidents. Using GIS, discovering where and when the accidents occur might allow greater understanding to be reached. This understanding influences improved and safer roadways, but the accidents first must be mapped and visualized spatially, rather than statistically. It might be thought that accidents occur randomly in time and space; however, they cluster spatially and temporally (Black 1991). As accidents cluster in time and space, safety is improved by identifying problem locations of hot spot areas within cities (Black 1998). Accidents vary spatially according to the time of day and day of week, reflecting patterns in changing traffic congestion levels (Kim et al. 1995a). Below is a four-fold plan to gain greater knowledge of accidents within the city.

Objectives

1. Using a GIS, cartographically represent and display traffic accidents of the city of Stillwater spatially, using location.

2. Identify hot spot locations where traffic accidents occur in time and space using various cartographic and visual representations.

3. Identify spatial and temporal patterns associated with traffic accidents in Stillwater, including city wide occurrences due to social activities, sporting events, and weather events. Determine an accident rate at road intersections to determine dangerous locations.

4. Gain understanding of the city's traffic accidents through crash mapping and visual representations of spatial-temporal patterns.

The objectives incorporate a four-fold plan at which to identify infected areas along Stillwater's road network. There are numerous methods of research in the topic of traffic accident and safety analysis. Viewing the previous research of this topic provides a firm foundation for the study in Stillwater, Oklahoma.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Relevance of Traffic Accidents and Safety

The automobile is a machine, but today one could make a strong argument that the automobile is a very necessary friend and foe in an American society. Before the rise and vast diffusion of the user-friendly automobile, it was not necessary to have intricate road network infrastructure; the idea of urban sprawl was not an issue. Today, road network infrastructure is studied by transportation planners and academic researchers to try to solve traffic congestion issues. A major issue with the automobile-oriented infrastructure is traffic accidents. Technology such as GIS offers a spatial solution to analyzing and critically evaluating traffic accidents on roadways. By studying accidents, solutions can be discovered to make roads safer for automobile-oriented users within an automobile-oriented society. Understanding academic literature of traffic accident analysis provides a solid foundation to my research in studying spatial-temporal characteristics of traffic accidents in Stillwater, Oklahoma.

Academic research concerning traffic accidents began using GIS as early as the 1990s. This chapter will review specific topics of traffic accidents in academic literature. First, I plan on discussing the emergence and importance of using GIS while studying traffic accidents. Secondly, I will point out pioneering figures of traffic accident studies, and discuss how their research is closely related to what I explore. These key figures analyze spatial-temporal patterns of traffic accidents, which is the foundation of my own research. Next, I will examine the literature analyzing the spatial-temporal aspects of traffic accidents—where accidents occur and when they occur, and whether there are associated patterns with those places and times. Lastly, I will examine literature that considers reform and treatment of safety deficient locations in cities. GIS is a major unifying theme among the articles.

Using maps as methods allows understanding to be gained through different geovisualizations of accident patterns. GIS, as a tool, has built strong bridges to other disciplines other than Geography that are interested in incorporating the new technology into current and relevant research. This is important to my research because other disciplines such as engineering and civil planning departments are also interested in traffic accident analysis. My work brings a geographic component of location to the accidents, instead of only statistics, allowing results to be viewed in spatial locations.

Emergence of Geographic Information Systems

Traffic Accident Factors: Systematic, not Random

Numerous factors influence the severity and frequency of traffic accidents (Li et al. 2007). A major assumption is that the higher the interaction of an area located on the road network, the higher the amount and frequency of vehicle accidents. Compared to rural areas, urbanized areas experience higher frequencies of traffic accidents simply because there is more traffic, and more opportunity for multi-vehicle traffic accidents (Levine et al. 1995c). The public holds a common misconception that traffic accidents are a direct effect of random events, meaning that crashes defy the ability to be researched systematically (Navin and Appeadu 1995). This is an incorrect notion because numerous factors lead to the direct influence and cause of traffic accidents (Li et al. 2007). Since traffic accidents are not random, they can be studied by location using GIS.

Discovering the First GIS Literature of Traffic Accident Research

In the past, traffic accidents were studied using statistics only, leaving out the spatial location component of where the accidents occur on the landscape. GIS is an important tool for traffic accident research to be studied by location along with statistics (Erdogan et al. 2008). Developments in GIS such as desktop GIS packages have made it easier to do research on traffic accident and safety analysis (Kim et al. 1995a). In the late 1990's, GIS had existed for over three decades, yet research in traffic accident and safety analysis was new with very few published articles (Austin et al. 1997). In 1995, only 29 state transportation departments utilized GIS (Kim et al. 1995a). The development of the Intermodal Surface Transportation Efficiency Act (ISTEA) supports the development of GIS technologies in researching transportation planning. Numerous states are expected to continue investing in GIS packages for transportation research and safety (Kim et al. 1995a). Identifying safety deficient locations on roadways with GIS will help decrease traffic accidents (Erdogan et al. 2008). There are a handful of academic researchers who have helped pioneer the analysis of traffic accident research using GIS as an important and useful tool.

Kim and Levine: Pioneers of Geographic Traffic Accident Research

Kim and Levine are two of the leading advocates in the geographic perspective towards the research of traffic accident safety and their locations. In 1995, they researched the spatial and temporal patterns of accidents in Honolulu, Hawaii (Kim et al. 1995a). Both the authors' articles are not only relevant to the present, but they also show the important emergence of GIS. In 1992, Hawaii became one of seven states selected to begin research and creation of a crash outcome data evaluation system (CODES). CODES aims to create database information on vehicle incidents as well as health and economic characteristics of the accidents. This system analyzes seatbelts, helmets, and current safety implementations on transportation networks (Kim et al. 1995a). Kim and Levine published several academic articles studying accidents in Honolulu, Hawaii. By analyzing traffic accidents on the island, Kim and Levine find patterns in the time and location of specific crashes. Honolulu is at a different scale than Stillwater; however, this study, much like Kim and Levine, examines where and when accidents occur within a city. Their research is a launching pad for my study because I concentrate on the spatial-temporal aspects of accidents in Stillwater, Oklahoma.

Teenage and Alcohol Related Accidents

Kim and Levine's work analyzed driver behavior to assess traffic accidents and personal safety. Kim and Levine studied the amount of accidents associated with alcohol and drugs. They specifically researched young male drivers affected by alcohol or drugs caught in a "rollover" accident (Kim et al. 1995a). Kim built a model that determined the probability of specific instances of accidents involving speeding, alcohol use, drugs, and severity of injury to rank the severity of the accident (Kim et al. 1995a). My research will examine specific age groups, locations, and times of traffic accidents. Studying accidents near high schools at 8 a.m. and 3 p.m. in conjunction with 16 and 17-year-old drivers may show patterns associated with teenagers arriving and departing from school.

Researching specific age group behavior is important to highlighting social problems such as teen drug and alcohol abuse. Teenage use of drugs and alcohol while driving has been a major concern of parents and insurance companies (Hellinga et al.

2007). Further research may lead to greater awareness of driver behavior. Behaviors like drinking alcoholic beverages and speeding are commonly associated factors that increase and influence traffic accidents (Kim et al. 1995b). Kim compares gender, mentioning that male drivers are more apt to experience severe accidents; young drivers (late teens to mid 20s) are more prone to experience accidents; female drivers are more prone to experience fatally injured traffic accidents (Kim et al. 1995b). Kim and Levine also study specific times during the day when traffic accidents occur, and where those accidents occur. Kim and Levine found that traffic accidents are products of higher levels of traffic, which are a result of concentrated daily travel patterns like work, home, shopping, and entertainment (Levine et al. 1995c). My study searches for spatial-temporal accident patterns influenced by social activities in the city of Stillwater.

Spatial Importance and Black Spot Analysis

Kim and Levine analyze spatial patterns associated with traffic accidents in Honolulu, Hawaii (Levine et al. 1995b). Researchers use GIS to geo-reference accident locations, gaining latitude and longitude points based on a projected map coordinate system. The points can be examined using GIS tools to describe the spatial arrangement of those accidents within an urban area (Levine et al. 1995b). The importance of more research coming on the scene shows a necessary need to research traffic accidents. Geographic articles use a spatial representation of a map, others lack maps completely. Chiou develops a neural network system in which to analyze car accidents, yet he does not concentrate on the locations (2006). Locations make a study geographic by studying the spatial arrangement of the traffic accidents. Black spots, or hot spots (used interchangeably), experience numerous traffic accidents compared to other roadway segments (Erdogan et al. 2008). Traffic black spot analysis is used in many academic studies (Levine et al. 1995b). Black spot analysis identifies hazardous areas on road networks. The purpose is to create safer road systems for users. This study uses different unique geo-visual representations to isolate specific patterns within the accident data. As the data is isolated temporally, hot spots are seen geographically. The freshness of this study is that it searches deep to discover social and spatial-temporal patterns of accidents, and represents them visually.

Temporal-Spatial Research and Road Safety

Kim, Levine, and Nitz contribute numerous articles on spatial-temporal traffic accidents within Honolulu. They examine not only spatial patterns, but also consider temporal patterns. Traffic accidents fluctuate daily at different hours per day (Levine et al. 1995c). By studying temporal patterns described by Levine, I identify and analyze accidents at certain days of the week and hours of the day. Levine explains the spatial patterns by population and census block groups (Levine et al. 1995c). This study analyzes the spatial and temporal patterns of traffic hot spots such as where accidents occur at certain hours throughout the day and days of the week. Several of these studies focus their research on a strict aim of model building and quantifying theory in hopes of gaining accident explainability and predictability. The problem with this is that it is difficult to measure, define, and predict human behavior in conjunction with factors that contribute to the creation of a traffic accident. Identifying accident hot spots and spatial-temporal patterns of this phenomenon points out the problem, and directs reform efforts.

Geographic Spatial-Temporal Characteristics

Social Activities and Accidents

Traffic accidents occur more frequently in high traffic congestion and levels of convergence among trips taken on a network, usually a result from a higher concentration of social activities such as shopping, eating, entertainment, or employment (Levine et al. 1995c). Examining these patterns reveals specific accidents at distinct locations based on the activity and the day of week. An interesting sub-topic is the pursuit of temporal patterns of traffic accidents. Daily fluctuations in traffic accidents have been recorded and examined revealing variations in hour, day, week, and month as well as weather (Levine et al. 1995a). The temporal pattern analysis of accidents is an approach that distinguishes Levine's work from other academics. Levine writes, "To our knowledge, there have been no studies which have documented day-to-day changes in motor vehicle accidents for an entire metropolitan area" (Levine et al. 1995a, 785). Li can be compared and contrasted to Levine because Li offers a new visual method to analyzing traffic accidents.

Li uses visual modes similar to Levine, but takes it a step further. Li (2007) uses 3-D visual representation, a method I incorporate into my research. I use ArcScene to three dimensionally represent traffic accidents at certain locations during specific times of the day and days of the week. This method is similar to Levine and Li. Their literature reveals that traffic accidents are influenced by a combination of weather, holidays, the amount of traffic, and normal weekly social activities (Levine et al. 1995a). A specific recreational social activity is drinking alcohol, and unfortunately driving while under the influence of alcohol. Alcohol and drug use are associated with traffic accidents at specific places and times. This is a spatial-temporal relationship of the phenomena of accidents occurring in conjunction with the trip to and from taverns. I examine this sub topic in my research by concentrating on certain tavern clusters around Stillwater at specific time periods.

Unique Themes of Improving Traffic Safety

Raising Public Awareness

As discussed earlier, the basic commonality among the existing research within this topic is the use of GIS. Studies of traffic accident analysis use GIS in different methods. Some research uses zones and polygons that reveal areas of more accidents than others (Austin et al. 1997). With this method, one cannot assess the exact locations of accidents, and it is difficult to determine which locations should be looked at for solutions and reform of hot spot areas. Arthur uses GIS and point data of traffic accidents at certain intersections. T-intersections and four-way intersections were analyzed to set the stage towards awareness of speed and how exceeding speed limits can increase the risk of a traffic accident (Arthur and Waters 1997). His methods were geared towards raising awareness of drunk-driving programs and organizations like MADD (Mothers Against Drunk Drivers). Organized programs are geared towards increasing public awareness and safety of driving (Arthur and Waters 1997). Besides raising awareness, there are many smaller topics to be researched in the spatial-temporal patterns of traffic accidents.

Road Design and Alternative Transportation as a Safety Solution

While most literature on the topic concentrates on the accidents, very few argue toward solutions to those accidents. Transportation planners use solutions such as improving road design and installing traffic calming devices to help reduce accidents. Urban planning plays an important role in analyzing traffic accidents because transportation issues and city planning are directly related. Other modes of transportation such as pedestrian, rail, subway, and buses decrease congestion as well as the likelihood of accidents. Proposing solutions is the key to developing safer streets and providing well-being to its users. Other research in the field has studied the commercial vehicle crashes, and has developed an online web tool interface designed to aid and educate businesses of the risks and dangers of traffic accidents (Bapna 2005). Raising awareness of public and local businesses that use roadways in a city will help reduce traffic accidents. Besides reform solutions to roads for cities, more research is needed to better understand accidents. Intersection accidents and police departments play a vital role in the chain of events during and after an accident. Other research methods help to gain a stronger understanding of traffic accidents.

Data Collection and Spatial Importance

Artificial neural networks and right-of-way scenes involving two-car crashes have been analyzed. There are numerous ways at which two cars will collide against each other at an intersection along a transportation network (Chiou 2006). Some recent literature on traffic accidents does not use spatial location or study patterns of phenomena. Most methodologies use GIS, and regardless of maps or analyzing crash locations geographically, the literature describes use of geocoding data received from government entities. There is a special chain of events in the methodology of data collection: the accident reports of traffic incidents are filled out by police officers arriving at the scene, almost immediately after the crash has occurred. For example, traffic accident data is collected in Hong Kong by the police: Hong Kong has three major databases for crash data and is referred to as Traffic Accident Data Systems, or TRADS (Loo 2006). TRADS contains the only data in Hong Kong with spatial variables of location in the crash data, this is vital to studying the location of phenomena (Loo 2006). This study shows the importance of the spatial locations of traffic accidents. Location is important in order to identify sites that need improved design for safer roads.

Closing Remarks

Pointing a Compass Toward Solutions

As the world evolves into a more automobile-oriented place, traffic congestion, accidents, and safety become increasingly important. Decreasing health standards and increasing congestion create problems that are reduced by traffic calming solutions like using alternate modes of transportation (Pulugurtha et al. 2007). Once transportation networks create better pedestrian crosswalks for user-oriented modes of travel, pedestrian-car crashes inevitably will increase, creating new problems with uncovered solutions: methods specifically geared towards pedestrian safety will take the forefront (Pulugurtha et al. 2007).

Congestion can be alleviated by reducing traffic accidents because car crashes significantly influence the creation of traffic congestion and traffic delays (Huang and Pan 2007). The relevance of studying these upsets within the arteries and systems of networks is important to resolving traffic issues. Geographically, location becomes top priority. Identifying hot spot problem areas aids in the development of safer, more enjoyable transportation networks within urban areas. Geovisualization is a necessary method to point out hot spots and understand accidents. Crampton states that geographic visualization (GVis) “uses the map’s power to explore, analyze and visualize spatial datasets to understand patterns better” (2001, 235). This study aims to act as a compass to point out infected hot spots within the city.

Traffic accidents are a major problem within society. Li writes, “Transportation accidents were the seventh single leading cause of death in the United States” (2007, 274). Traffic accidents are the leader in cause of teenage fatalities in the United States (Hellinga et al. 2007). Further research is needed to help prevent this phenomenon.

Society places great importance upon health safety and road transportation. Society places large importance on the value of life, and traffic accident reduction is worth pursuing. The purpose of this study concentrates, not only on finding patterns, but how those patterns are represented. Maps are powerful methods that communicate geographic data clearly to a viewer (Brewer 2005). Maps are visualization methods, they aid in finding patterns through "visual exploration" of data sets using GISs (Kraak and Ormeling 1996). This study is successful in visually exploring traffic accident patterns to gain more understanding of the phenomenon.

The issue will not go away as traffic continues to rise. Major urban centers are continually revamping road networks as the automobile continues to rise in usage. Local, state, and federal entities are pursuing solutions. Traffic safety has become the most critical issue within government agencies of transportation (Erdogan et al. 2008). Research through these agencies in cooperation with academia can help create safer roads for society's everyday use of roads. Traffic has been a result of increased trips by its users of road networks.

The literature covering the topic of traffic accidents discovers various degrees of traffic patterns, geographic locations, methods using GIS, and unique subsets of narrowed areas. The geographic aspect is absent in much of the literature; instead, it concentrates upon quantitative model building. This allows my research to gain extreme relevance by adding a spatial incentive. Using spatial-temporal patterns in my research allows results to be visualized geographically, making location important to studying traffic accidents. As this study concentrates on finding spatial-temporal relationships in the accident data, graphics and images highlight the relationships through geovisualization (Crampton

2001). The topic of traffic accidents has a solid foundation of previous and ongoing research. The city of Stillwater is a new location for incorporating the methods and GIS techniques of these studies.

CHAPTER III

METHODOLOGY

Three Datasets

City Data

Various methods are used to examine traffic accidents. This study will use three datasets to develop a GIS of traffic accidents in Stillwater, Oklahoma. The methods, design, and visual representations of the accidents are widely accepted within the literature on the topic, and are useful and relevant. ESRI's ArcMap (2009a) is used to create the GIS and contain the datasets of the traffic accidents of Stillwater. The first dataset (City) was received in the spring of 2008. The data was obtained through the Stillwater Police Department. Its format is Microsoft Excel (2007) and contains over 7,500 cases of traffic accidents within a 5 year period from 2003 to 2008. Attributes of each accident in the data include location, severity, date, day of week, and time of day of the accident. The location is defined as two types: address and intersection. Each accident is unique containing the attributes listed, and the data is in a GIS-ready format. Manipulation of this first dataset is minimal, and includes determining which intersection distance to use.

Each intersection accident will be geocoded as a single point in the GIS. Geocoding will take each traffic accident location and place that specific accident within the GIS map. The accident will be placed where it occurred in time and space on the street network of Stillwater. The distance of an accident might be listed as 300 ft from that intersection, yet geocoding this example would place the point directly at the intersection. I decided what distance to use based on an accident occurring as it is influenced by the intersection—the vehicle needs to be close enough to the intersection to have been influenced by it during the accident. I have chosen the distance of being at or less than 100 ft because of the legal distance required for signaling one's vehicle based on the influence of the intersection (DPS 2008). The second dataset will require more manipulation before it can be geocoded.

DPS Data

The second dataset was received in the winter of 2009 from the Oklahoma Department of Public Safety. This dataset was in two parts. The first was a Microsoft Excel file containing almost 12,000 entries of accidents in Stillwater from a 6 year period from 2001 to 2006. This file contained columns such as the temporal characteristics of the accident as well as age and gender, but lacked location. The City data does not contain age and gender, giving the DPS data an advantage. The second part was a large PDF file containing the location of the accidents from the same years: 2001 to 2006. The Excel file lacked location, and the PDF contained the locations of the accidents. Both files contained a unique key, the DPS case number, which was used to join location from the PDF to the Excel file. This process took a substantial amount of time and required a considerable labor intensive effort. Intersection location was the only usable location from the PDF file. The end product contains only intersection accidents of Stillwater.

OSU Data

The third dataset was received from the Oklahoma State University Police Department in the summer of 2009. It contains the traffic accidents that occurred only within the university's boundaries from 2001-2008. Over 2,000 records contain location, temporal characteristics, age, and gender. The data is in Excel format, and is ready for use. The OSU data is important to the study because it fills in the "donut hole" where accidents were not present within the City or DPS data. The university and city are separate, handling traffic accidents separately. The OSU data was used alongside each of the first two datasets to complete the assessment of traffic accidents within the city—to fill in the donut hole of where the university is located. The OSU data from 2003-2008 was combined with the City data to match the time period of the accidents. Also, the OSU data from 2001-2006 was combined with the DPS data for the same reason. The City data will be used for all of the study, except for an intersection rate assessment using the DPS data.

Geocoding and Descriptive Searches

The street network layer file of the city contains the street names and address locations within the city. The two datasets (City and DPS) contain the locations of the accidents. An address locator was created within ArcCatalog and was used to geocode the accidents. Geocoding places a feature in the GIS based on location. The City data was geocoded and matched 6,310 (85%) out of 7,434 records. Additionally, the DPS data matched 4,227 (78%) out of 5,401 records. Much of the OSU data did not geocode due to parking lot locations not existing within the street network of the city. The GIS shows points on the street network of the city, representing a single accident at that location (Figures 4 and 5). Some locations have multiple accidents and will appear as a

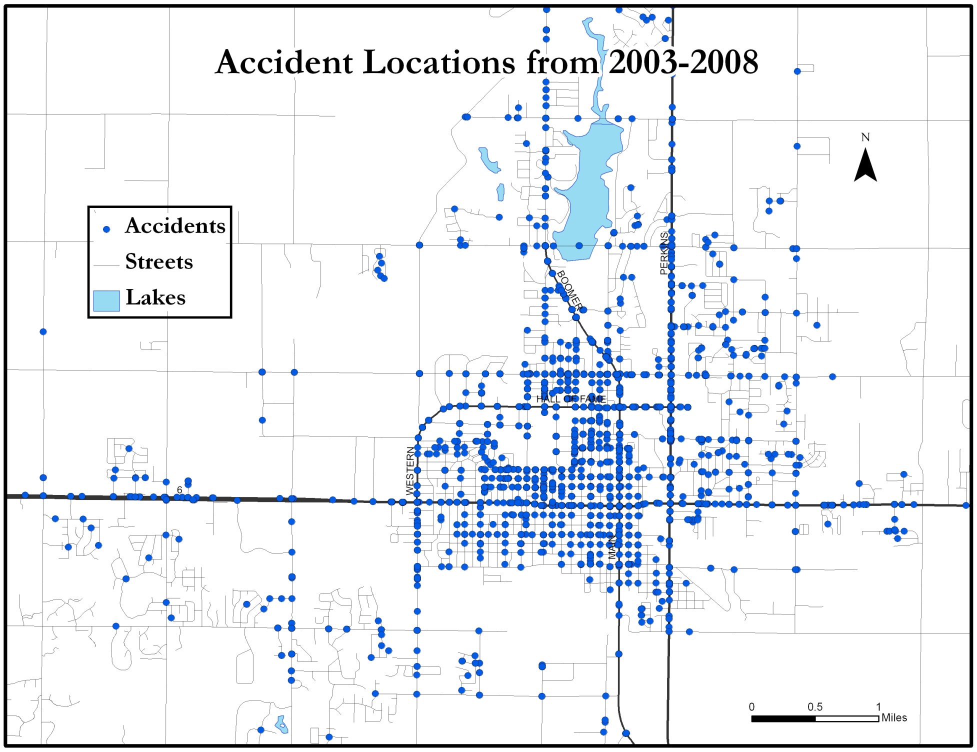

Figure 4. Geocoded traffic accident locations using City data from 2003-2008. These are used for most of the study. Each point represents one location, not one accident.

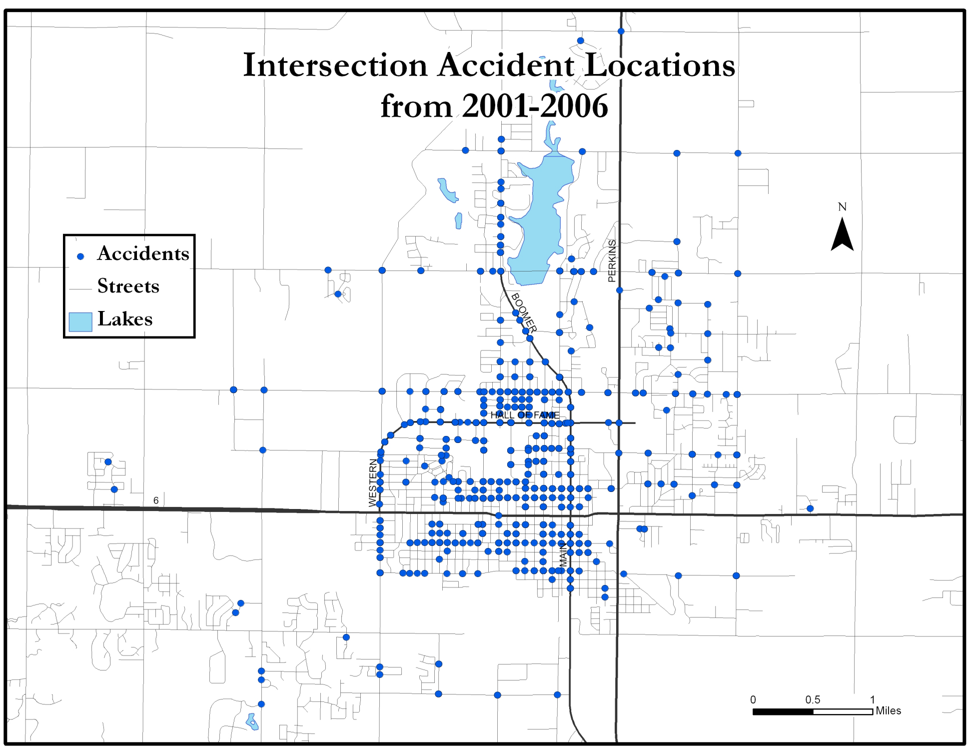

Figure 5. Intersection accident locations of DPS data from 2001-2006; these will only be used for the intersection rate. Each point represents one location, not one accident.

single point. One dot on a GIS map does not necessarily equal one accident: several crashes could have occurred at a particular location (Pulugurtha et al. 2007). This will be corrected using different visualization techniques of Kernel Density and 3-D representations in ArcScene. The point data displayed in the GIS contains its attribute data such as where (location) and when (date, day of week, time of day) the accidents are occurring. Descriptive searches within the attribute data reveal spatial-temporal characteristics of the accidents.

Spatial-Temporal Patterns and Hot Spots

The descriptive searches of the accidents reveal specific fluctuations in where and when the accidents occur. This study analyzes numerous degrees of location and temporal instances. I examine each day of the week to see the patterns of accidents throughout each day of the week. Breaking down accidents occurring at each hour in the day reveals spatial patterns around the city. I examine how different locations have accidents occurring at specific times of the day. These differences are influenced by social activities such as employment, shopping, and home-based activities (Levine et al. 1995c). Specifically, examining a location such as Stillwater High School has specific temporal patterns of accidents when students arrive and depart from school. Teenagers have accidents between 7:00-8:00 a.m. and 3:00-4:00 p.m. based on the school commute times and the driver's travel patterns (Hellinga et al. 2007).

Another age cohort of drivers is the elderly. Older adults are at a higher risk of being injured in a traffic accident. Longer life spans and the aging of the Baby Boom generation will increase the amount of drivers in this age group and further influence accidents (McKnight 2003). Many college students engage in social activities involving alcohol. The accidents occurring when taverns (bars) close during weekends reveals accidents occurring close to those establishments. I also examine gender of accidents. Some research reveals that high masculinity and male personalities make the driver more likely to participate in risky driving, influencing an accident (Özkan and Lajunen 2005). Accidents vary with age, gender, and social events: I explore these characteristics to gain insight of crashes in the city. Accidents in Stillwater vary with seasonality, influenced by social holidays, large sporting events with OSU, and weather occurrences (Levine et al. 1995a). Spatial-temporal patterns are discovered, and displayed visually to communicate those patterns to viewers. Spatial-temporal patterns of accidents reveal locations of where the accidents occur.

Hot Spots

Certain locations in the city have accidents occurring more frequently in other areas. Identifying these hot spots is an improved way of determining what locations are experiencing more occurrences than simply one traffic accident. Levine states, "there is no absolute definition of a hot spot" (2006). Much research does not define criteria making a location a hot spot. Generally, it is accepted to define it as a cluster of collision points in one area or on a line (Anderson 2006). A hot spot refers to any location with clusters (concentrations) of traffic accidents. Accidents will be clustered, or concentrated (Levine 2006), in specific areas during particular temporal periods. For the density maps in this study, I have decided that a hot spot refers to the "high" and "very high" categories colored orange and red, respectively. Since the density values are equal interval, a hot spot refers to the top 40% of the values—this is explained further under Kernel Density. By mapping these locations, traffic accidents can be better understood within the city through visual representations of crashes.

Site Specific Locations

Specific locations around the city influence large amounts of traffic and congestion due to the activities of the drivers. Many OSU students socialize just south of the campus on Washington Street. This street, called “The Strip,” has numerous taverns that draw in students on the evenings of weekends. Accident clustering can be examined in this area as well as Stillwater High School. Wal-Mart, on Perkins Road, is another location worth examining because of the high traffic volumes flowing in and out of the store. As hot spots are identified, these sites can be spatially viewed to gain greater understanding of crashes within the city. The DPS data analyzed where accidents occurred at road intersections within the city.

Intersection Accident Rate

Using the DPS data, the intersections become meaningful by determining a rate from the number of crash occurrences. For instance, one intersection may have 50 accidents with another having 1,000 accidents, both from 2001-2006. I have obtained AADT traffic counts of specific streets from the City GIS Department. AADT is a measurement of Annual Average Daily Traffic. This is the annual average number of vehicles traveling through a certain location each day. Using the AADT counts, traffic was calculated through 40 intersections in the city. Only these 40 intersections were able to be counted because the AADT counts did not exist at every intersection within the city. Four AADT counts exist at one intersection, thus one vehicle traveling through is double-counted (Figure 6). Each AADT count (north, south, east, and west) at an intersection was added together and then divided by 2 to equal the number of vehicles passing through the intersection.

Using the AADT, if the intersection with 50 accidents has 50 cars traveling through it from 2001-2006, the location is considered extremely hazardous. The intersection with 1,000 accidents may have 500,000 vehicles traveling through from 2001-2006, making the intersection not as hazardous as the previous. Using the AADT counts, I calculated a rate by using a ratio of one accident occurrence to a certain number

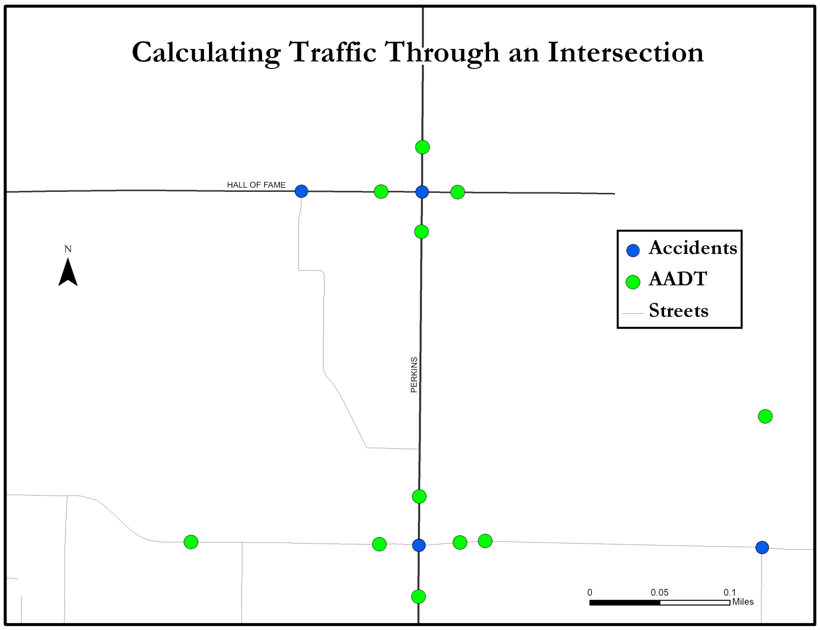

Figure 6. The green dots are AADT counts at an intersection. The AADT was used to determine traffic through intersections having traffic accidents.

of vehicles. I took the total number of accidents in an intersection for the 6 year period, and then used the AADT count to determine how many vehicles travel through that particular intersection within the same time period—6 years. Finally, there is an accident rate for each of the 40 intersections showing one accident occurring for every "n" number of vehicles traveling through that road intersection. This intersection risk assessment identifies hazardous sites by making the accident count meaningful. Besides using intersection rates in the city to analyze accidents, Stillwater experiences city wide occurrences of traffic accidents.

City Wide Occurrences

Social Activities and Weather

Significant weather events and social activities such as holidays and major sporting events associated with OSU influence traffic accidents within the city. Stillwater experiences ice storms in the winters, which influences much of Oklahoma. One of the factors influencing accidents is weather and its effect on road surfaces in the form of slippery ice (Li et al. 2007). Within the City data, January 16th and 31st, 2007 each experienced 34 traffic accidents in 24 hours. Both days record the highest amount of accidents within one day. These dates are significant because this was also during the January 2007 North American Ice Storm. I personally remember, while attending OSU, the university closing for multiple consecutive days in January 2007 due to the ice storm. Oklahoma Governor Brad Henry declared a state of emergency due to the storm (KOCO 2007).

OSU often attracts a high volume of visitors for sporting events. OSU football and basketball games influence the occurrence of traffic accidents due to the influx of traffic and the congestion of roads in the city due to the crowds they attract both from in town and the surrounding region. Along with the ice storm on January 16, 2007, the OSU Cowboys defeated the University of Texas Longhorns 105-103 in triple overtime the same day in front of an official crowd of 13,611 (OSU 2008) who had to travel to the arena despite the slick roads. A combination of the basketball game during a hazardous weather event influenced the high occurrence of accidents on that day. Seasonality also influences the occurrence of accidents in the city. Many of the OSU students vacate Stillwater for holidays and the summer season. Traffic congestion and accident occurrence decrease during these holiday seasons. Displaying each GIS map of the spatial-temporal patterns, hot spots, intersection rates, and social/weather occurrences are important to the awareness and effectiveness of the study. Multiple visual representation methods have been used for each GIS map.

Visual Representations

3-D and ArcScene

Representing each map of the GIS visually is important to the effectiveness of the study and the awareness of the viewer. The data is displayed using various visual methods. Accident occurrence throughout days of the week and times of the day are displayed using charts from Excel. The representations of the point data might have one point at a location, but have multiple occurrences of accidents at that same location. Using ArcScene, I represent accidents in 3-D, with vertical lines as extrusions showing where higher occurrences of accidents are happening in the city. Another method I will use is Kernel Density to visually represent my results.

Kernel Density

ArcMap uses two ways to calculate density, the Simple Method and Kernel Density. The significant advantage of visualizing accidents with these methods is the ability to see accidents that would have been hidden on top of one another in point data. Both methods involve creating a raster layer. A raster layer is made up of numerous cells with each cell having a unique value (like a mosaic). A density value is determined for each cell. The Simple Method uses a search radius around each raster cell. The points that are within the search radius are totaled. The total number of points is then divided by the total area enclosed with the search radius (Mitchell 1999). For instance, say the search radius is 100 ft, and 3 accidents are within the search area. That is a total area (πr^2) of 31,349 square feet, or .72 acres. The density value is 3 accidents divided by .72

acres to equal 4.2 accidents per acre (Mitchell 1999). That specific density value is then applied to that cell in the raster, eventually making a density surface. Kernel Density works in a similar fashion.

Kernel Density is a weighted method for calculating density (Mitchell 1999). With Kernel Density, A search radius is used around each point (Figure 7). A "smoothly curved surface" is fitted over each point (ESRI 2009b). The surface value is the highest over the point, and "diminishes" in value further away from that point (ESRI 2009b). The value eventually reaches zero at the search radius distance from that point. ArcMap applies a quadratic kernel function (Silverman 1986) to calculate the surface values over each point. The density for each raster cell is then calculated by summing the surface values, of each point, where they overlap that specific cell (ESRI 2009b). The output creates a "smoother density surface" than the Simple Method that better identifies crash locations with dangerous crash problems (Pulugurtha et al. 2007). Using the weighted method creates a map with better understood patterns (Mitchell 1999). Applying this method allows clear visual representation of hot spots where crash concentrations are clustered in the city.

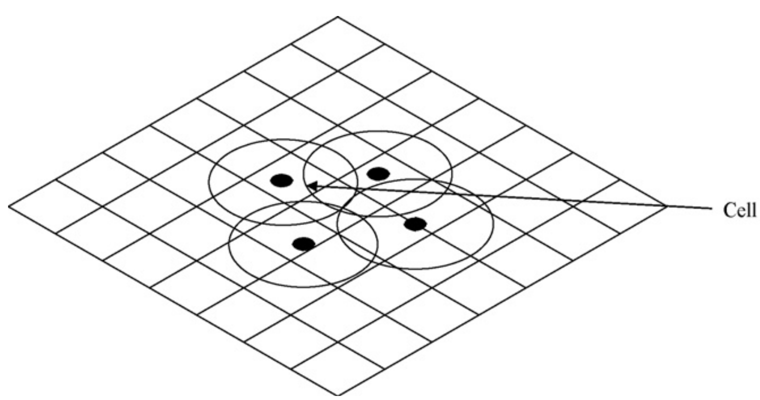

Figure 7. A search radius is around each traffic accident (Pulugurtha et al. 2007).

The maps allow viewers to visualize crash hot spots using the weighted density method. On each map, the density concentrations are categorized into very low, low, medium, high, and very high. These categories refer to the crash densities, and are classified using equal intervals. The "very low" category refers to the density values from 0 to the 20th percentile. So, the "very high" category has the top 20 percentile of the density values—values greater than 80% (Pulugurtha et al. 2007). The "very high" category refers to a higher number of occurrences (high intensity) in or at that location (Corcoran et al. 2007a). The categories aid decision makers such as police to identify hot spots within the city (Pulugurtha et al. 2007).

Two important choices to be made during this process are cell size and search radius (bandwidth). The cell size refers to the size of each raster cell: a smaller cell size will appear smoother. A lower search radius will yield a "spiky" density map, while a higher radius will have a more generable and smooth surface. An acceptable bandwidth is neither too "spiky" nor too generable (Corcoran et al. 2007b). For this study, the cell size was set to 20 feet. The search radius was set to 400 feet, unless specified otherwise. The resulting visual map displays hot spot zones where accident occurrence is higher than other areas. This method is useful for determining concentrations of accidents in the urban area, and has been used in a considerable amount of literature on the topic (Steenberghen et al. 2004). Using the Kernel Method to identify crash concentrations has been used in cities such as Las Vegas to mitigate safety for pedestrian crash zones (Pulugurtha et al. 2007). Using this method for Stillwater visually highlights crash clusters in the city.

Working like a compass, this visualization technique points out clusters in Stillwater. Using maps to represent my results is effective because the viewer can see and understand what is represented. By identifying hot spots using GIS, a more “robust” understanding is gained through the visualization of spatial data (Anderson 2009). Taking Kernel Density a step further allows the crash densities to be visualized in 3-D.

Topographic Accident Density

3-D visualization of accidents is a helpful technique because it allows viewers to perceive where the densities are highest at certain locations within the city using a different representation method. Using the values from the Kernel Density raster layers, each map is represented in ArcScene using base heights. The base heights for each layer use the density values along a z-axis, enabling the output to be visualized in 3-D. The color scheme remains the same, with hot spot areas being orange and red—high and very high, respectively. The categories are also the same as in Kernel Density (very low, low, medium, high, and very high); the classifications for the 3-D representations are also equal intervals. Now, the accident densities are shown as topography over the landscape of the city. The higher peaks refer to more clustered accidents. This method of visualization becomes useful when looking at each hour of the day. By isolating traffic accidents at each hour of the day, patterns are able to be perceived within the city. For instance, 7:00-7:59 a.m. shows accidents of people traveling to work and school. This temporal isolation of the data displays spatial patterns of where accidents occur more frequently in dense clusters. By using different geovisualization methods, new understanding is gained on traffic accidents in the city. The process has been difficult; there are several limitations to this study.

Limitations

The most significant limitation to this study is the data and its manipulation to become usable for the GIS. The DPS data took a considerable amount of time attaching location to the file so it could be used in ArcMap. It was very difficult obtaining all three datasets separately because it involved communicating between several entities to retrieve data that still needs some manipulation before it is in a ready format. There are several features within ArcGIS, and a single study could incorporate many methods; however, I have needed to limit myself in what is delivered based on the time constraints of the study. The highest accident location in the city is the Wal-Mart location on Perkins Road. This is slightly misleading because many points geocoded at this address: 111 N Perkins Road. The address includes all of the large parking lot, as well as the entrances into the store. This is misleading because many vehicles travel through this area; however, accidents are still clustered at that location. The same reasoning applies to the city's high school.

The OSU data did not match a large portion of its records due to the addresses. These locations are described as lots, or parking lots. These locations did not geocode because they were not a street address or two intersecting roads. Despite this, many OSU accidents do fill in the "donut hole" of the university nicely. Lastly, along with most of Oklahoma, GPS coordinates of crash locations are not regularly taken. This means that the location of each accident is not a precise location, but rather a street address or an intersection of two roads. Despite the limitations, I have a solid foundation of results from this study of traffic accidents in Stillwater.

CHAPTER IV

FINDINGS

City Wide Representations

Vertical Line Approach

Each map tells a story of how traffic accidents are situated in time and space. Seeing these visual representations allows the viewer to gain greater understanding of traffic accidents within the city of Stillwater. Figure 4 displays traffic accidents from 2003-2008. Using ArcScene, a different visual approach is used (Figures 8 and 9). In Figures 4 and 5, there are multiple accidents at one location, but the maps only display one instance of an accident at each single location. Using ArcScene, each location can be represented to show the amount of accidents that occurred at each location using vertical lines. Each displays its exact amount of accidents.

Wal-Mart, at 111 North Perkins Road, had 273 accidents. The 2nd highest location is the intersection of 6th Avenue and Monroe Street with 77 accidents. Stillwater High School, at 1224 North Husband Street, had the 3rd highest amount of 66 accidents. The 4th and 5th highest locations are the intersections of McElroy Road and Husband Street, and 6th Avenue and Western Road with 59 and 55 accidents, respectively. The Wal-Mart and High School locations are significant because they reflect social activities of drivers. Large numbers of people shop for goods at Wal-Mart, while teenagers, who are new drivers, are driving around the school. Visualizing the spatial data with these maps allows a viewer the ability to see where more accidents are happening within the city. Multiple accidents at one location can also be viewed using Kernel Density.

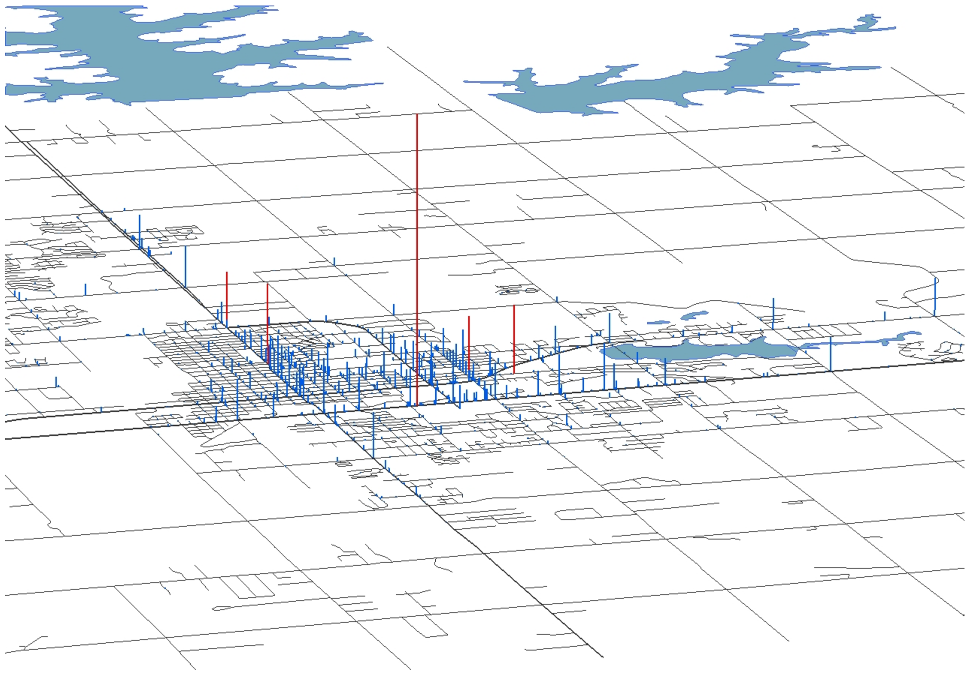

Figure 8. Looking northwest, traffic accidents are represented as vertical lines. The five red lines indicate the city's highest 5 locations for accident occurrences. The tallest red line is the Wal-Mart on Perkins Road.

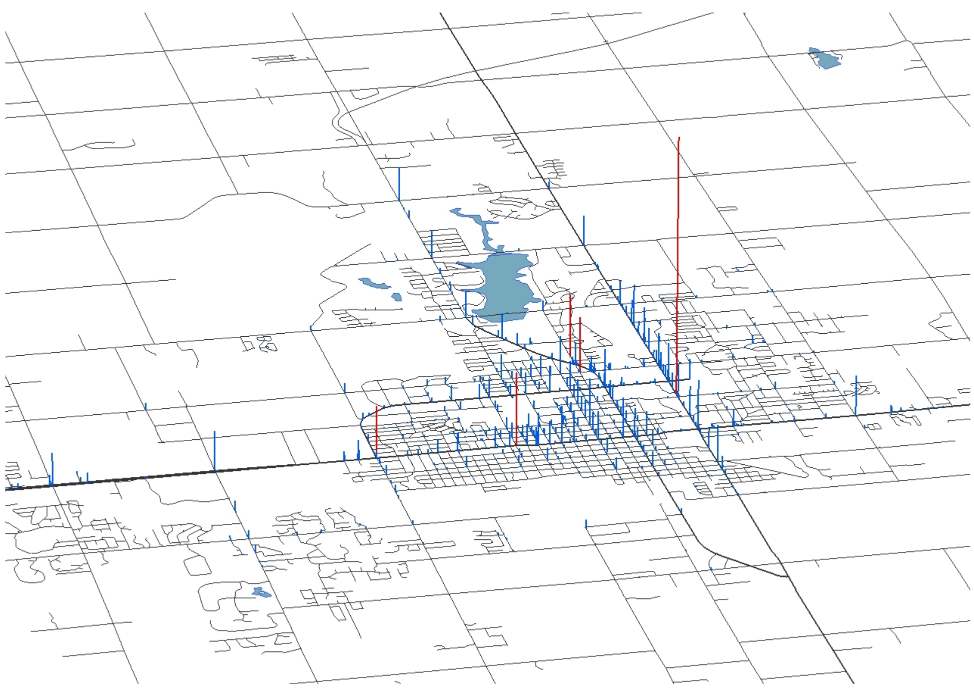

Figure 9. Looking northeast, this shows another viewpoint of the same scene as in Figure 8.

Hot Spot Density

Using Kernel Density allows a viewer to see which locations and areas of the city experience clusters and high occurrences of accidents. Figure 10 reveals the hot spots in the city where accidents are clustered together. These locations are significant because it directs proper authorities to improve safety on roadways. For this map, the densities are classified using natural breaks. This displays patterns that are more distinct rather than generalized. The "very low" category refers to 0 - 1.28 accidents per acre. "Low" refers to 1.29- 5.47, "medium" is 5.48 - 13.19, "high" is 13.20 - 38.30, and "very high" is 38.31 - 82.08. The values are recorded from the Kernel Density output. Using natural breaks instead of equal intervals for this map's classification allowed for more detailed patterns within the overall accidents in the city. The five high occurrences of accidents in Figure 8 and 9 are also visible as hot spots in Figure 10. The Wal-Mart location on Perkins Road is, again, categorized as having very high concentrations of accidents. The

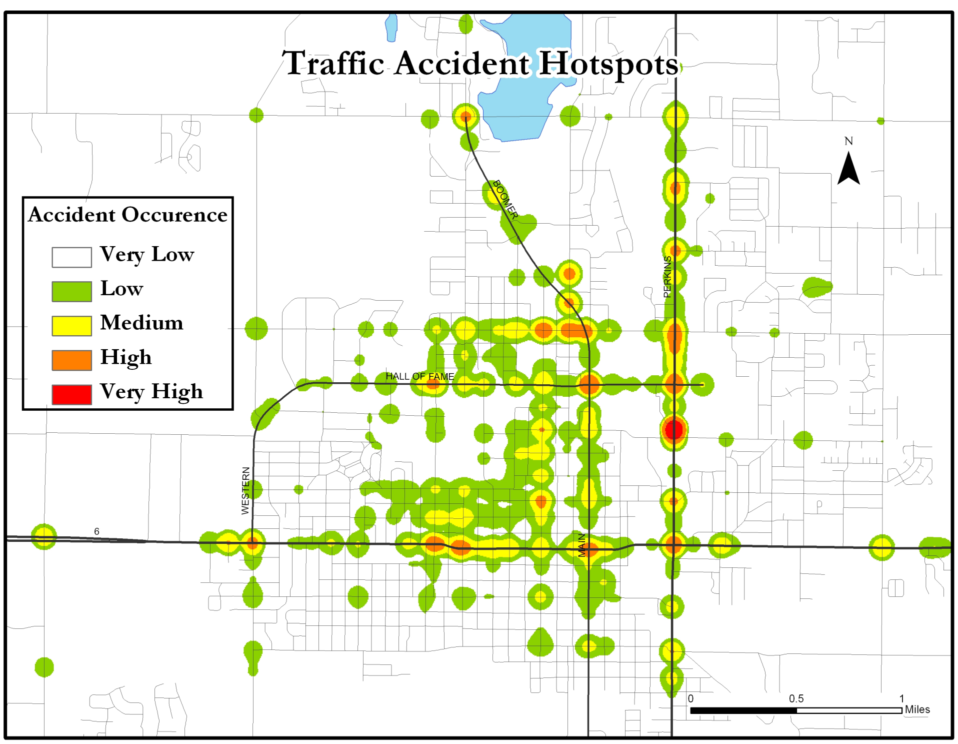

Figure 10. The map reveals where dense clusters/concentrations of accidents are occurring in the city.

intersection of McElroy Road and Husband Street is in the high category, and is surrounded by a larger area showing the same density of the high category. Near this location are several eateries in close proximity to the high school. This is also near an irregularly designed intersection. This method of representation becomes helpful at identifying the dense areas of the city where accidents are clustered. The map is useful at pointing the direction towards locations in need of safety reform. Other visualization techniques can take a hot spot map into 3-D.

3-D Hot Spot Density

By converting a hot spot map into 3-D, accident density can be spatially visualized in 3-D. Another hot spot map displays a more generalized pattern of the city's traffic accidents (Figure 11). Using a larger search radius makes accident patterns more

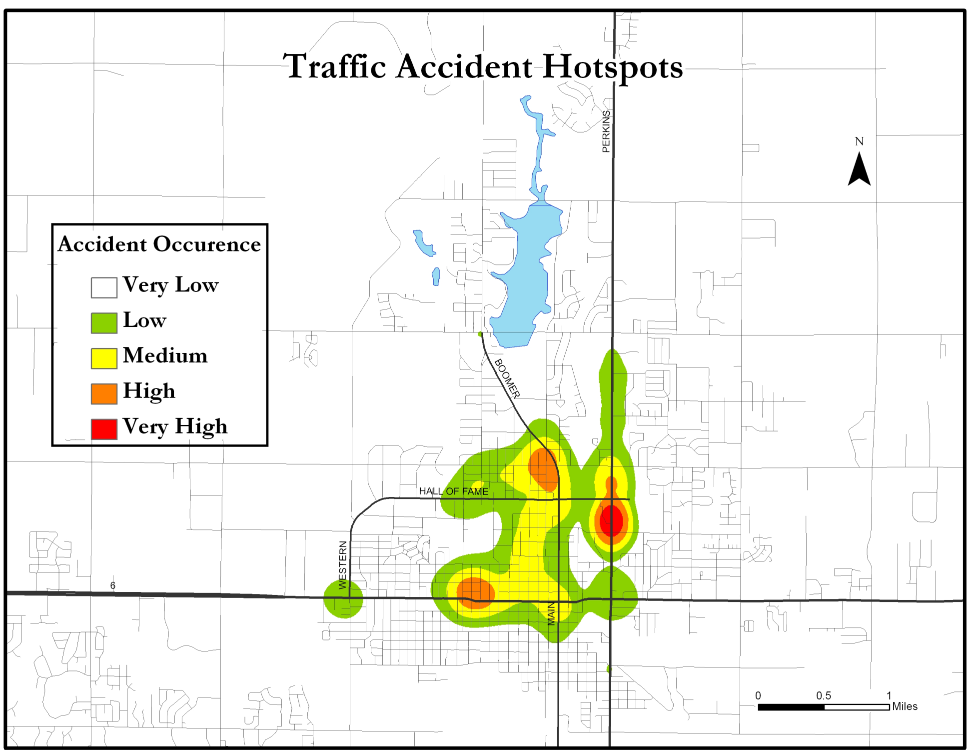

Figure 11. Using a larger search radius produces a more generalized pattern of different densities of accident clusters.

observable for larger areas of the city. There are three areas classified as high clusters of accidents. Wal-Mart is still visible, as well as the irregular intersection close to several eateries and the high school. Also, the intersections of 6th Avenue and Monroe Street, and 6th Avenue and Washington Street show up as hot spots. Washington Street experiences social activities: "The Strip" is a popular area for college students just south of OSU's campus. Figure 11 is then used to create a 3-D visualization.

A benefit to this visualization technique is being able to view accidents in 3-D. 3-D is used to represent elevation, allowing the viewer to see hills and peaks of mountains on the landscape. In this case, the topography model is representing traffic accident densities. The patterns of crash clusters are still concentrated in the same areas in the city, but this is now able to be viewed in 3-D using ArcScene. Instead of a tall peak representing elevation, it now represents a location with high crash densities. Wal-Mart on Perkins Road is categorized as very high, while the area near the high school and several eateries appears high. The two intersections of 6th Avenue and Monroe Street, and 6th Avenue and Washington Street appear as having high concentrations as well. Representing in 3-D allows the densities to be viewed as topography.

Viewing the city three-dimensionally allows viewers to gain a significant understanding of where accidents are occurring more often. Seeing height and width, along with color (classification), of different locations allows for better understanding of how densely clustered a certain area is within the city. Figures 12 and 13 depict the scene from different angles. The city streets have been draped over the topography of densities to aid viewers in location identification. The three areas are still significantly clustered, with Wal-Mart being the tallest peak. Each peak on the map indicates how dense a

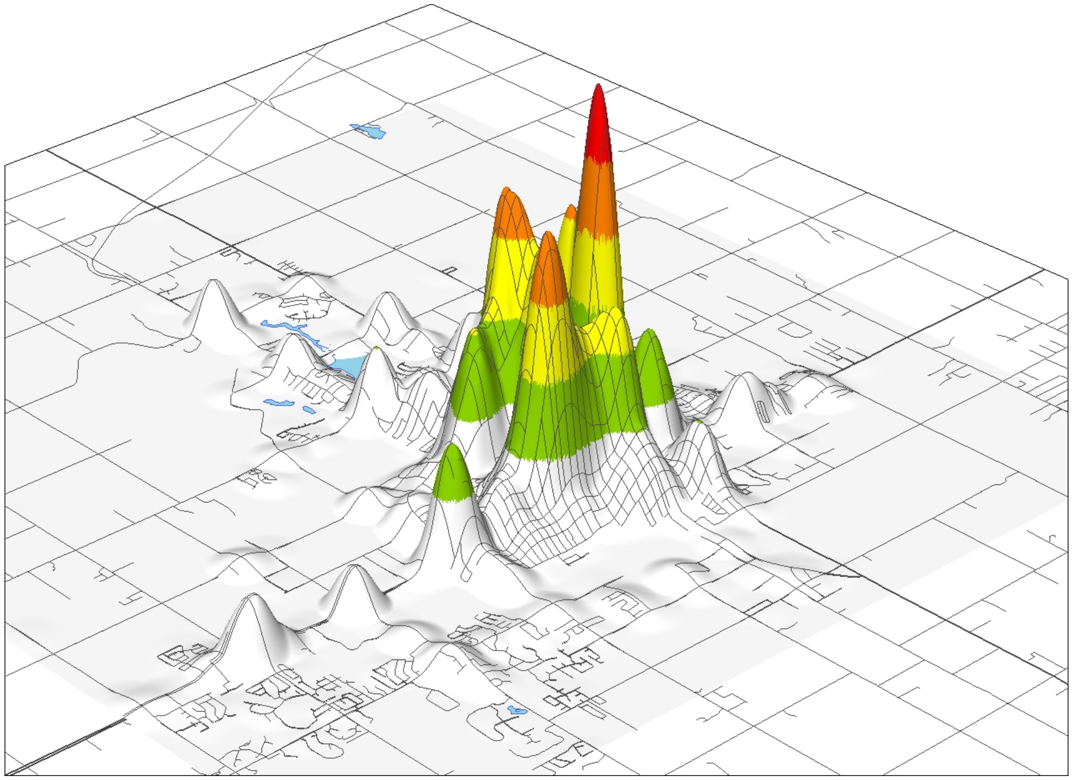

Figure 12. Looking northeast, this scene depicts a topographic model of traffic accident density in the city. The highest peak is Wal-Mart on Perkins Road.

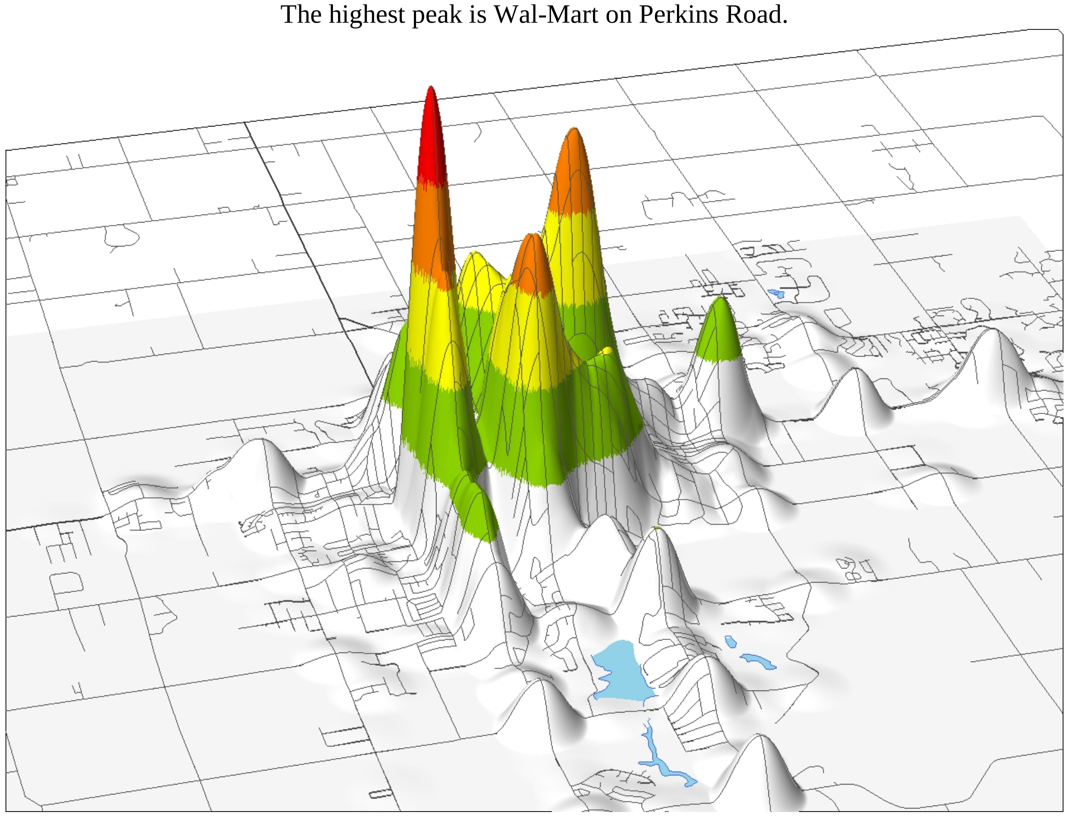

Figure 13. Looking southwest, this same scene from Figure 12 is visualized from a different viewpoint.

location is with traffic accidents. This different visualization technique communicates the same information as Figure 11, but gives a different view of the accidents in the city. This visual representation allows accidents to be viewed as “topographic accident density.” The 3-D map allows a viewer to see higher peaks of where accidents are occurring on the landscape. This gives 3-D an advantage over a 2-D map. It is through different representations that greater understanding of crashes in the city can be realized. Specific spatial-temporal patterns in the data can be visualized by isolating certain days and times.

Weather Occurrences

By isolating specific days and times within the data, two days had the highest number of accidents occurring within a 24 hour period. January 16th and 31st, 2007 both experienced 34 accidents each (Figures 14 and 15). Different patterns can be observed

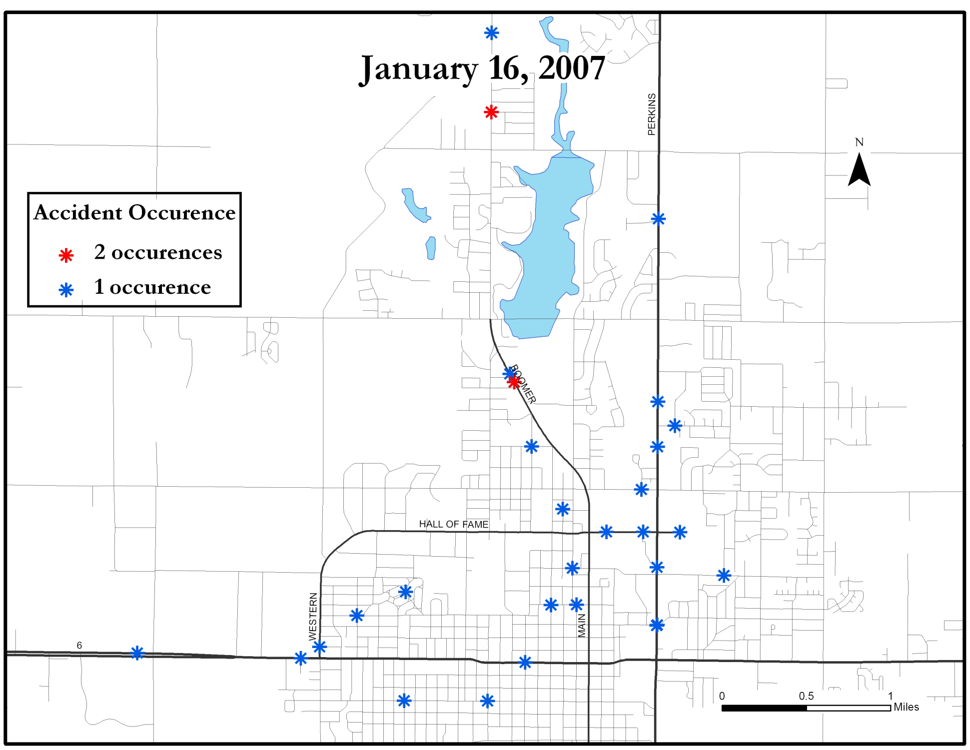

Figure 14. This day experienced 34 accidents strongly influenced by an ice storm and a university basketball game.

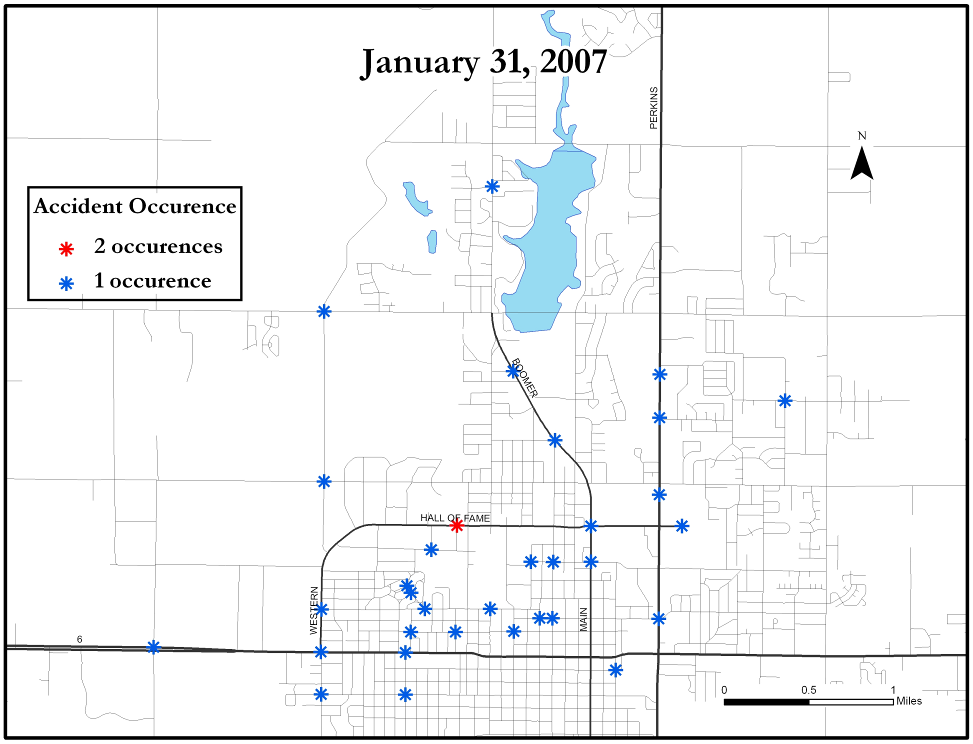

Figure 15. This day also had 34 accidents and experienced an ice storm.

with both days. January 16th was the night of a large rivalry basketball game. Also, the city experienced a severe ice storm during the month of January, and produced slick icy roads influencing occurrences of traffic accidents. Both days experienced multiple accidents happening at the same locations. On January 16th (Figure 14), the accidents are not clustered south of Hall of Fame Avenue, but that is just opposite on January 31st (Figure 15). January 31st had more crashes south of Hall of Fame Avenue. This area is a neighborhood close to the OSU campus.

The neighborhood roads within cities ice over first, then the main roads. This happens because traffic uses the main roads more frequently than the neighborhood roads, allowing the ice to dissipate and melt faster outside the neighborhood. The patterns between the two maps are able to tell a viewer how accidents occurred on those specific days. These maps are useful in pointing out locations experiencing accidents during ice storms, and the city of Stillwater can examine these locations where multiple accidents occurred during this time period. Isolating the accident data reveals spatial-temporal patterns. By slicing the data temporally, viewing time periods during the social activities of city residents can portray where traffic accidents are occurring at those times.

Adult Establishment Hot Spots

Accidents involve the weekly patterning of specific social activities (Levine et al. 1995a). Social activities involving adult establishments (taverns, bars) and alcoholic beverages can strongly influence traffic accidents. By viewing the temporal periods in which these activities take place, an understanding can be gained from visualizing traffic accidents associated with those activities. In Stillwater, this social activity begins Thursday evening and continues through Saturday evening. The concept of "data slicing" was applied to search for patterns within the traffic accidents. Traffic accidents occurring on Friday, Saturday, and Sunday were first isolated. Out of those days, accidents occurring between 1:00-3:00 a.m. were isolated. This specific time frame was chosen because taverns close at 2:00 a.m., in which people leave early as well as linger or drive to a different location. Most people engage in this activity during weekend days and not during the week. Figure 16 shows the accidents that occurred during that specific time frame. A large cluster of accidents can be identified at "The Strip," a popular college student destination just south of the university's campus. Hot spots are identified when the densities are calculated (Figure 17).

The patterns of traffic accidents appear in three distinct locations (Figure 17). The largest concentration of accidents is clustered on "The Strip." This location is a

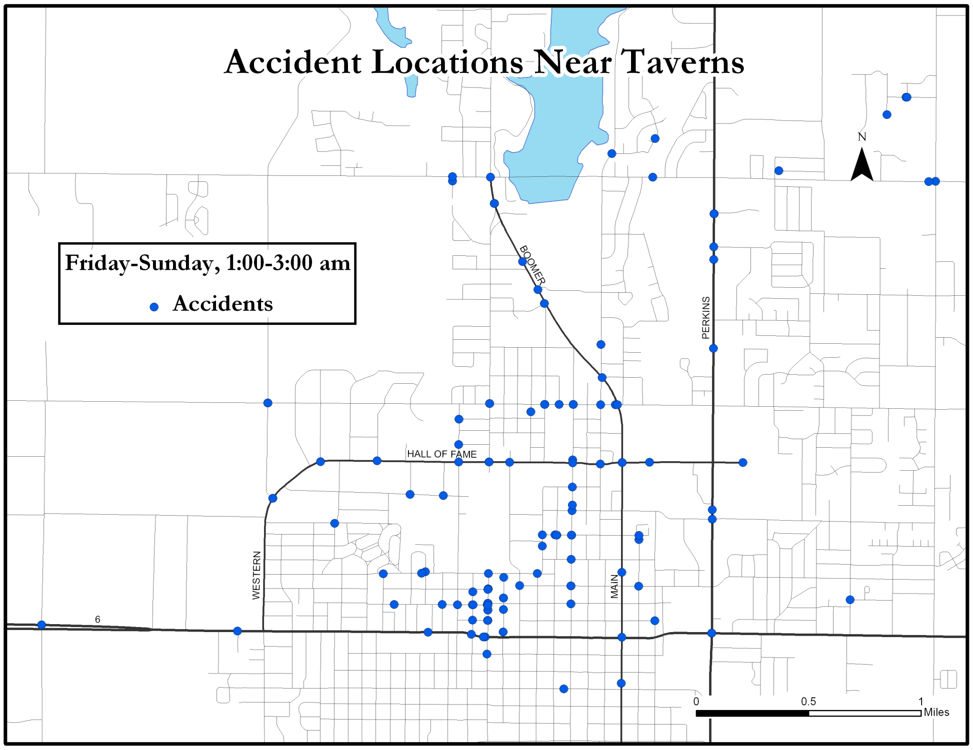

Figure 16. The large cluster of accidents occurred at "The Strip" on Washington Street; a popular weekend location for socializing.

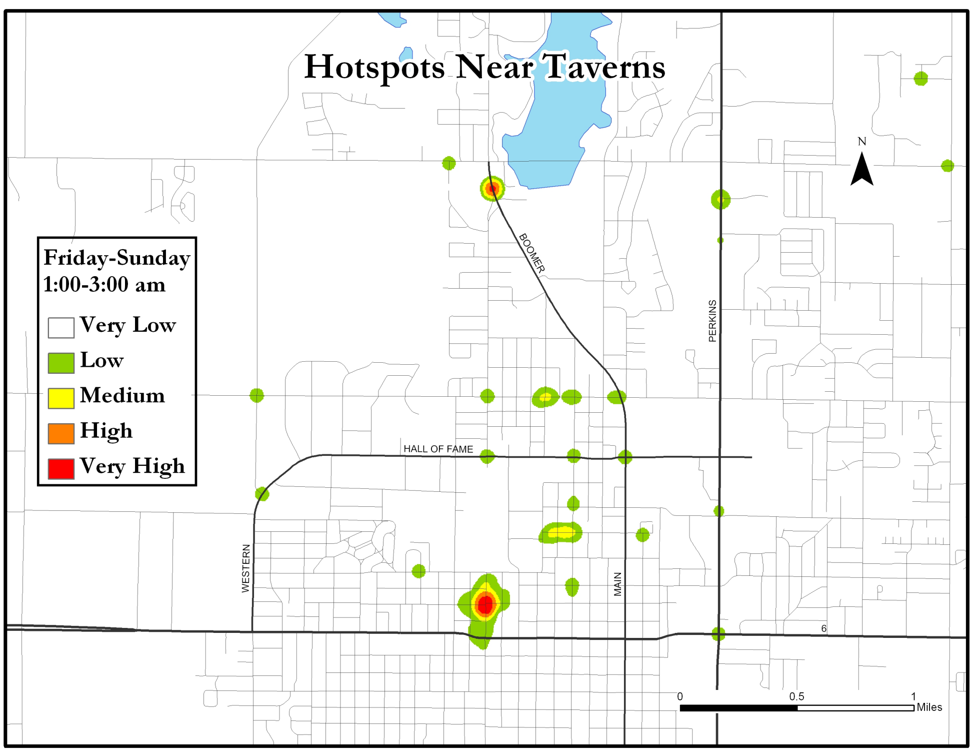

Figure 17. The large hot spot is "The Strip."

popular socializing destination for many college students. Existing on the university's southern boundary, this is the location of many taverns. Just to the northeast of this location is another smaller hot spot. This is the location of Eskimo Joe's, a restaurant and bar. To the far north, this hot spot is the location of the Dragon's Lair, and adult entertainment establishment. These hot spots are visualized in 3-D to show a different representation of this spatial-temporal pattern. The map (Figure 17) was converted into 3-D (Figures 18 and 19) for more visualization. The same patterns are visible in 3-D. The large clusters of hot spots are in close proximity or located at adult establishments where weekend social activities occur. Viewing this spatial-temporal pattern using ArcScene allows the viewer to grasp the different amounts of accident clusters at or near these locations.

A significant finding of these hot spots is that the accidents occur at or in close proximity to the adult establishments. The accidents, during this time period, are not randomly dispersed throughout the city. Accidents cluster near and at adult establishments. Viewing the hot spots in 3-D reveals different heights and widths of peaks (Figures 18 and 19). The largest peak is "The Strip" just south of the university. This location is lined with bars serving alcohol to socializing customers. The second largest peak near Boomer Lake is the location of the Dragon's Lair, a popular adult entertainment establishment. The third largest peak is the location of the famous restaurant, Eskimo Joe's. The restaurant has a two full service bars inside, upstairs and downstairs, allowing for a large clientele. Along with color, 3-D represents the accidents with height, giving it an advantage over the 2-D map. Visualizing this pattern helps

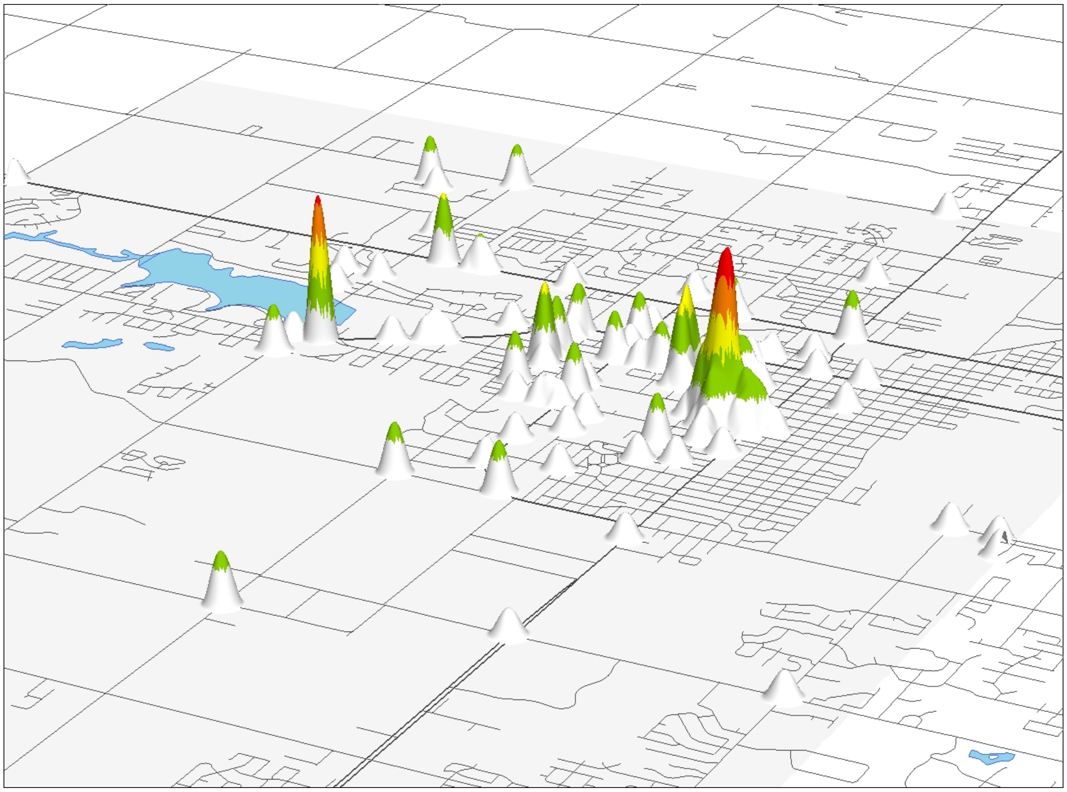

Figure 18. Looking northeast, the map shows 3-D density of traffic accidents near adult establishments between 1:00-3:00 a.m., Friday through Sunday.

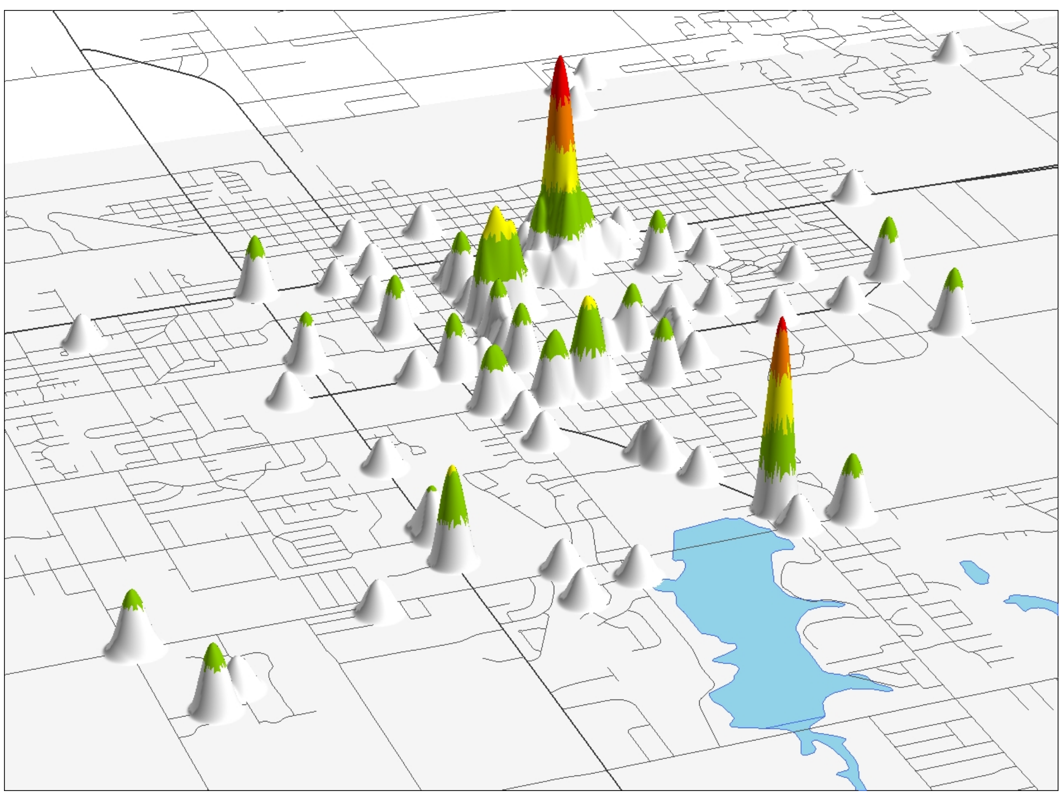

Figure 19. Looking southwest, the same scene from Figure 18 reveals clusters of accidents. The largest peak is "The Strip." The second largest peak is an adult entertainment establishment.

viewers gain understanding of where the accidents are occurring at certain times, and what activities influence the phenomenon.

Intersection Accidents

Gender and Age

Using the DPS data, accidents at intersections from 2001 to 2006 contain age and gender. Viewing different patterns of locations for different age groups proved difficult, and produced little to no patterns partly due to the data only being at intersections. An overall assessment of the intersection accidents for the six year period shows that gender is nearly split in half between male and female accidents. Female (51%) is slightly higher than male (49%). Spatial patterns of gender were not found, but that does not mean that they are nonexistent. Analyzing the spatial locations of gender at specific time periods revealed no apparent hot spots of gender groupings. Age was also viewed to determine any spatial patterns.

Age also had little to no clustering at specific locations with certain ages. The majority of accidents at the intersections were from drivers between the ages of 18 and 22. This can be compared to the city's age demographics: ages 20 to 24 years make up almost 30% of the overall population in Stillwater (U.S. Census Bureau 2000). Smaller spikes in the graph (Figure 20) show drivers with specific ages, but the majority of the accidents come from the late teen to early twenties age group. Figure 20 shows age around the rim of the circle, and the largest occurrence of accidents are from college aged drivers. The university students influence this statistic, partly due to social activities and the sheer size of the student population within the city—around 30% (U.S. Census Bureau 2000). The elderly population (80 years and older) were isolated to visualize any

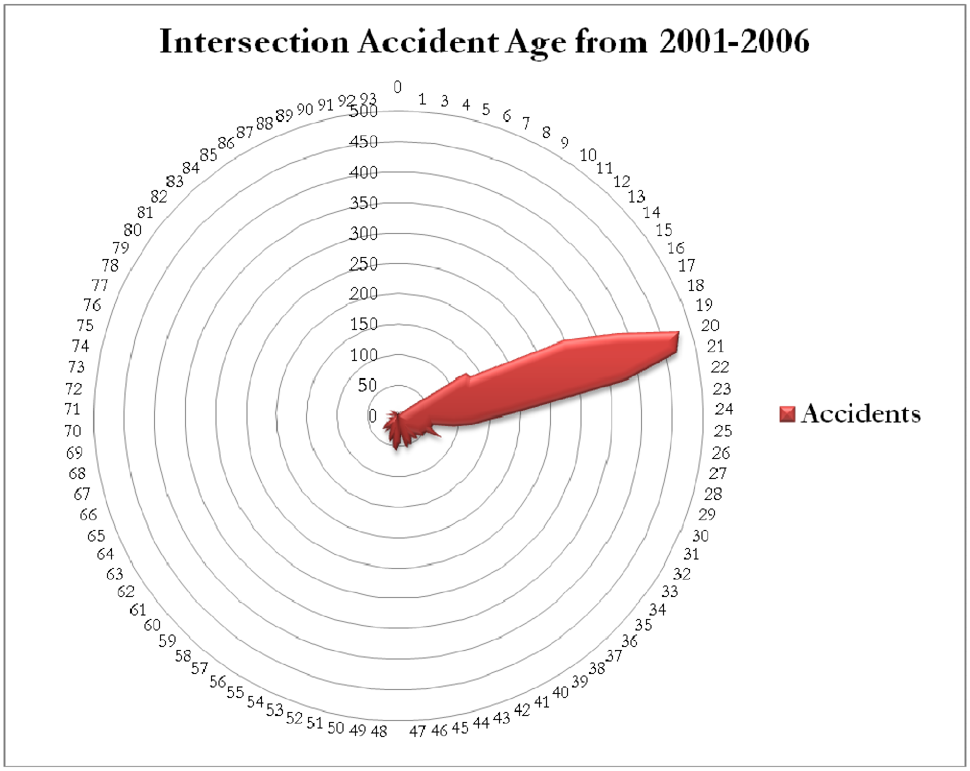

Figure 20. The outer rim is age. Most intersection accidents are drivers 18-22 years of age.

patterns or concentrations in accidents. Most of the accidents involving the elderly were concentrated within the neighborhoods, not on the arterial streets. Besides gender and age, the intersection accidents were used to determine a rate of vehicles per accident.

Intersection Accident Rate

The AADT counts were at forty intersections in the city where an accident occurred. The intersection with the highest accident occurrence is Main Street and Hall of Fame Avenue, having 236 accidents within the six year period (Table 1). An accident occurs at this intersection every 248,522 vehicles traveling through the intersection, every 9 days. Duck Street and 3rd Avenue has 142 accidents within that time frame. An accident will occur every 135,387 vehicles—every 15 days. At the bottom of the list, Perkins Road and Hall of Fame Avenue has only two accidents. Its rate is 36,120,851 vehicles needed for an accident, or 1,096 days. Based on the data I used for this study,

Table 1. The forty intersections are sorted by "Vehicles Per Crash." The rate refers to an accident occurrence every "n" number of vehicles traveling through the intersection.

Intersection	Crash Count	North	South	East	West	AADT of Intersection	Vehicles Per Crash	Days Per Crash
DUCK ST & 3 AV	142	5495	5940	2592	3518	8773	135387	15
MAIN ST & HALL OF FAME AV	236	14642	14962	13989	9933	26763	248522	9
DUCK ST & MCELROY RD	131	7151	12159	13069	5761	19070	319022	17
DUCK ST & 9 AV	56	6442	5288	3837	5534	10551	412883	39
WASHINGTON ST & AIRPORT RD	80	12624	12619	2842	2499	15292	418905	27
WASHINGTON ST & LAKEVIEW RD	126	14226	18596	9954	7345	25061	435874	17
MAIN ST & MILLER AV	95	15634	14666	5048	4903	20126	464264	23
MAIN ST & 9 AV	24	1351	5283	4078	181	5447	497334	91
DUCK ST & MILLER AV	89	17094	15706	4998	6531	22165	545770	25
WASHINGTON ST & 26 AV	4	81	162	1464	335	1021	559380	548
HUSBAND ST & LAKEVIEW RD	39	2431	3551	9668	4388	10019	562991	56
WASHINGTON ST & MCELROY RD	69	7072	9222	12996	9794	19542	620671	32
DUCK ST & HALL OF FAME AV	78	11527	18613	10099	4515	22377	628708	28
MAIN ST & 3 AV	57	14257	12661	3006	3394	16659	640495	38
DUCK ST & 12 AV	32	6133	406	7760	5939	10119	692993	68
SHALAMAR DR & 16 AV	2	579		411	317	654	716073	1096
WESTERN & MCELROY	25	5338	5022	3662	2620	8321	729419	88
JARDOT RD & 12 AV	7	2302	548	295	1896	2521	789097	313
MONROE ST & UNIVERSITY AV	43	5615	6280	9874	9944	15857	808128	51
WESTERN RD & 9 AV	31	10595	9632	3370	123	11860	838425	71
WESTERN RD & UNIVERSITY AV	40	13683	13747	5286		16358	896214	55
MAIN ST & MCELROY RD	67	14115	15126	15593	12122	28478	931486	33
MAIN ST & 12 AV	27	3803	8123	5315	8595	12918	1048511	81
ORCHARD ST & 4 AV	2	589	685	360	404	1019	1116569	1096
WESTERN RD & 12 AV	16	6814	7400	3553		8884	1216762	137
HALL OF FAME AV & WASHINGTON	37	11847	1277	19012	10974	21555	1276697	59
HESTER ST & UNIVERSITY AV	18	4483	3192	8907	11218	13900	1692325	122
JARDOT RD & MCELROY RD	10	3970	5222	2886	4737	8408	1842504	219
MARINE ST & MERCURY AV	3	2476	856		2152	2742	2003031	731
WESTERN RD & LAKEVIEW RD	10	1919	5136	6818	5246	9560	2094964	219
WASHINGTON ST & UNIVERSITY AV	10		3242	7727	10206	10588	2320251	219
HUSBAND ST & 26 AV	2	236	308	1994	2064	2301	2521321	1096
WESTERN & HALL OF FAME AV	13	5877		10462	14421	15380	2592713	169
JARDOT RD & LAKEVIEW RD	3	330	3021	1716	3351	4209	3074675	731
STAR DR & MCELROY RD	11	478		16124	15911	16257	3238738	199
RICHMOND & PERKINS	1	4422	7929	556	3882	8395	18396547	2192
PERKINS RD & VIRGINIA AV	3	21786	18782	10178	5692	28219	20613980	731
WASHINGTON ST & 6 ST	2	4165	2579	29656	21736	29068	31851261	1096
PERKINS RD & HALL OF FAME AV	2	24675	22829	5563	12862	32965	36120851	1096
JARDOT RD & 3 AV	4	0	0		0	0	0	0

Perkins Road and Hall of Fame Avenue experiences 32,965 vehicles traveling through it per day, the highest out of the forty intersections; however, it is considered the safest. Jardot Road and 3rd Avenue is slightly misleading because its AADT count is 0, while still having 4 accidents within the 6 year period. This intersection ranks number one in being the most dangerous in the city, but it is placed at the bottom of the list. Some of the locations are T-intersections, which is why there are null values in the cardinal directions (Table 1). The AADT count through a T-intersection only requires 3 directions, so the counts are still accurate because every vehicle is double counted. The intersections are mapped to allow viewers the ability to understand the spatial arrangement of where the locations are in the city.

Representing the intersections spatially gives a sense of the arrangement of the locations. The forty locations are all mapped with the five highest intersections in red, including the star (Figure 21). These locations have the highest amount of accidents within the six year period. Main Street and Hall of Fame Avenue has 236 accidents, the highest. Duck Street and 3rd Avenue has 142, Duck Street and McElroy Road has 131, Washington Street and Lakeview Road has 126, and Main Street and Miller Avenue has 95 accidents. When the rate is applied, the locations change due to the rate determining the safeness of an intersection.

In Figure 22, the safest intersection is situated at the crossing of two arterial streets, Perkins Road and Hall of Fame Avenue. The two most dangerous intersections are Jardot Road and 3rd Avenue, and Duck Street and 3rd Avenue. These locations are adjacent to residential areas and are situated along collector streets. Jardot Road and 3rd Avenue, according to Table 1, requires no vehicles to produce an accident. The AADT count is correct, but the rate is misleading because more than 0 vehicles traveled through that location in 6 years. It is still considered dangerous. The top five unsafe intersections include the two red stars as well. Three intersections remained in the top five highest occurring and top five most dangerous locations: Main Street and Hall of Fame Avenue,

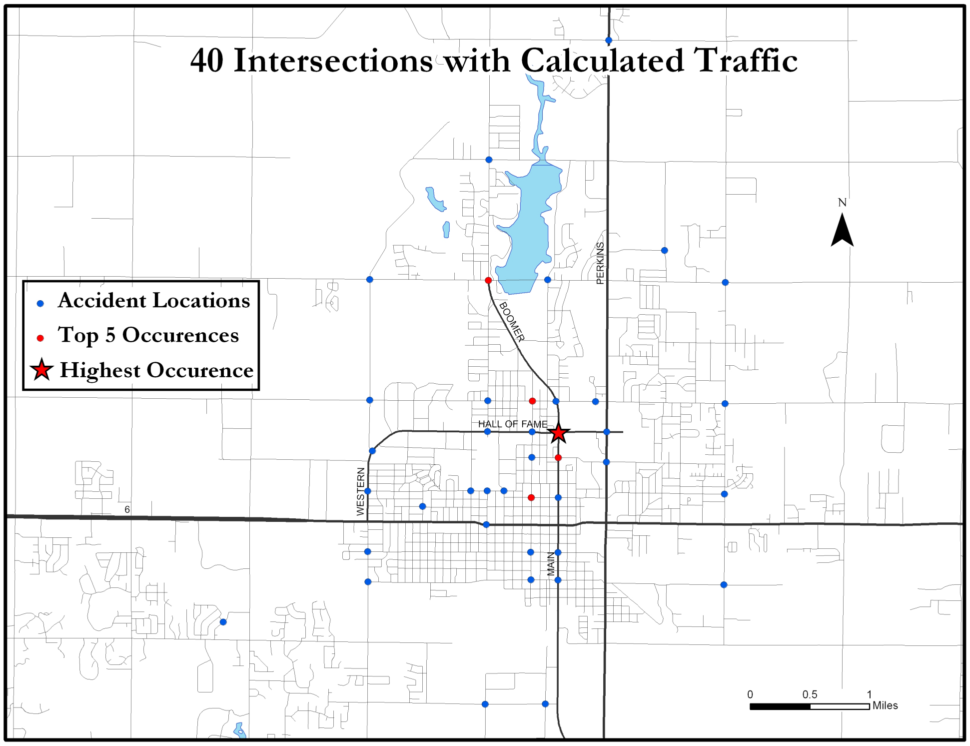

Figure 21. Forty intersections are shown. The locations with the five highest occurrences are in red. Main Street and Hall of Fame Avenue has 236 accidents, the highest occurrence.

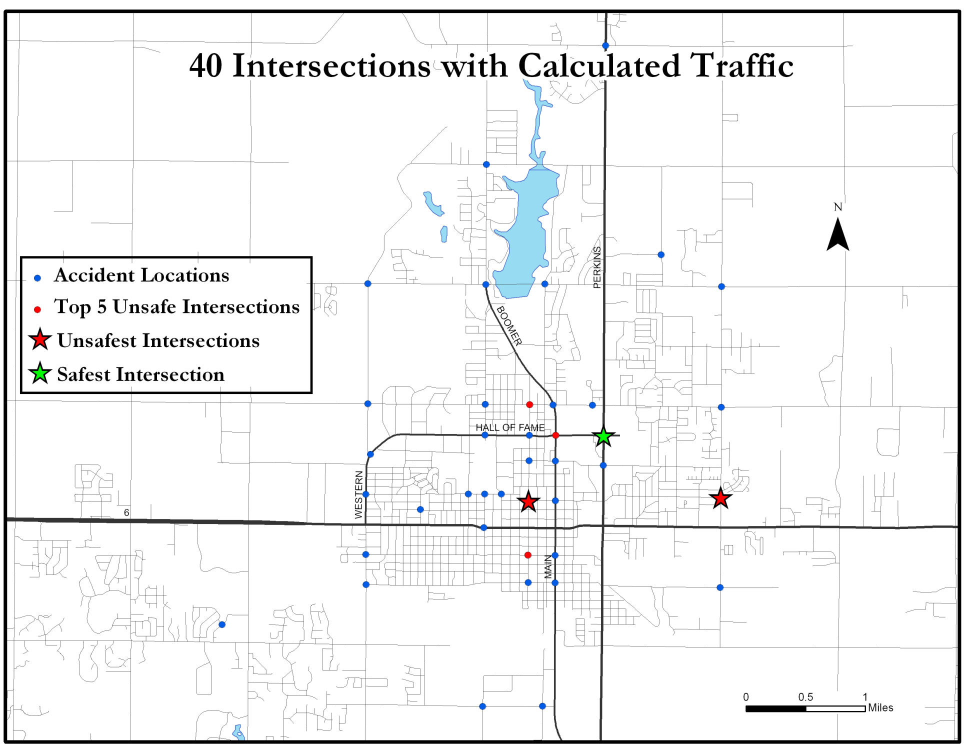

Figure 22. The safest intersection is made up of arterial streets, while the two most dangerous intersections are near neighborhoods situated on collector streets.

Duck Street and 3rd Avenue, and Duck Street and McElroy Road. These three intersections have both high occurrences of accidents and are also rated very unsafe. The rating maps are important to the city for assessing which intersections are producing more accidents and how often. The maps have an advantage over the raw data by showing where the locations are inside the city. The city and transportation planning offices benefit from these maps and rates by identifying which locations are in need of reform. The maps play a significant part in the chronological chain of events leading towards safety improvement of roads in the city. More understanding can be gained from spatial-temporal breakdowns of when accidents occur more often.

Spatial and Temporal Breakdowns

Temporal Breakdowns

By visualizing different temporal breakdowns of accidents occurring in the city, a deeper knowledge of this phenomenon is gained. Using the City data, accidents are broken down temporally by hour, day of the week, and by month. These breakdowns are visually represented using charts. The spatial component is added by viewing accidents by each hour of the day. Each hour is visually represented to reveal where hot spots are at the individual hours of the day. They are then represented in ArcScene to reveal the density of the accidents in 3-D. Through these various methods of visual representations, each method acts as a different geovisualization tool.

Breaking down the accidents by each hour of the day shows which part of the day experiences more crashes. The chart (Figure 23) begins at midnight, that hour refers to the time from 12:00 a.m. to 12:59 a.m., and ends at the 11:00 p.m. to 11:59 p.m. hour. The accidents occur as a result of daily patterning of activities (Levine et al. 1995c).

Accidents increase at 8:00 a.m. as more drivers travel to work. There is another spike at lunchtime. The highest part of the day is at 3:00 p.m. when the high school is dismissed, and also at 5:00 p.m. when drivers travel home from work. Another visual representation is shown as a supplementary chart in the appendix. It shows the same data, but in a different way (Appendix 1). The hours of the day are around the rim. Next, the accidents are broken down by day of the week.

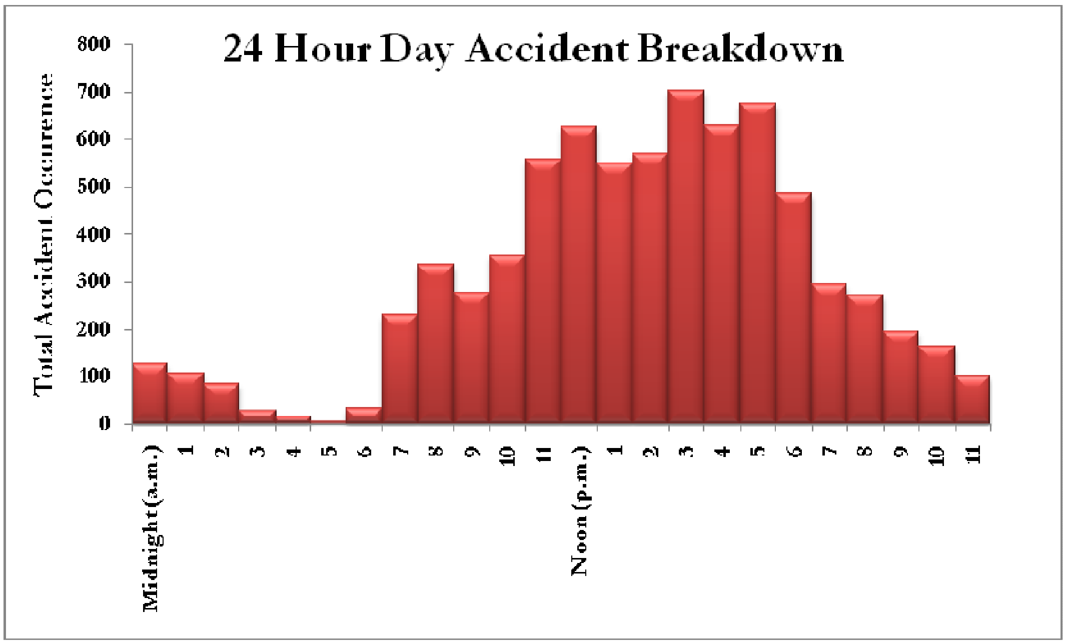

Figure 23. The chart shows the breakdown, by hour, of accidents in the city. The highest occurrence of accidents is experienced between 3:00 p.m. and 3:59 p.m. in the afternoon.

Using a pie chart, the accidents are displayed for each weekday (Figure 24). A pie chart was used to resemble the repeating of the week throughout time. Sunday experiences the least amount; altogether the weekend experiences fewer accidents than the rest of the week. The most accidents happen on Friday, while Monday through Thursday experiences roughly the same amount. These various perspectives give a clearer picture of when the accidents are happening. Seasonal patterns can be seen with the monthly breakdown of accidents.

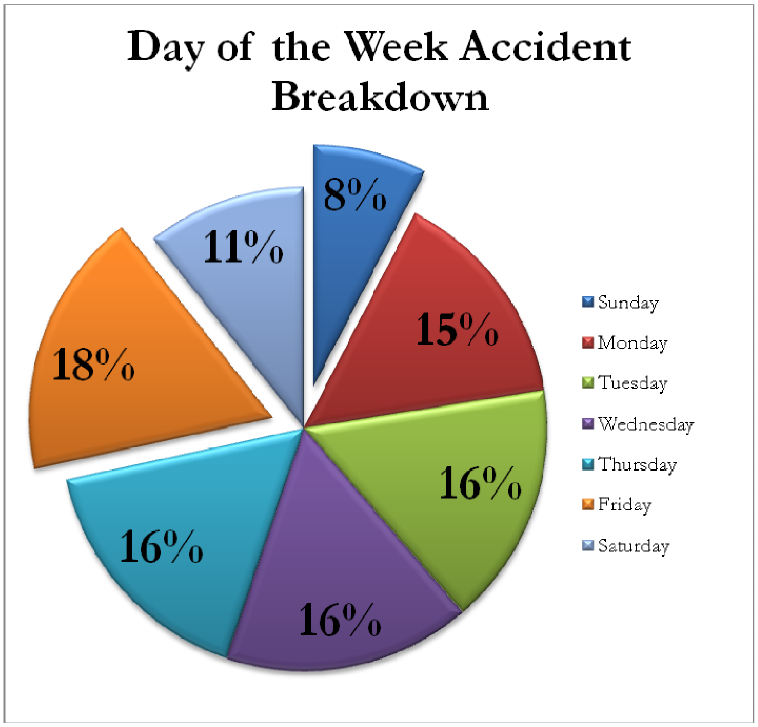

Figure 24. The city experiences the least amount of accidents on Sunday, while the most occur on Friday.

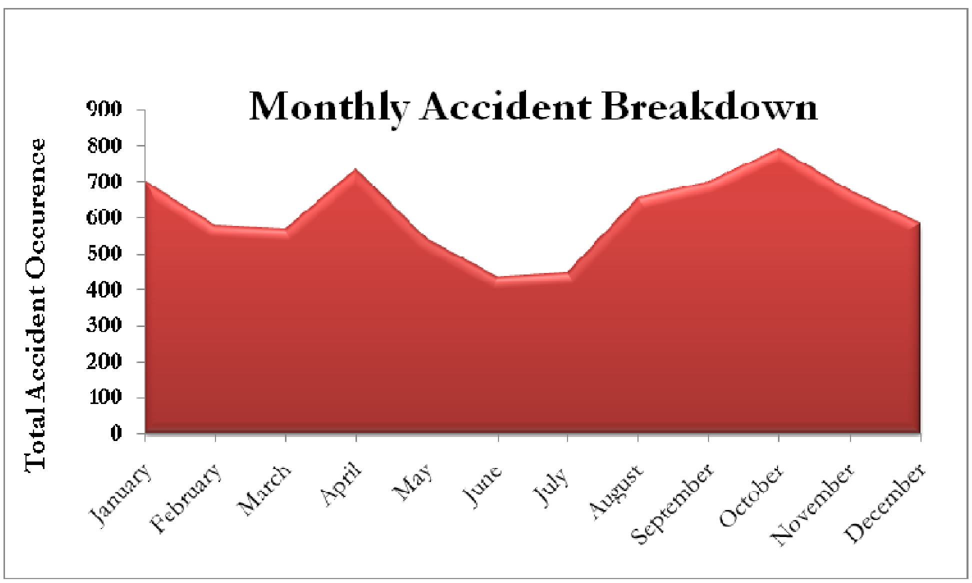

Figure 25. Seasonal patterns are revealed in the chart. Most of the university students leave the city during the summer months.

The monthly breakdown of accidents is done two ways. First, the breakdown is done for the entire period of the City data—five years (Figure 25). Then, each year is broken down to see yearly patterns from month to month (Figure 26). The overall monthly breakdown from 2003-2008 reveals distinct phenomena attributed to seasonal

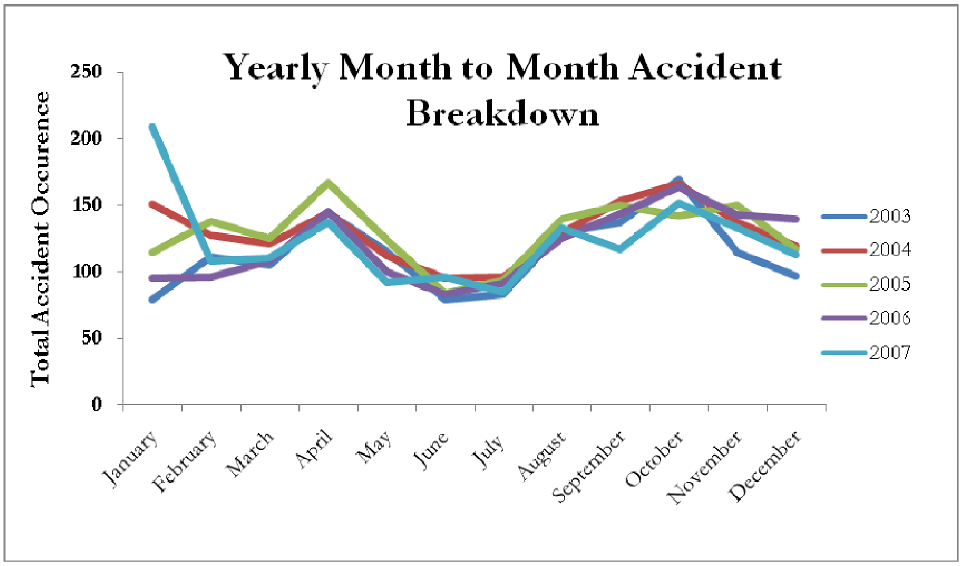

Figure 26. This chart breaks down each year by month. The same general pattern is seen here as in Figure 25. January, 2007 is a large spike, influenced by the large ice storm that affected much of Oklahoma.

patterns. The accidents decrease dramatically during the summer months. The university students leave the city and return to permanent residence while not attending semester classes. Another display shows the same data, but with a different visual representation.

The same general shape exists among all years for monthly accidents (Figure 26) as it does for the overall monthly breakdown (Figure 25). There are subtle patterns among the individual years. April, 2005 experienced a larger than average amount of accidents. September, 2007 had a lower than average amount. Having more years of data would allow for more pronounced patterns because five years is a limited amount to explain; however, construction of roads and weather can influence traffic as well as accidents. A substantial spike occurred in January, 2007. This was strongly influenced by the ice storm event that affected most of Oklahoma during that month.

Each year in Figure 26 is individually represented with a different visual chart in the appendix. The visual representations of the charts (Appendix 2-7) are shown by month for each of the five years. The months are along the outer rim, giving a continual chronological picture of when the accidents occurred. January, 2007 appears with a more pronounced spike of accidents, influenced by the ice storm (Appendix 7). Understanding the temporal breakdowns in the accident data allows viewers to gain deeper and more valuable insight in when the accidents occur. Spatially, accidents cluster in specific areas during different hours of the day. These results are visually represented to not only know when the accidents are occurring by hour of the day, but also where they are concentrated for each hour of the day.

Spatial-Temporal Hourly Breakdown

Figure 23 shows accidents at each hour in the day, but they are also represented spatially. This advantage, in viewing the accidents by each hour spatially, enhances understanding of where the accidents occur at specific times. This method of visualization has a superior advantage because it shows spatial arrangements of 3-D densities. The differences in the arrangements of accidents can be seen through every hour in the city. Each hour is now represented using Kernel Density, and is then converted into 3-D to be visualized in ArcScene. The visualization maps for each hour of the day are referenced within the Appendix. Each hour is grouped into two maps: "a" and "b". For instance, 12:00-12:59 a.m. is first displayed using Kernel Density (Appendix 8a). Next, the same hour is shown in 3-D with ArcScene (Appendix 8b). Each hour of the day proceeds chronologically, in groups of two, through the twenty-four hours. This method was chosen because the patterns progress and change location throughout the day. The patterns are better understood by observing the changes in density between chronological hours. The Kernel Density and 3-D maps use the equal interval classification described in the methodology section. Each category of density represents the range of values as a percentile. "very high" includes the top 20 percentile of the density values (Pulugurtha et al. 2007). Spatial-temporal patterns can be observed throughout the day.

From 8:00 to 8:59 a.m. drivers are still traveling to work from home, a daily activity pattern. There is a small spike in traffic accidents during this hour (Figure 23). The high school experiences a large concentration of accidents from 7:00 to 7:59 a.m. as well as from 8:00 to 8:59 a.m. (Appendix 15 and 16). Lunchtime experiences a spike from noon to 12:59 p.m. (Figure 23). The high school also has a high concentration of accidents during the students' lunchtime, from 11:00 a.m. to noon (Appendix 19). At noon, Wal-Mart, on Perkins Road, begins to experience high concentrations of accidents due to the large parking lot as well as the many consumers needing desired goods. In 3-D the store shows a high peak density at noon time (Appendix 19 and 20). Wal-Mart continues to stay highly dense with accidents throughout the rest of the day until it tapers off throughout the evening hours. The Wal-Mart peak snuffs out between the 10 o'clock and 11o'clock hours (Appendix 30 and 31). After 11:00 p.m., the peak decreases dramatically (Appendix 31). This is partly influenced by Wal-Mart closing one of its two entrances into the store at 11:00 p.m. every evening. Each hour of the day has spatial-temporal patterns of accident hot spots. These patterns are easily perceived and understood through the geovisualization representations within the maps. Through mapping methods and visual tools, deeper insight is gained towards understanding the accident patterns in the city.

CHAPTER V

CONCLUSION

Relevance of Traffic Accident Research

Society is continually becoming more dependent on the automobile. This dependence is the strongest in U.S. cities (Kenworthy and Laube 1999). Usage of the automobile experienced rapid growth in the post-WWII era when owning a new car was both trendy and affordable (Randall et al. 2005). Cities, such as Los Angeles, have been built around the automobile. Its auto-based design allows the urban landscape to sprawl (Kenworthy and Laube 1999). Cities are designed to accommodate the driver with roads, drive-thru restaurants, and houses with garage doors. In 2007, about 160 million drivers used U.S. roads for convenience of travel (Li et al. 2007). With numerous drivers on roadways, traffic congestion and accidents become an important safety issue.

Traffic safety research is relevant when faced with the crash statistics. In 2007, over 41,000 people died as a result of traffic accidents—one person every 13 minutes (NHTSA 2009). With the installation of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, traffic safety continues to be an important and necessary issue to be researched (Kim et al. 1995a). Out of the many forms of traffic accident and safety research, the identification of areas where accidents occur more frequently helps to reduce crashes using GIS (Erdogan et al. 2008). Location identification of where accidents occur more often is useful at improving safety on roadways. Hot spot detection has been a useful tool and GIS uses crash mapping to make this possible.

Benefits of Crash Mapping

One of the major advantages to using GIS is the geographic component. Analyzing traffic accidents in tabular form in, for example, Microsoft Access is a "daunting" task (Kaufman 2008). The data contains numerous records, and it is difficult to visualize the spatial locations of patterns within the traffic accidents. Crash mapping using a GIS allows a safety analysis of patterns to happen in minutes (Kaufman 2008). By pinpointing where concentrations of accidents are located, police and transportation planners are able to treat these hot spots and improve roads. By using GIS, the accidents can be visualized spatially.

Geovisualization

Visualizing traffic accidents becomes a vital tool for gaining insight into spatial and temporal patterns within a city. GIS has allowed police and city officials to view incidents visually, a method that was not previously possible (Levine 2006). Geovisualization is a powerful tool in which to represent traffic accidents. It engages the "most powerful of human information-processing abilities"—the eyes (MacEachren et al. 1999). The "geographical dimension" enhances the ability to see patterns and connections among phenomena within large spatial datasets (Kwan 2000). Geovisualization is an improvement to road safety, as it plays an important function in the many steps needed to achieve reform on roadways. By identifying patterns of when and where accidents happen in a city, this greatly enhances the understanding of crashes.

Social Activity Patterns

Searching for spatial and temporal patterns of traffic accidents in Stillwater, Oklahoma was an improvement and benefit towards road safety. Drivers' activity patterns influence where and when the accidents occur. Accidents are a "function" of clustered social activities involving employment, residential, and entertainment (such as holidays and shopping) (Levine et al. 1995c). This study found that traffic accidents on weekend evenings from 1:00 a.m. to 3:00 a.m. showed highly clustered crashes near adult establishments. Drivers engaging in this social activity were involved in accidents at or in close proximity to these locations, influenced by the driver's involvement in this social activity. Shopping areas and eateries also had hot spots of accidents.

The high school experiences concentrations of accidents in the morning as students and teachers go to school, and also around lunch time. Certain locations in the city are clustered with various eateries, and these locations have high concentrations of accidents around lunch time. Wal-Mart is used by many drivers for desired goods. This location was found to have dense concentrations of accidents throughout afternoons and well into evening hours. The accidents in the city involve the weekly patterning of regular social activities (Levine et al. 1995a). Weather is one of the five major contributing factors affecting traffic safety (Li et al. 2007). Extreme weather events play important roles towards accidents in the city. January, 2007 experienced an ice storm. This, along with large sporting events at the university can greatly influence accidents in the city. Representations of temporal and spatial patterns of the accidents enhance understanding of the phenomena.

By breaking down the accidents temporally, and representing them visually, viewers are able to gain understanding. By seeing visual charts on accident breakdown by hour, day of the week, and month, one is able to see when the accidents occur more often. Incorporating multiple visual techniques help viewers to spatially understand the patterns of traffic accidents. The accidents were displayed as hot spots, showing where they occurred at certain times of the day. These densities, or concentrations, were represented visually in 3-D to enhance the patterns associated with the accidents. Viewing accidents as “mountainous peaks” of density allowed the study to incorporate visual methods of seeing patterns. Spatial and temporal patterns of the city’s traffic accidents have been revealed through visual representations. Greater insight can be influenced by the unique methods of geovisualization.

Further Study

Future study on this specific research should also examine risk of traffic accidents during different time periods. More research is needed in order to anticipate traffic accidents and when certain events occur in cityscapes. For instance, the police and city planners of Stillwater could benefit from this study. They could anticipate certain areas of the city that would become accident hot spots during certain seasons, weather events, or distinct social activities such as evening weekend attendance at adult establishments. Safety improvements on specific locations would be a financial benefit to the city and the drivers involved. Model building could also help to predict the occurrence of accidents.

Perhaps the most important attempt at accident research is anticipating and predicting crashes. This research could produce a model for crash severity. Severity such as whether an injury or fatality occurred could help to assign greater importance to certain locations needing safety reform. The public, police, and city of Stillwater can benefit from this study. Using a web-based application to allow viewers to browse the different patterns of accidents may increase public awareness. The university students and permanent residents of the city would gain greater insight of accidents through web applications by viewing the different visual representations. Google Earth (2009) is able to display files from ArcGIS, and this would be a helpful tool in spreading the knowledge of this study's findings to the general public. Traffic accident safety is important to improving roadways for its users. This study plays a significant role in the steps toward safety reform. A deeper and beneficial understanding is gained by these representations. They act as a compass to lead police and city officials to specific locations in the city needing safety implementation. By representing the phenomena through visual methods, greater understanding of the city's traffic accident patterns can be increased. This study contributes gained insight in the spatial and temporal patterns of traffic accidents in Stillwater, Oklahoma.

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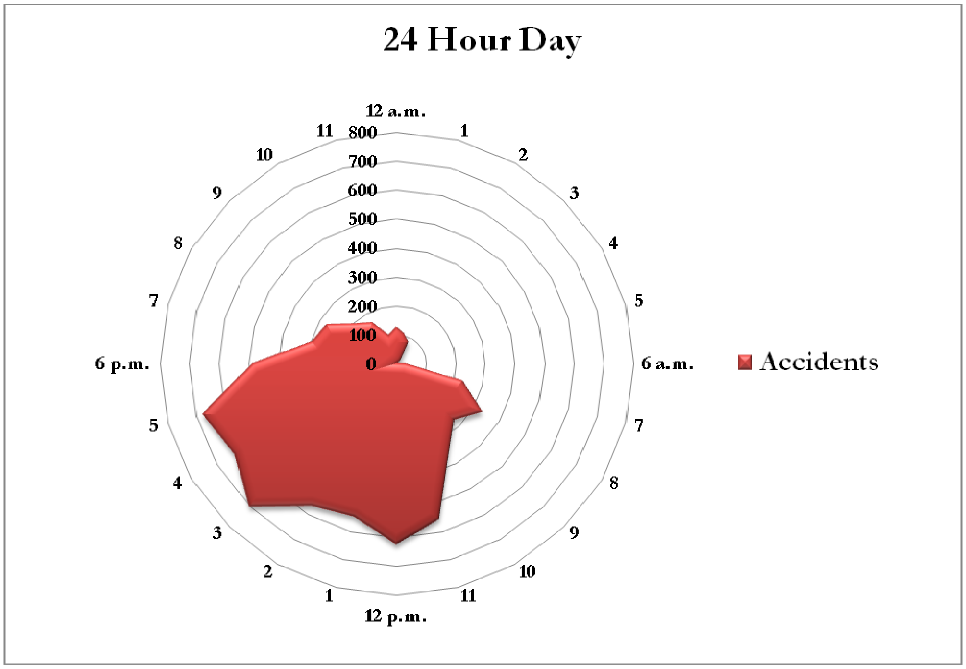
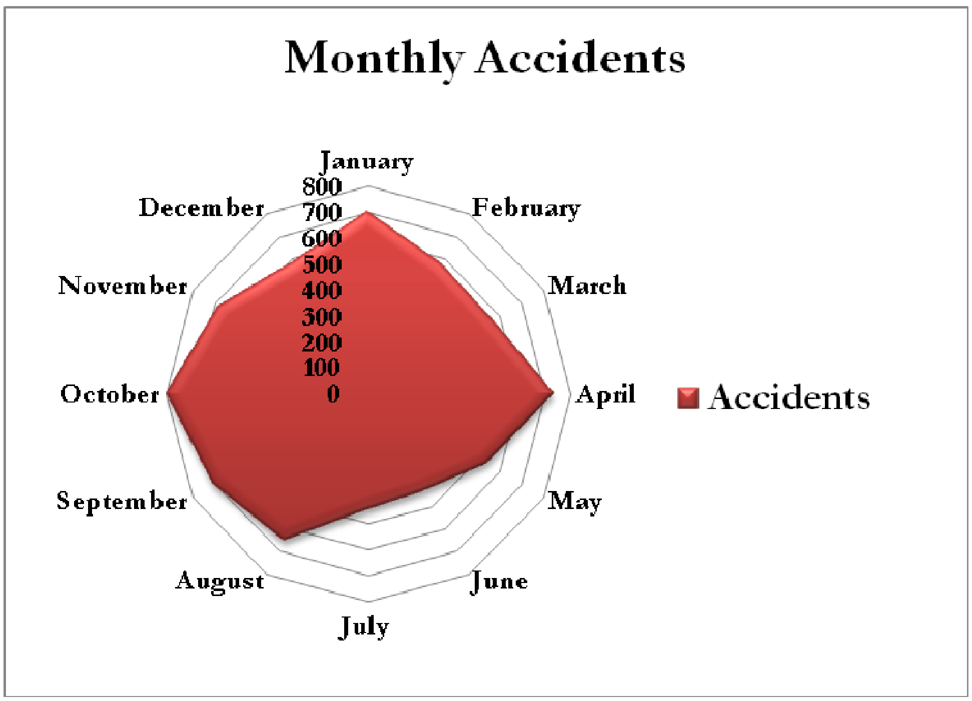
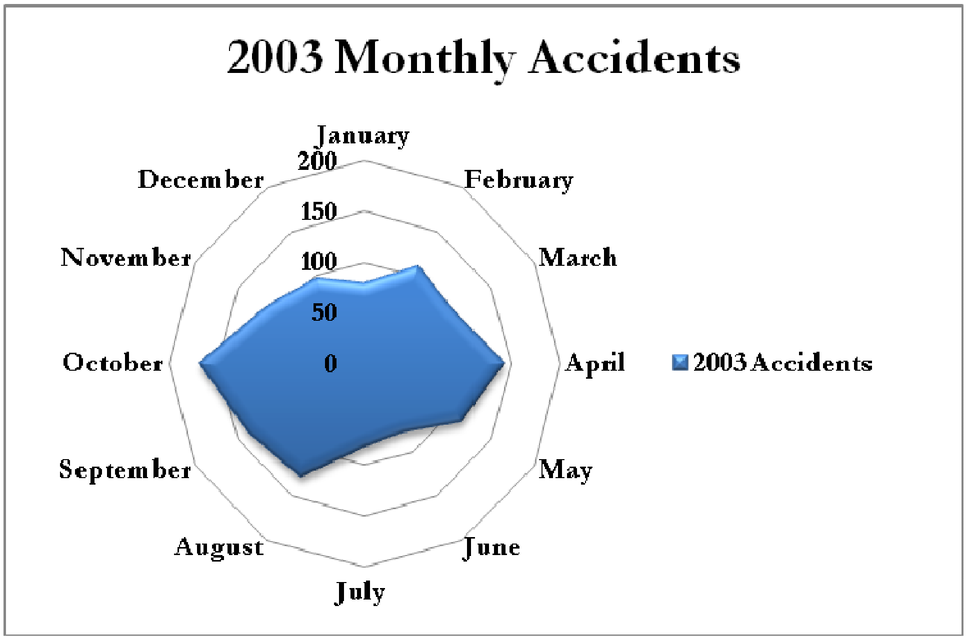
APPENDICES



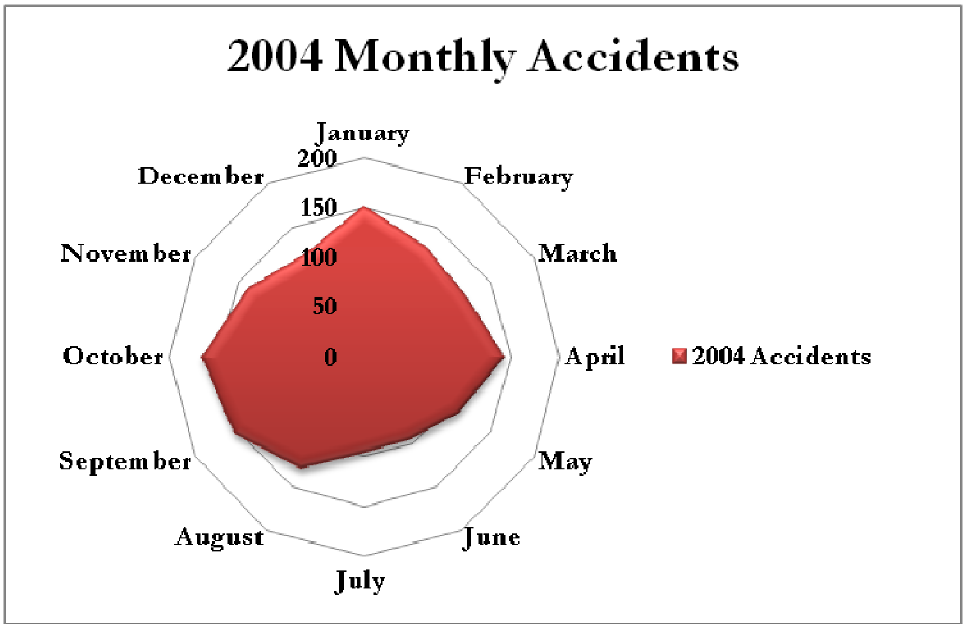
Appendix 1.



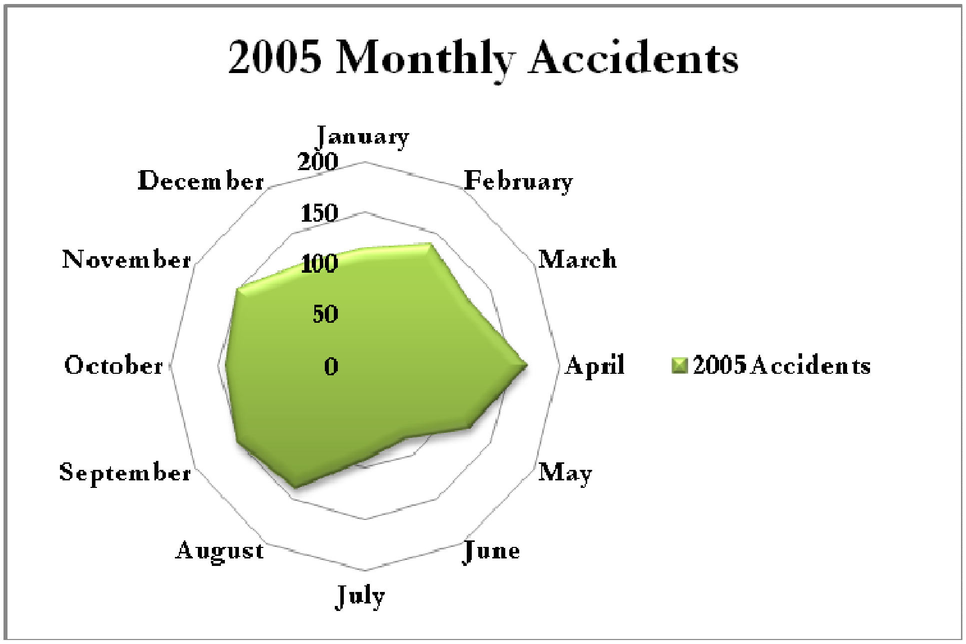
Appendix 2.



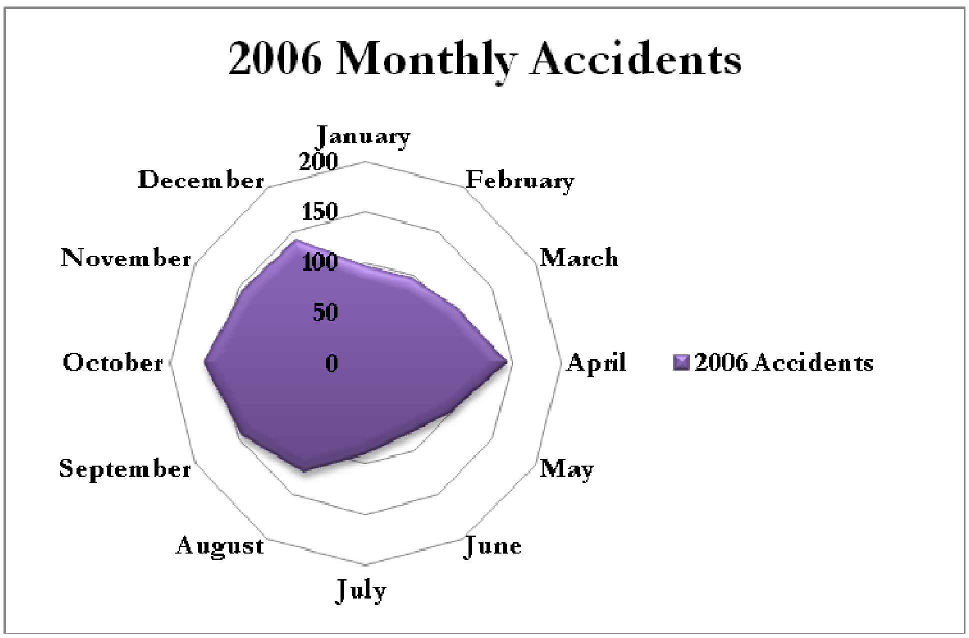
Appendix 3.



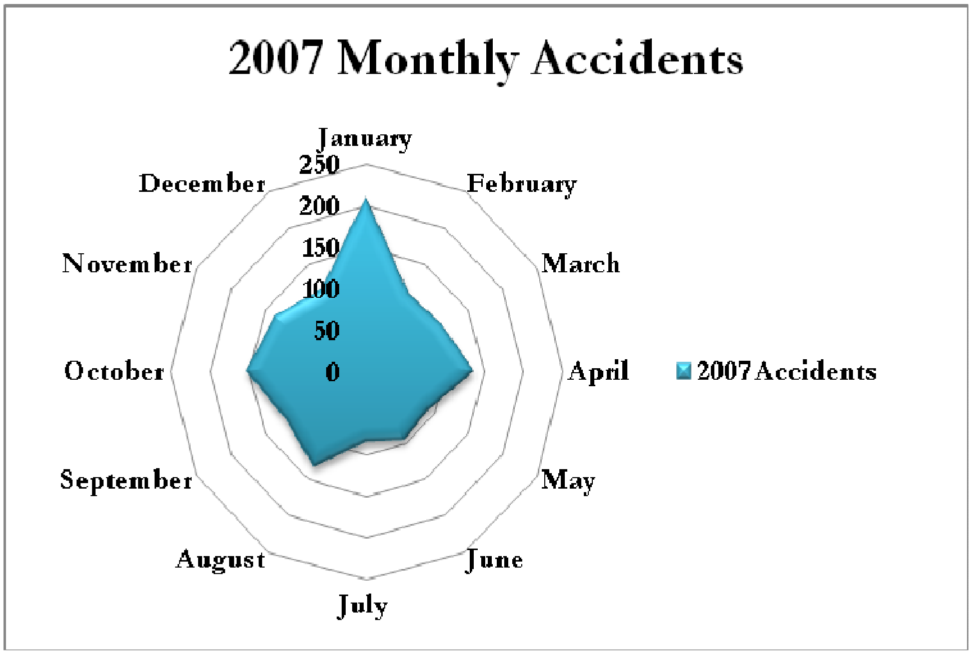
Appendix 4.



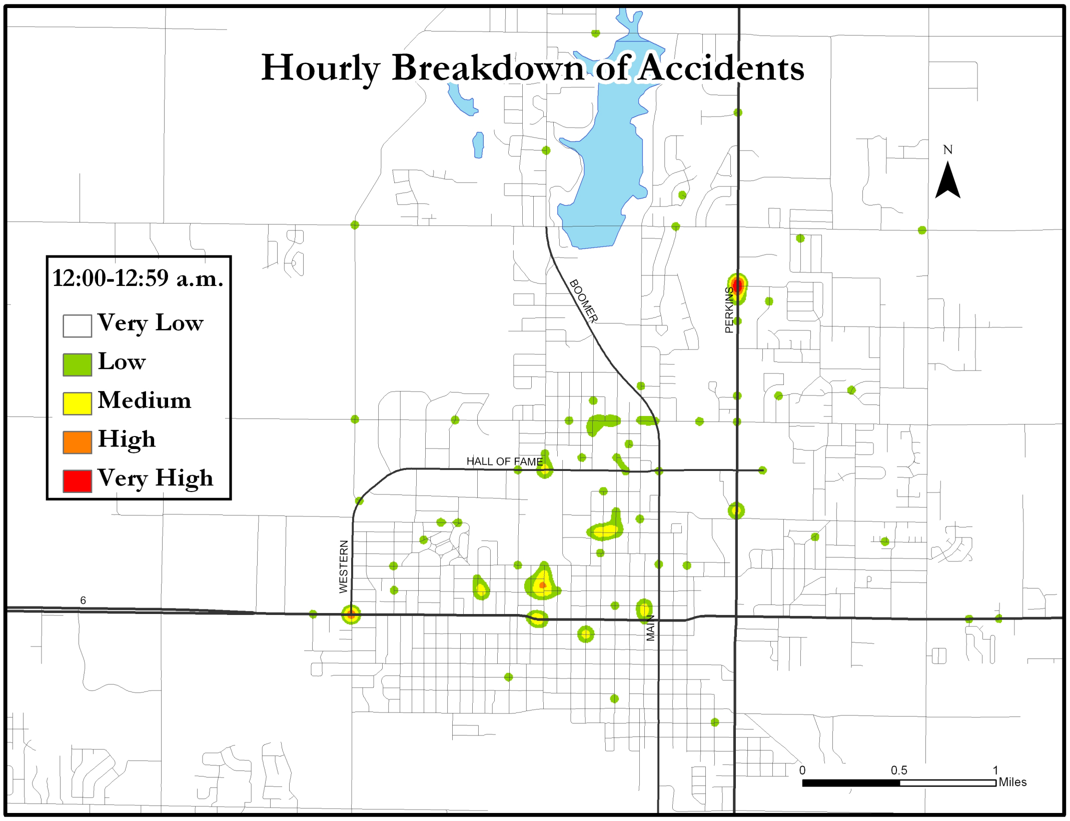
Appendix 5.



Appendix 6.

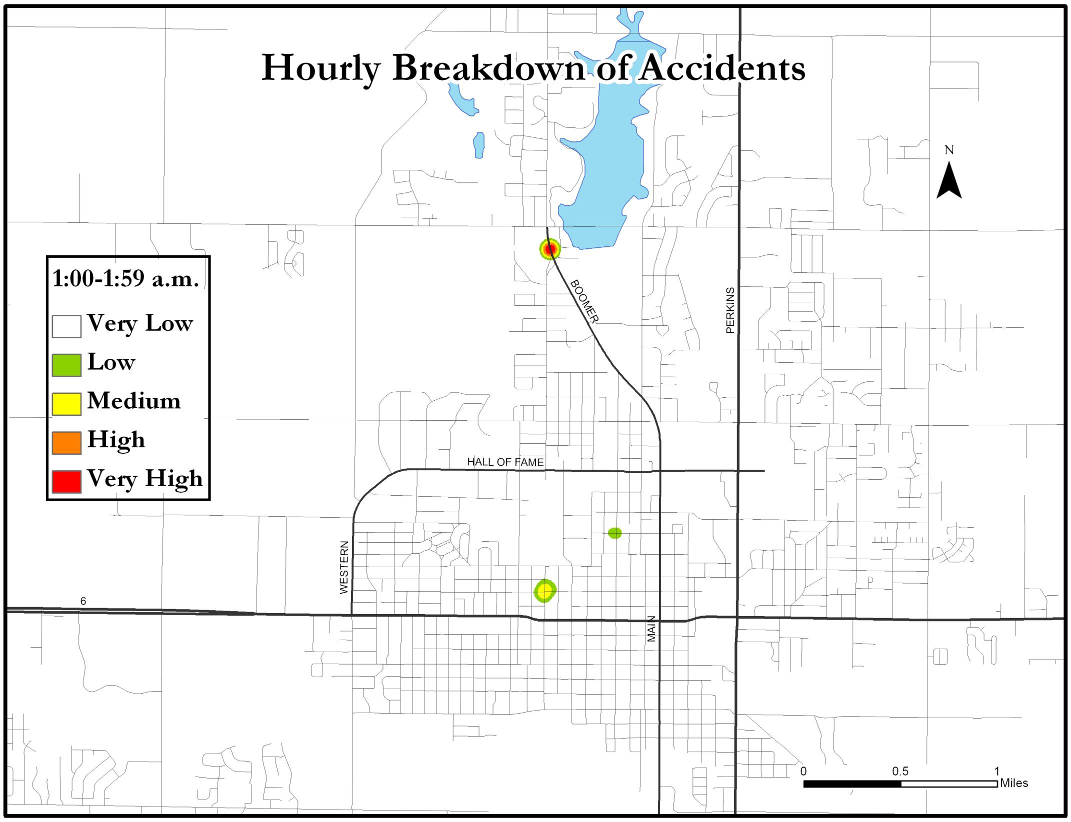

2007 Monthly Accidents
January
February
March
April
May
June
July
August
September
October
November
December
250
200
150
100
50
0
2007 Accidents

Appendix 7.

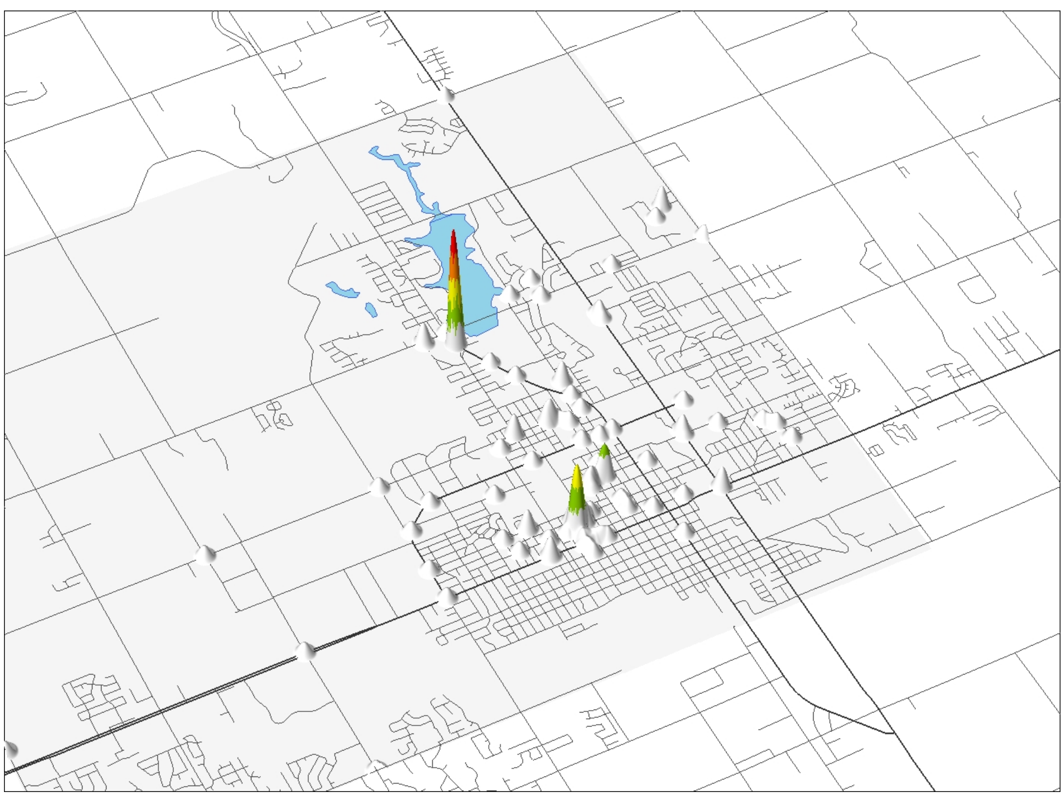


Appendix 8a.

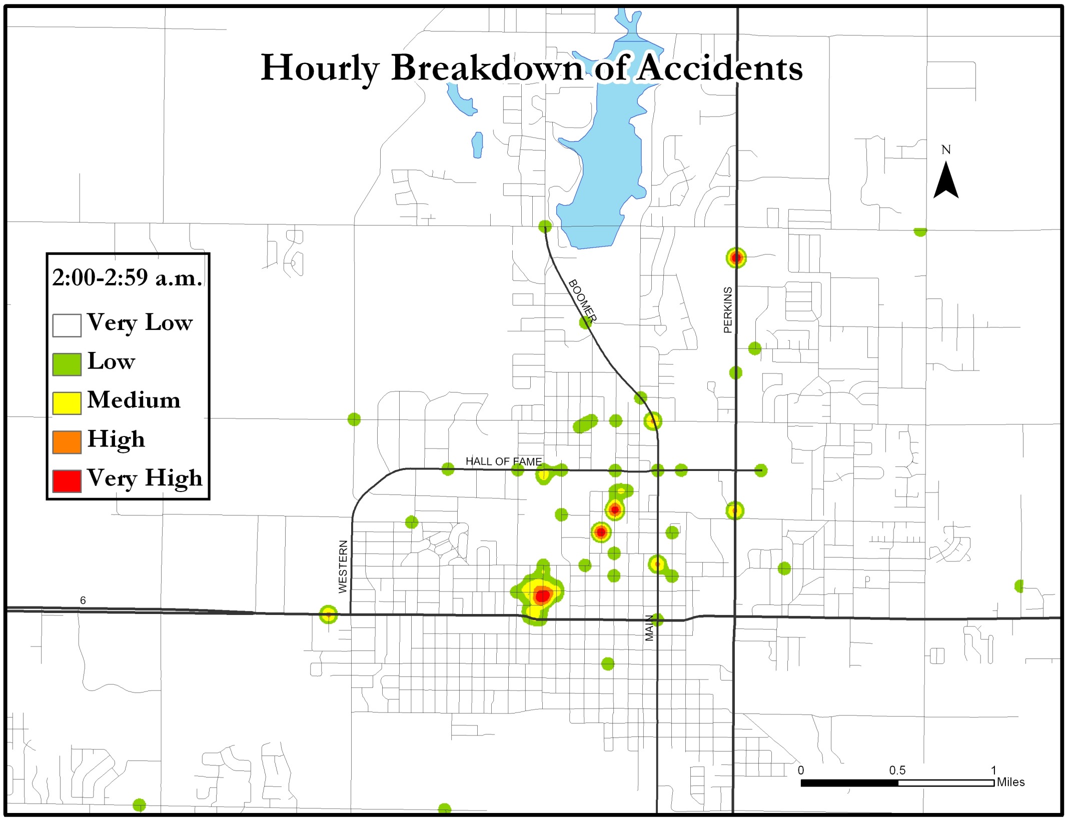
Appendix 8b. Looking northeast, 3-D densities from 12:00-12:59 a.m.



Appendix 9a.

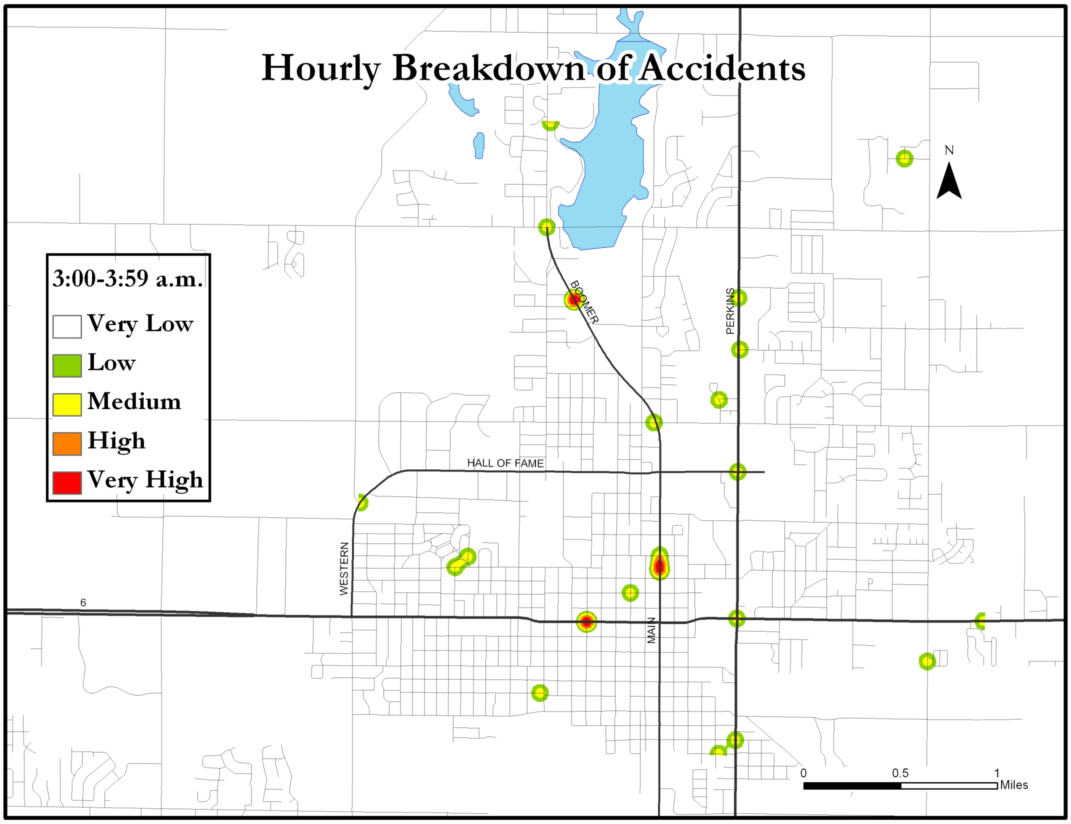


Appendix 9b. Looking northeast, 3-D densities from 1:00-1:59 a.m.



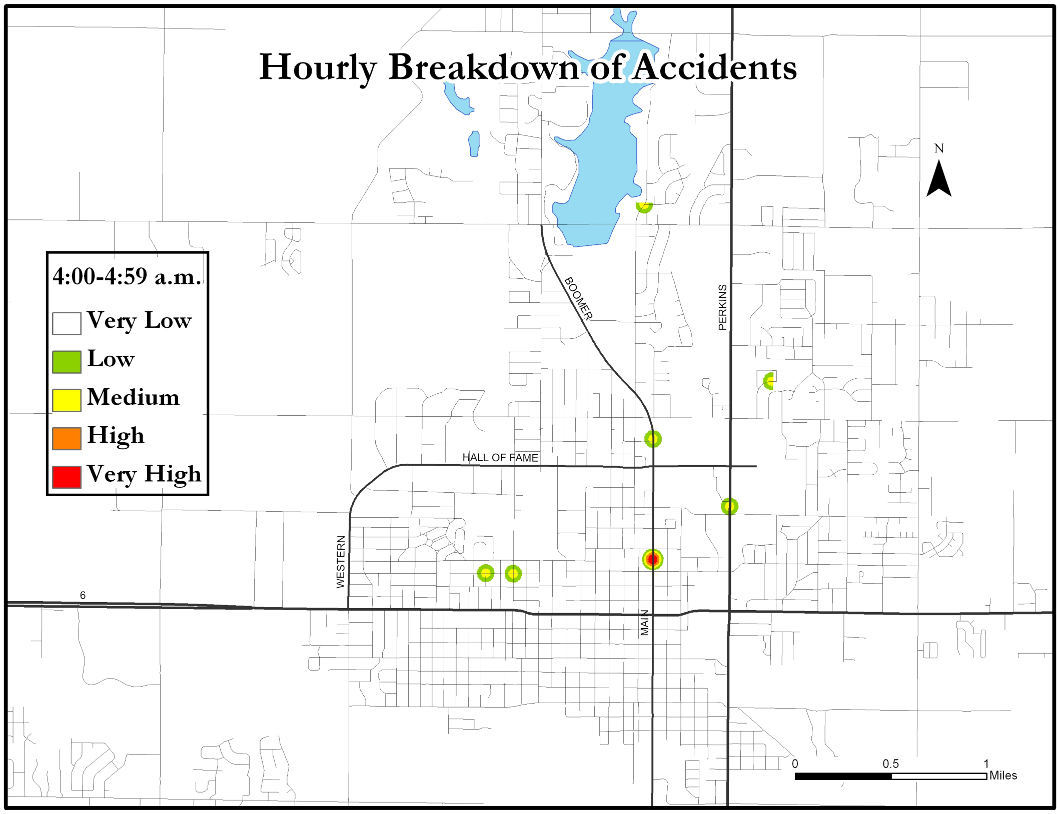
Appendix 10a.

Appendix 10b. Looking northeast, 3-D densities from 2:00-2:59 a.m.



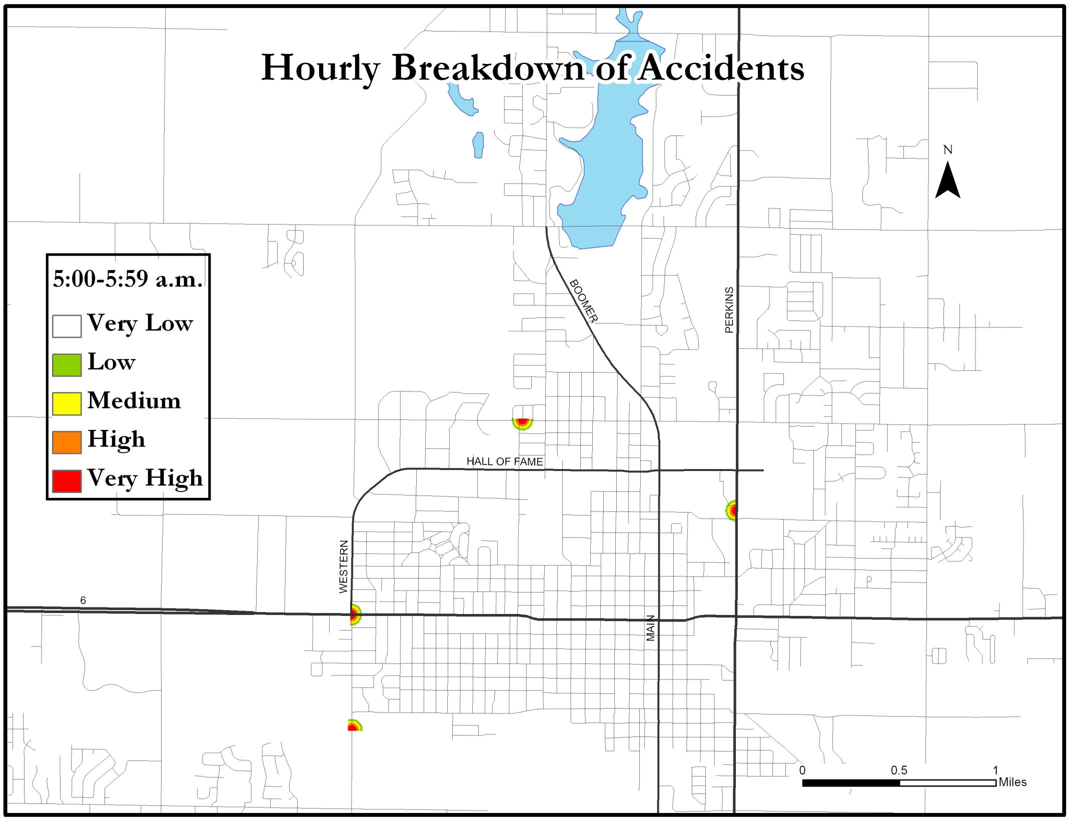
Appendix 11a.

Appendix 11b. Looking northeast, 3-D densities from 3:00-3:59 a.m.



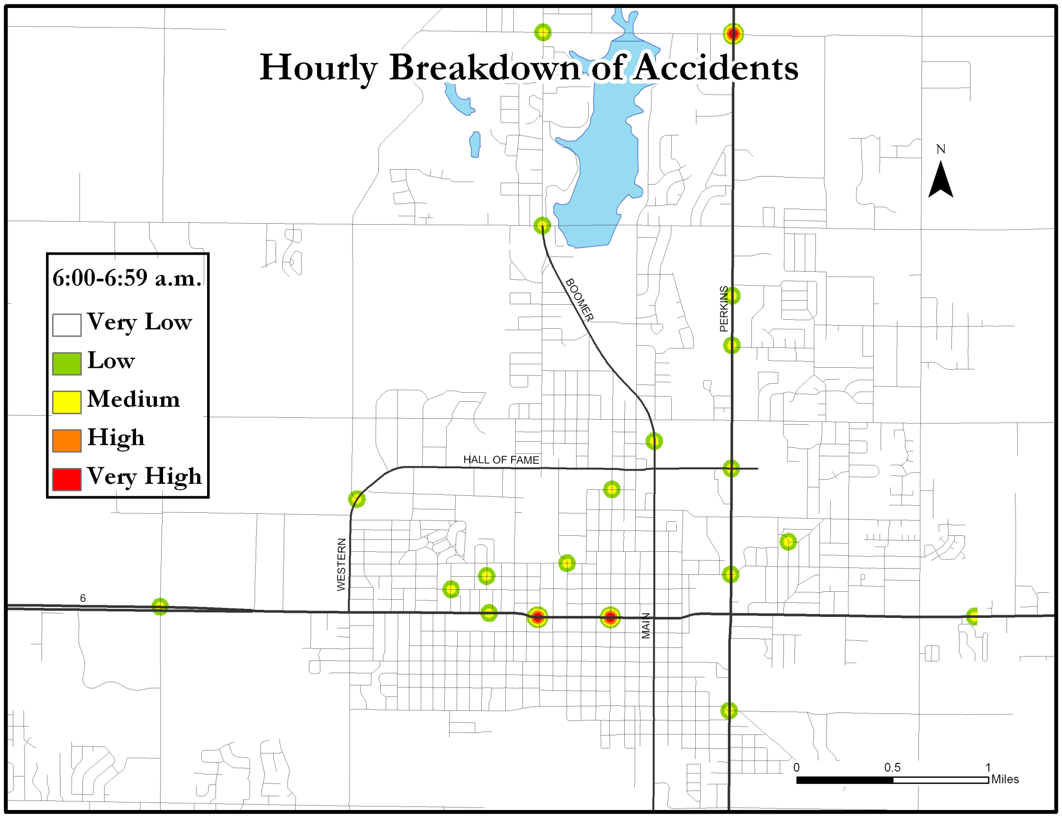
Appendix 12a.

Appendix 12b. Looking northeast, 3-D densities from 4:00-4:59 a.m.

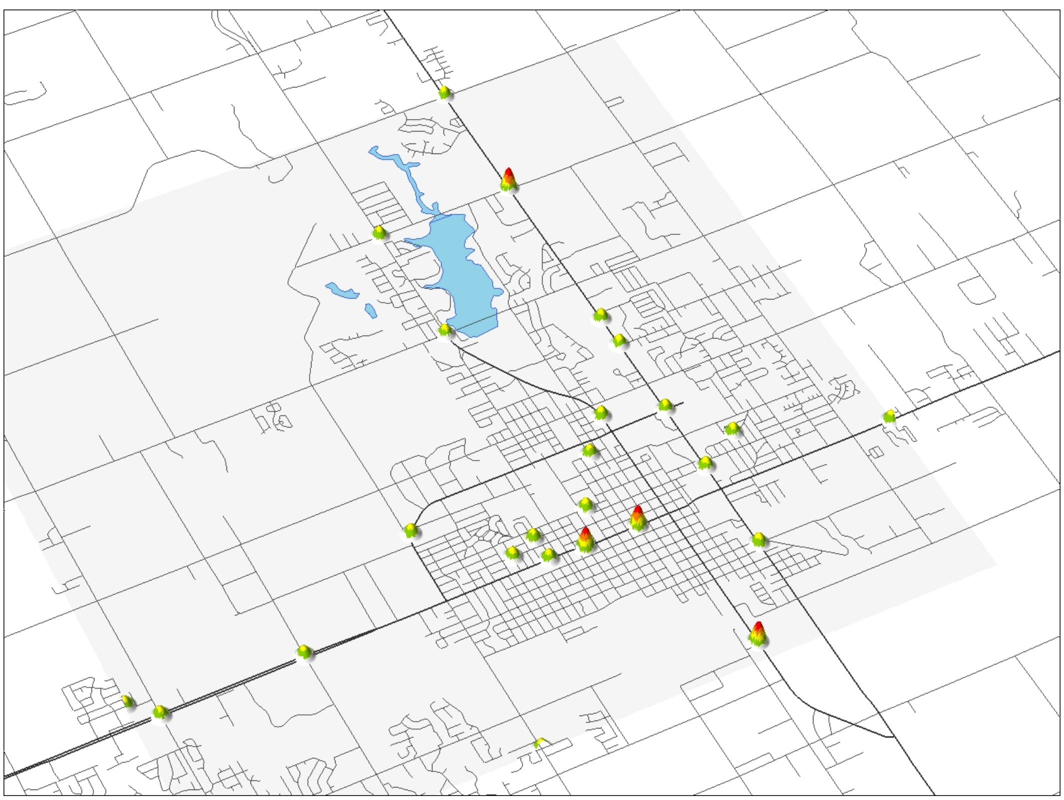


Appendix 13a.

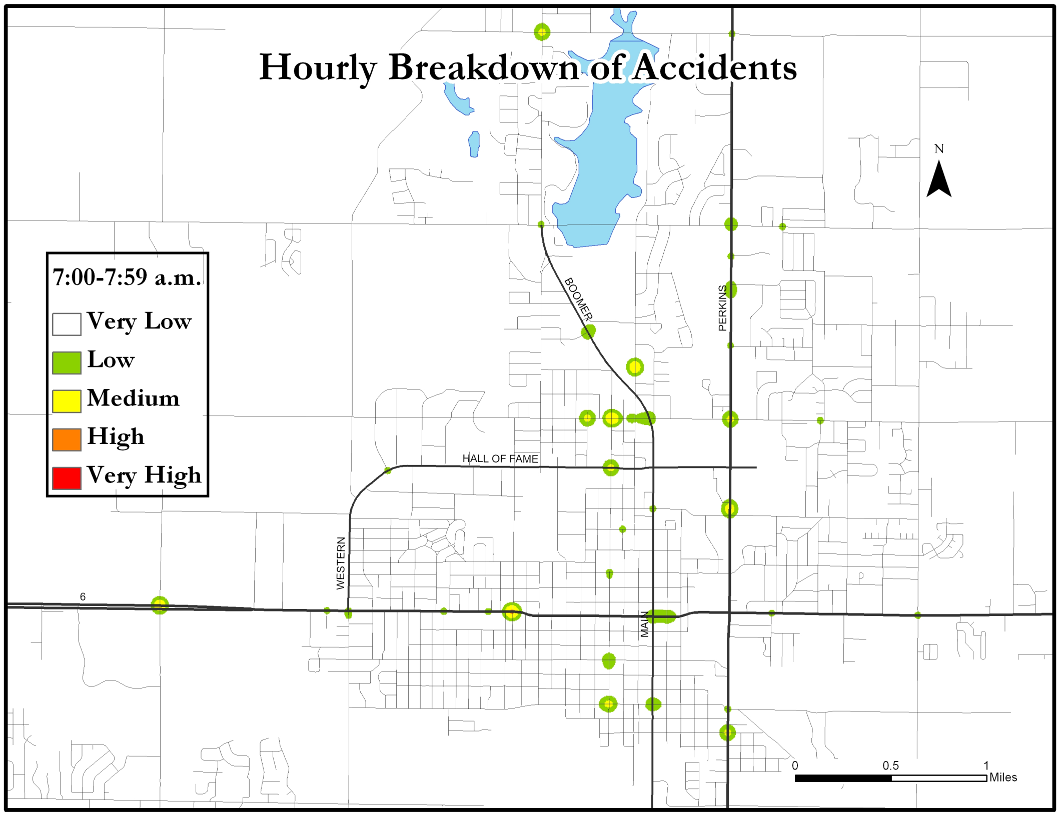
Appendix 13b. Looking northeast, 3-D densities from 5:00-5:59 a.m.



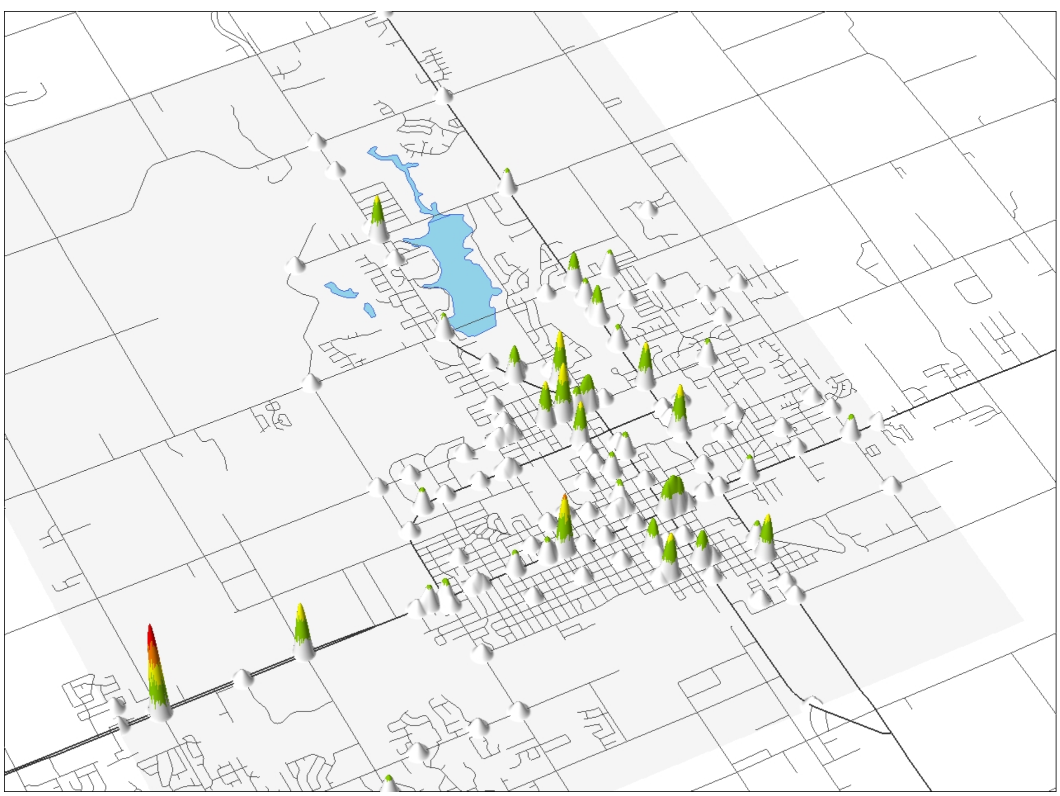
Appendix 14a.



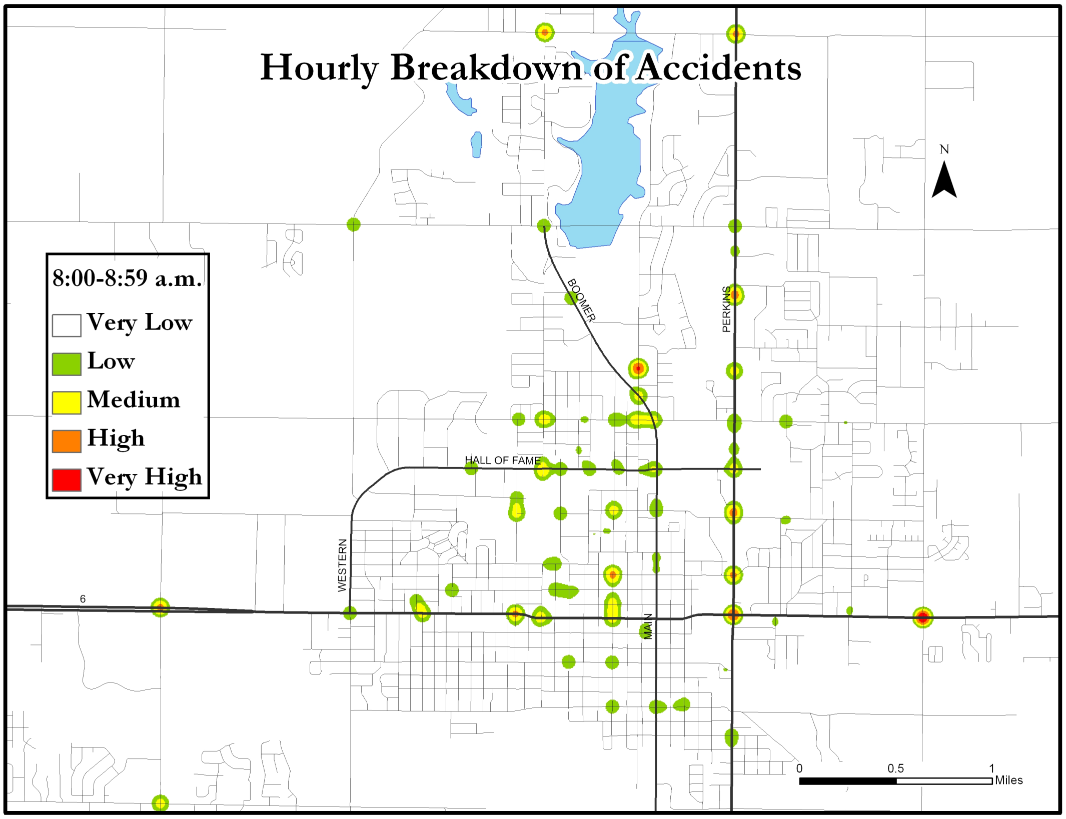
Appendix 14b. Looking northeast, 3-D densities from 6:00-6:59 a.m.



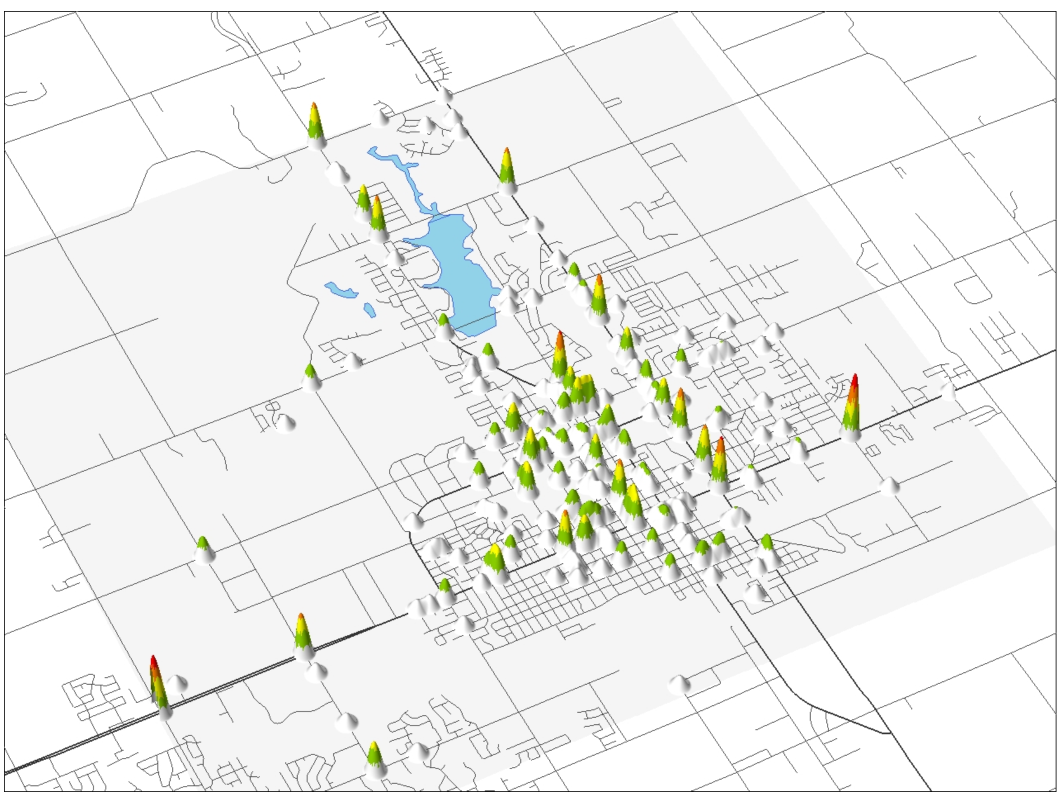
Appendix 15a.



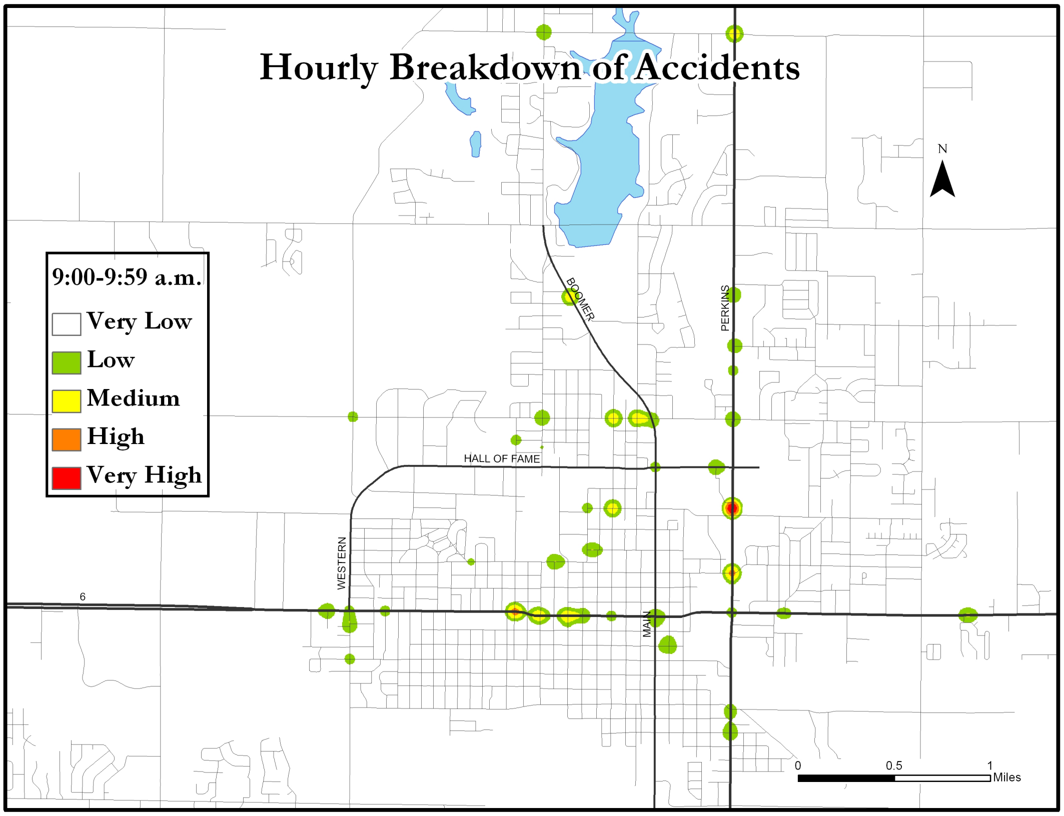
Appendix 15b. Looking northeast, 3-D densities from 7:00-7:59 a.m.



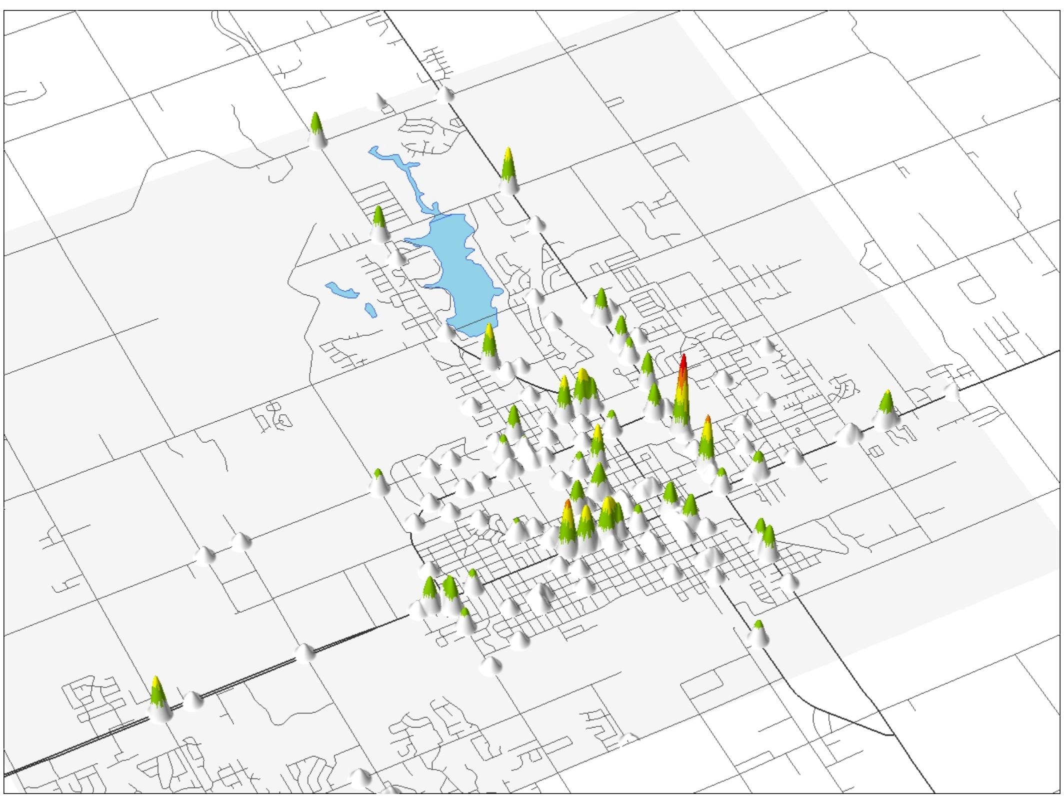
Appendix 16a.



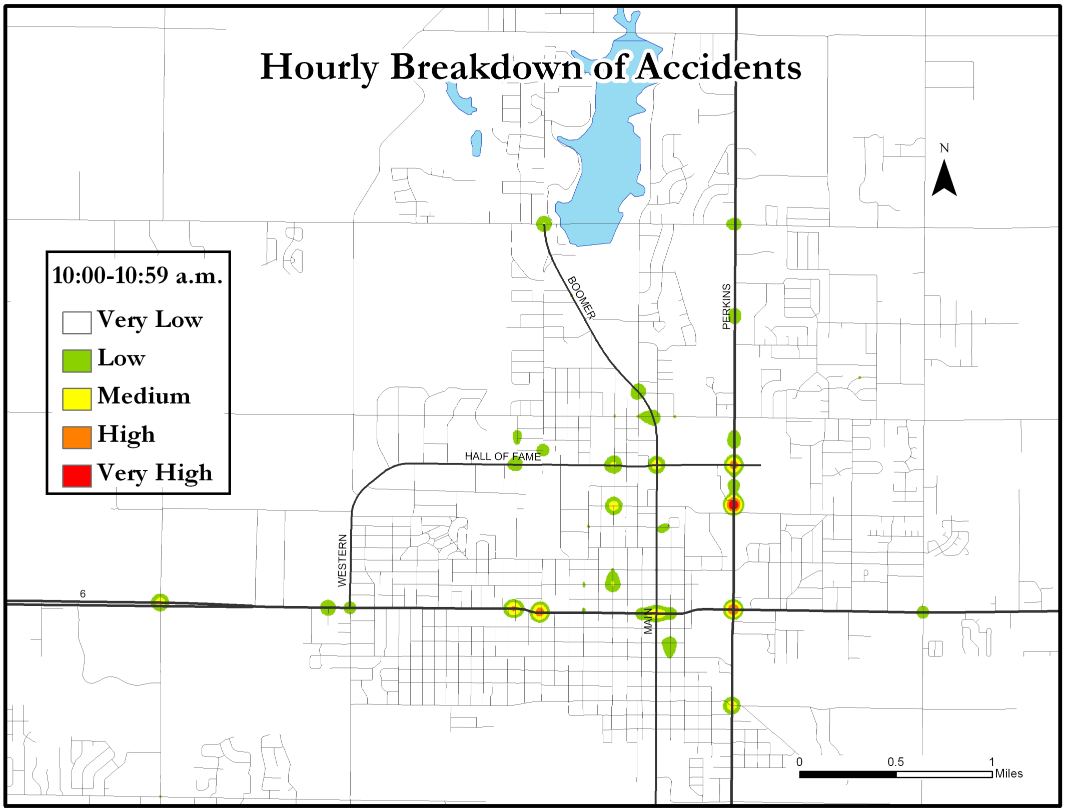
Appendix 16b. Looking northeast, 3-D densities from 8:00-8:59 a.m.



Appendix 17a.

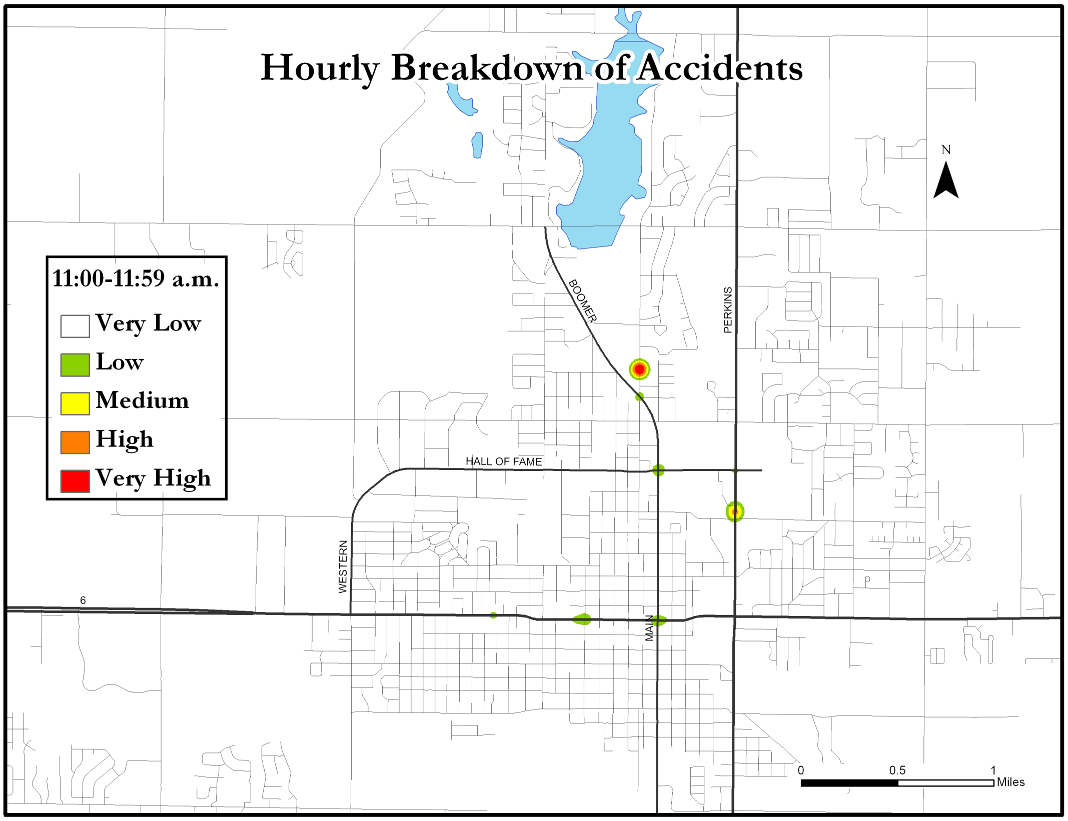


Appendix 17b. Looking northeast, 3-D densities from 9:00-9:59 a.m.

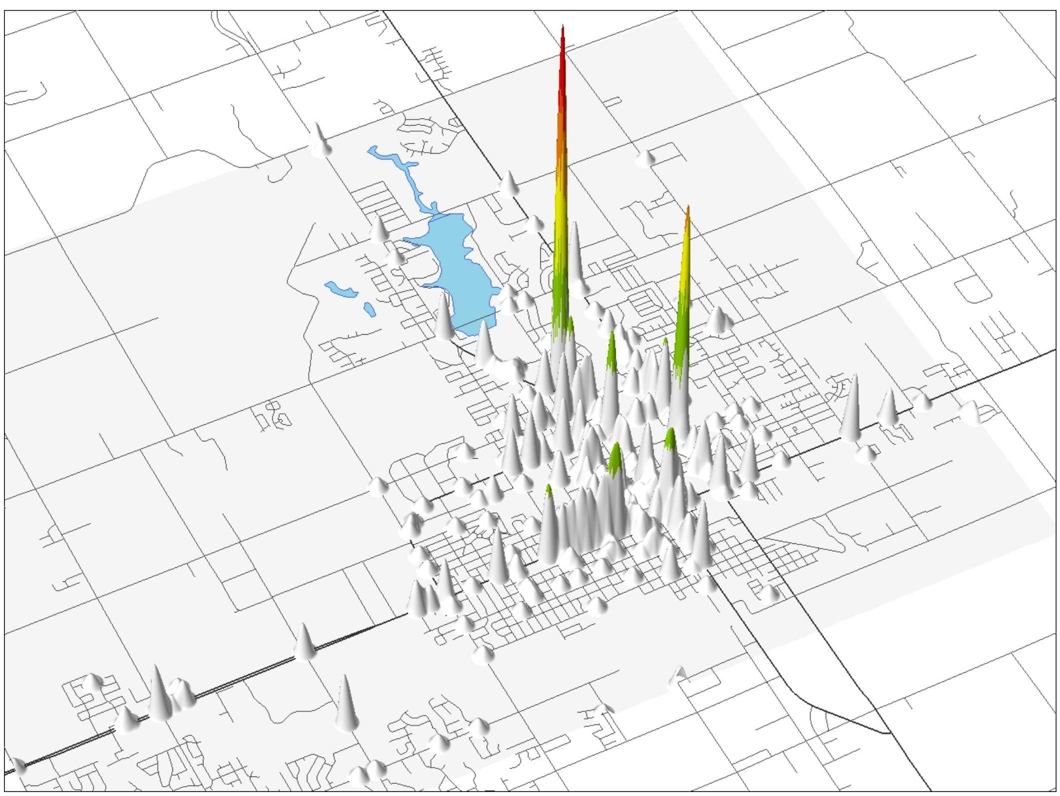


Appendix 18a.

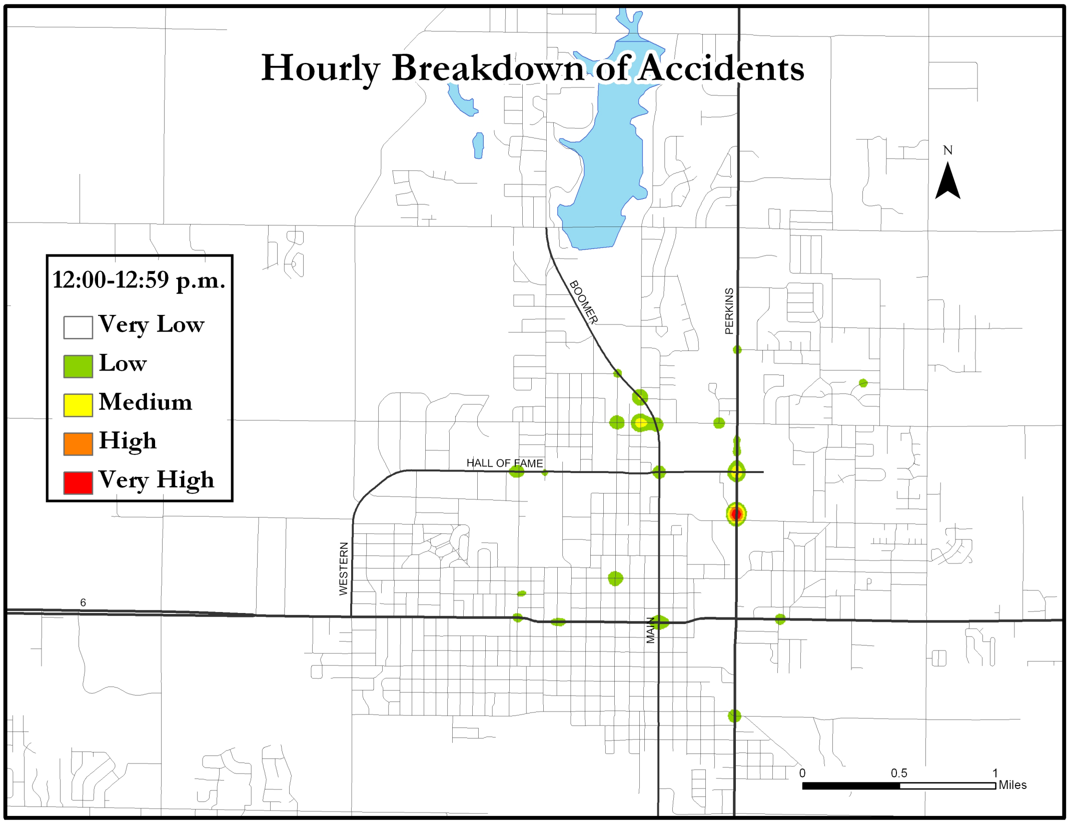
Appendix 18b. Looking northeast, 3-D densities from 10:00-10:59 a.m.



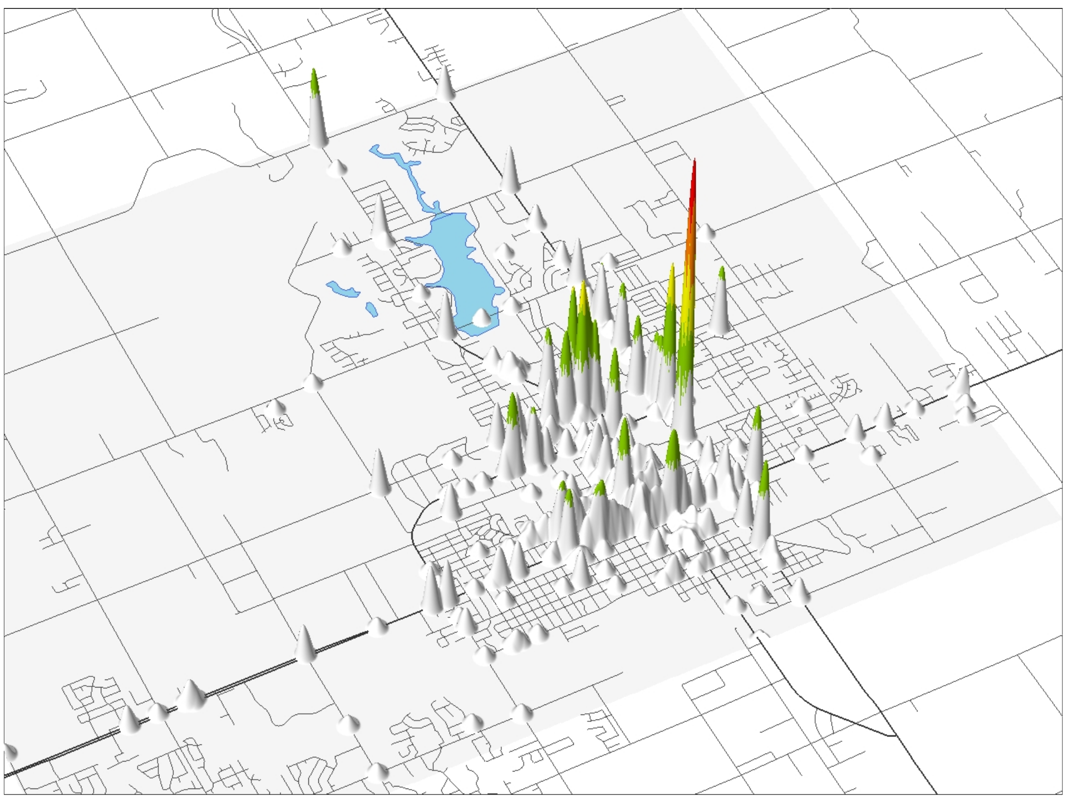
Appendix 19a.



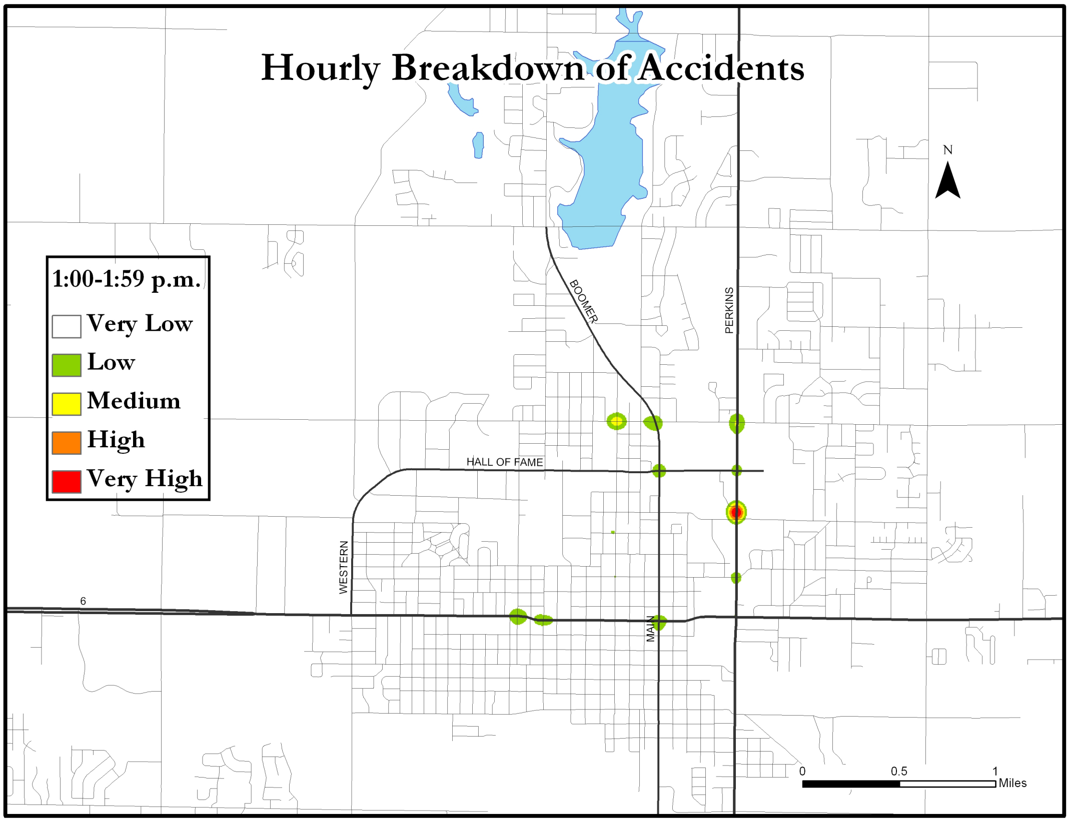
Appendix 19b. Looking northeast, 3-D densities from 11:00-11:59 a.m.



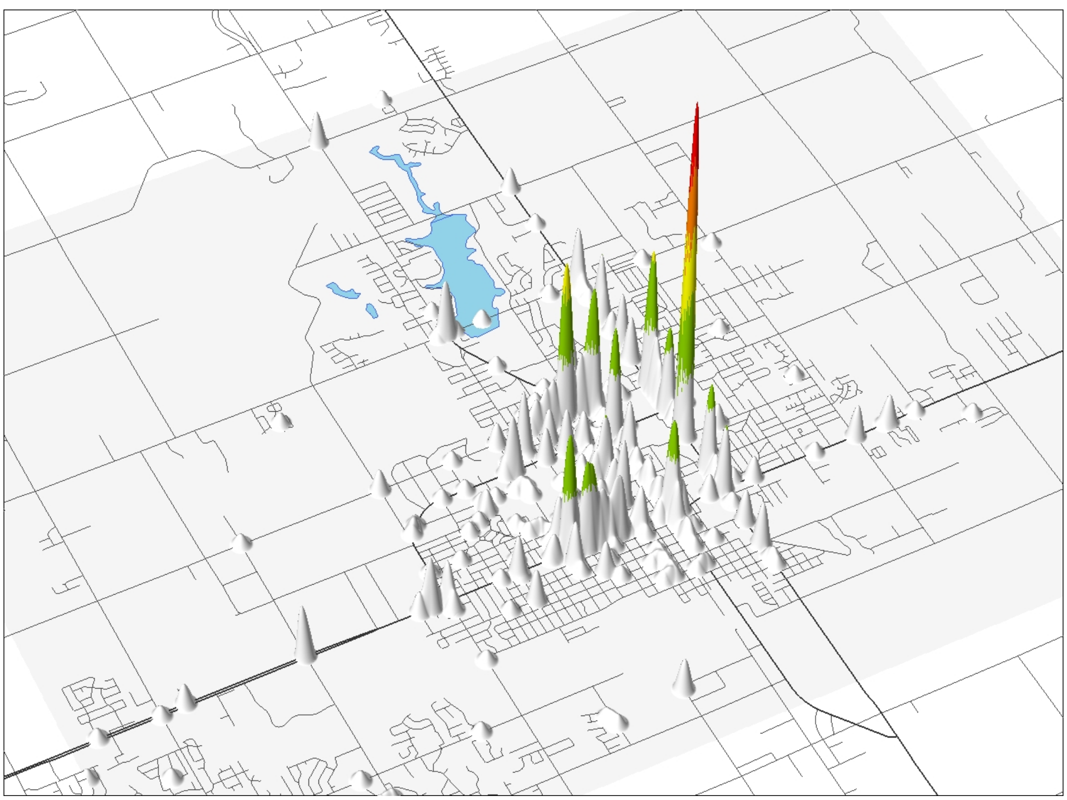
Appendix 20a.



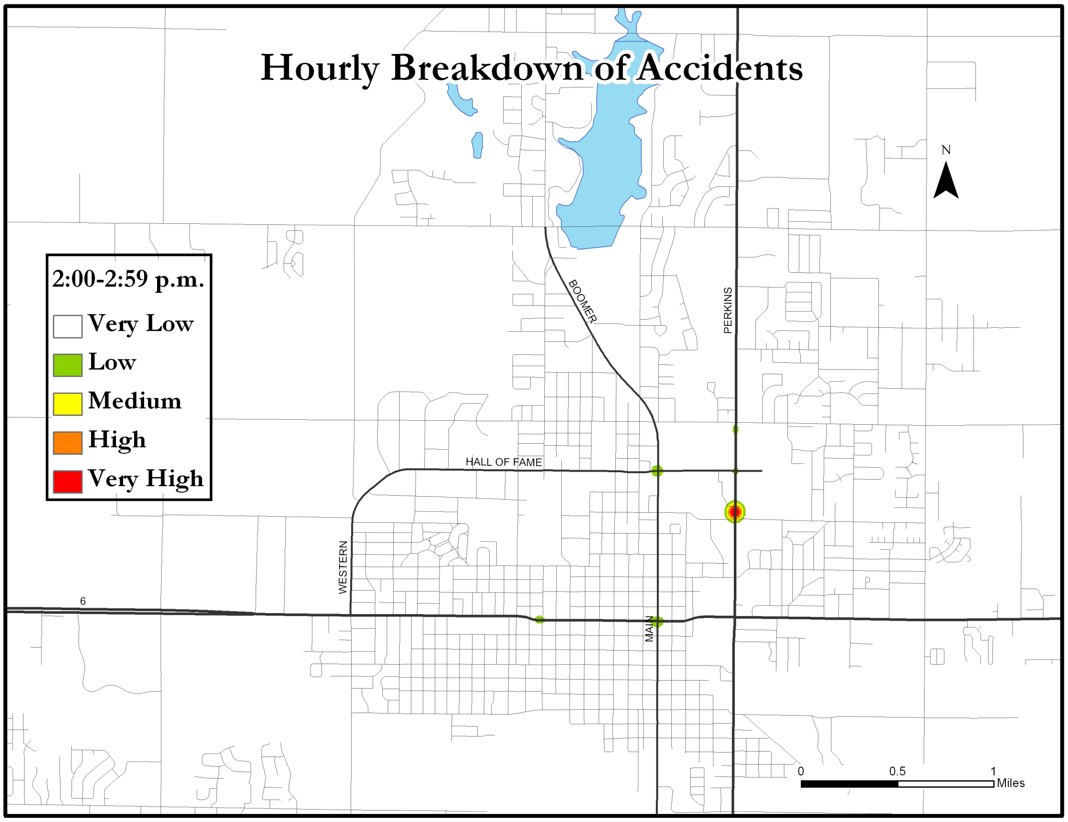
Appendix 20b. Looking northeast, 3-D densities from 12:00-12:59 p.m.



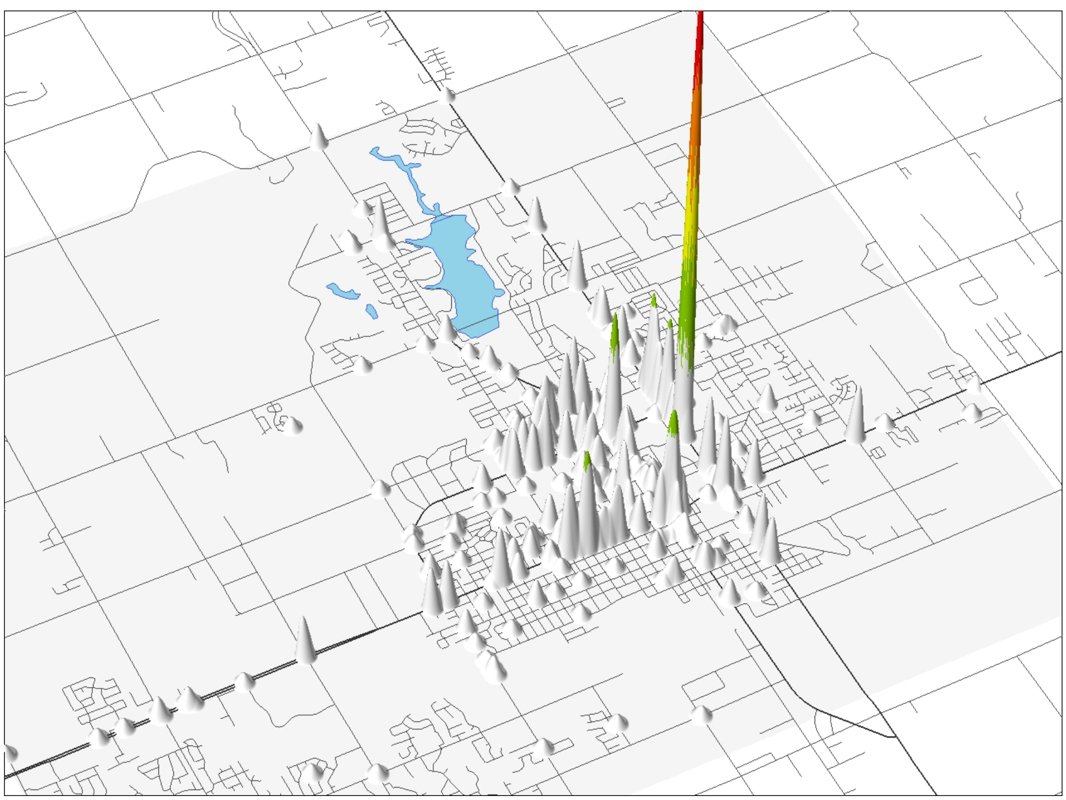
Appendix 21a.



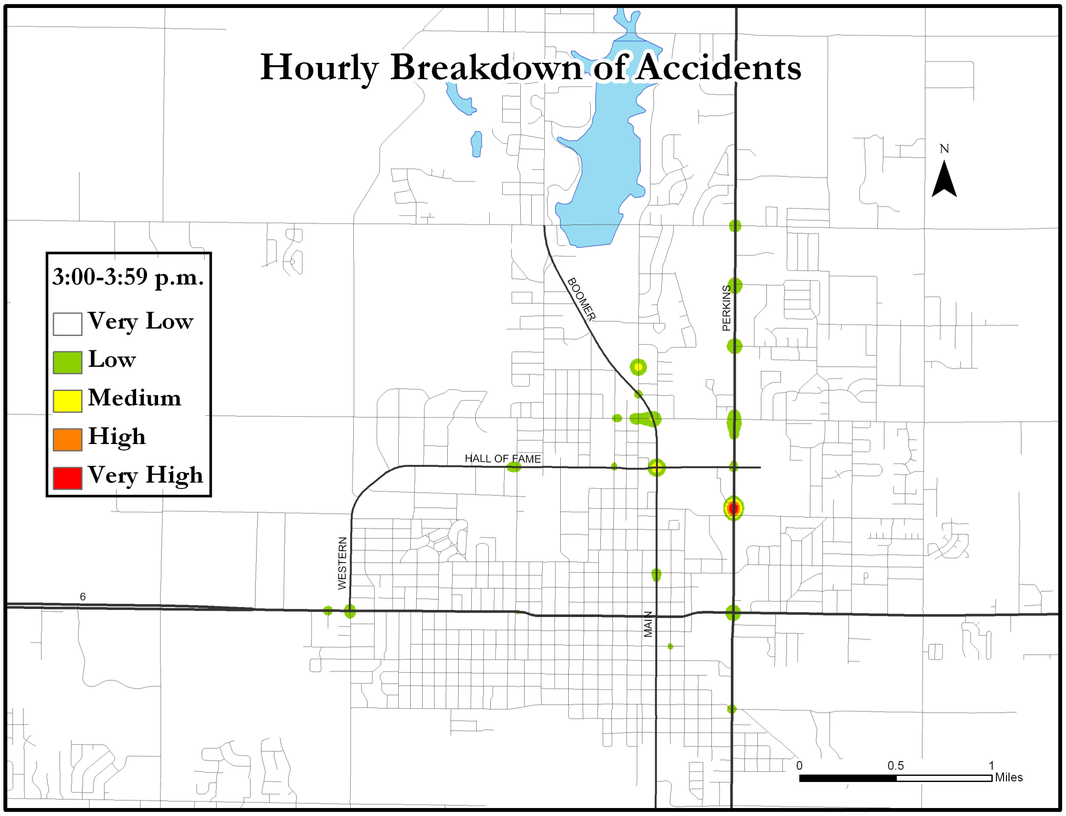
Appendix 21b. Looking northeast, 3-D densities from 1:00-1:59 p.m.



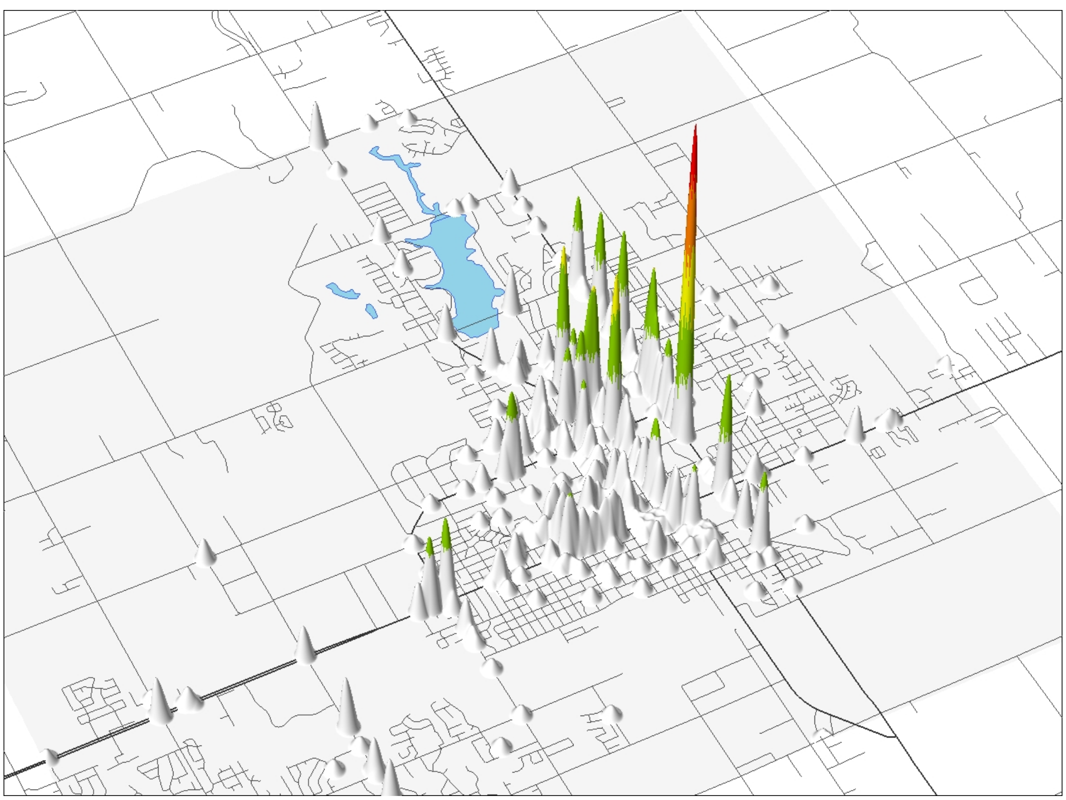
Appendix 22a.



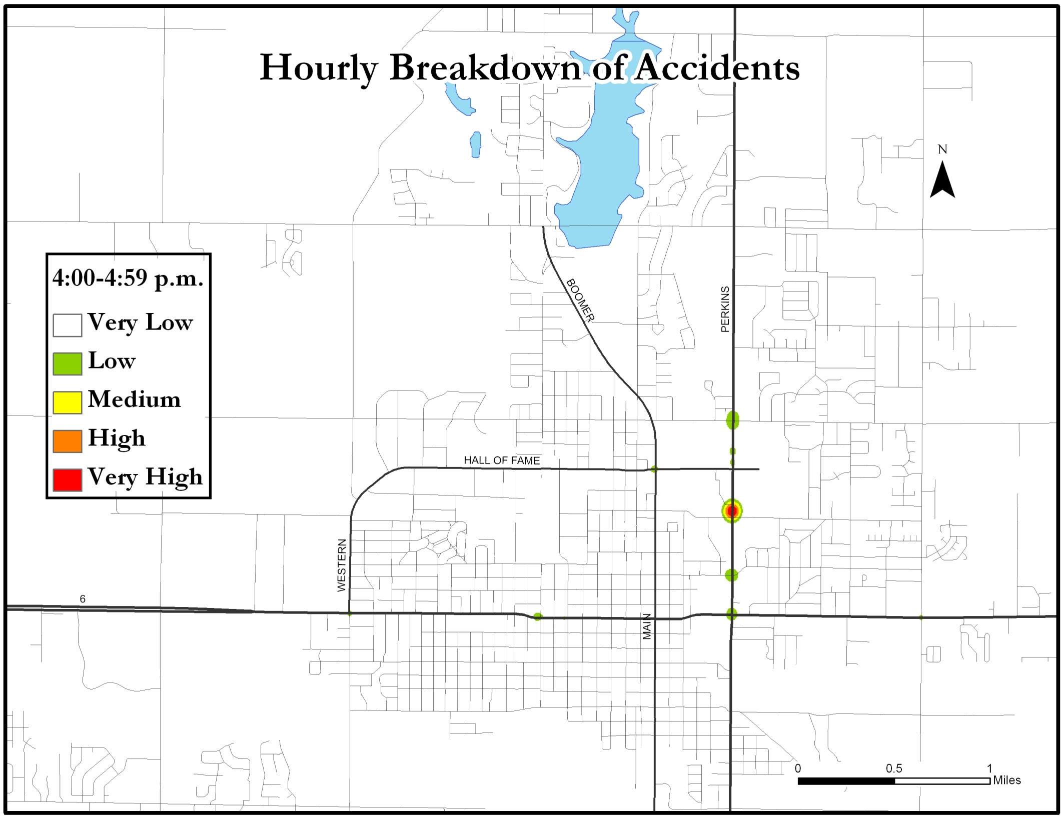
Appendix 22b. Looking northeast, 3-D densities from 2:00-2:59 p.m



Appendix 23a.



Appendix 23b. Looking northeast, 3-D densities from 3:00-3:59 p.m.



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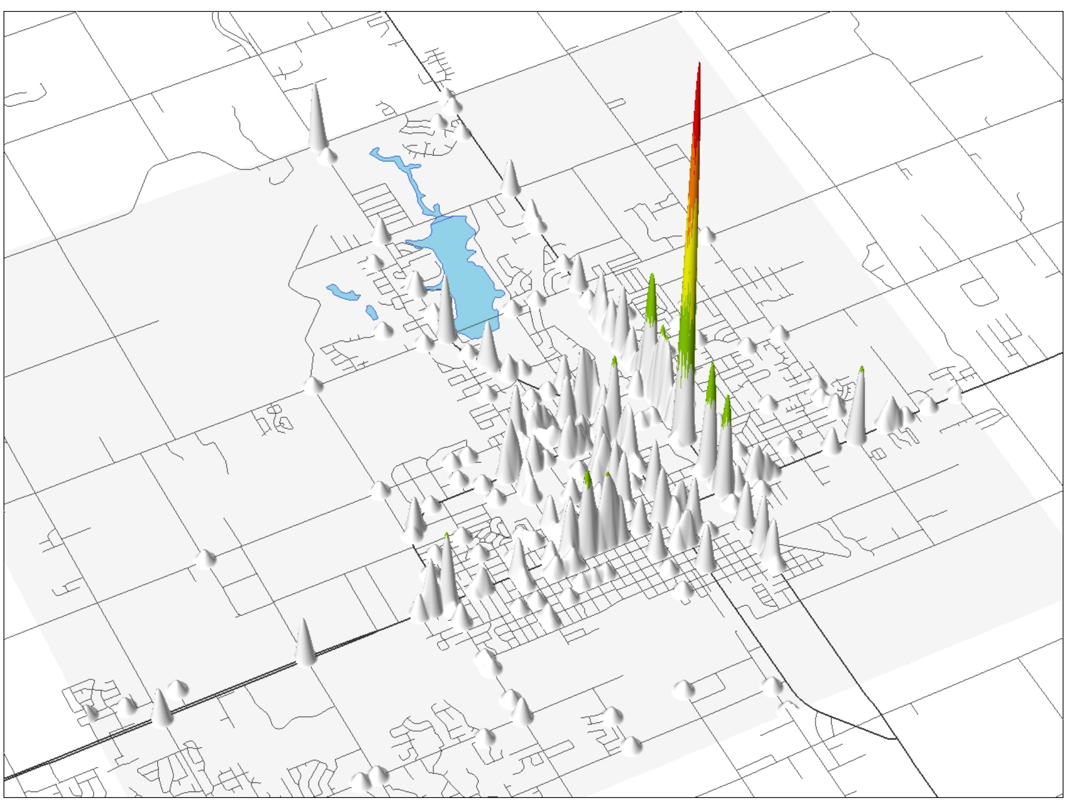
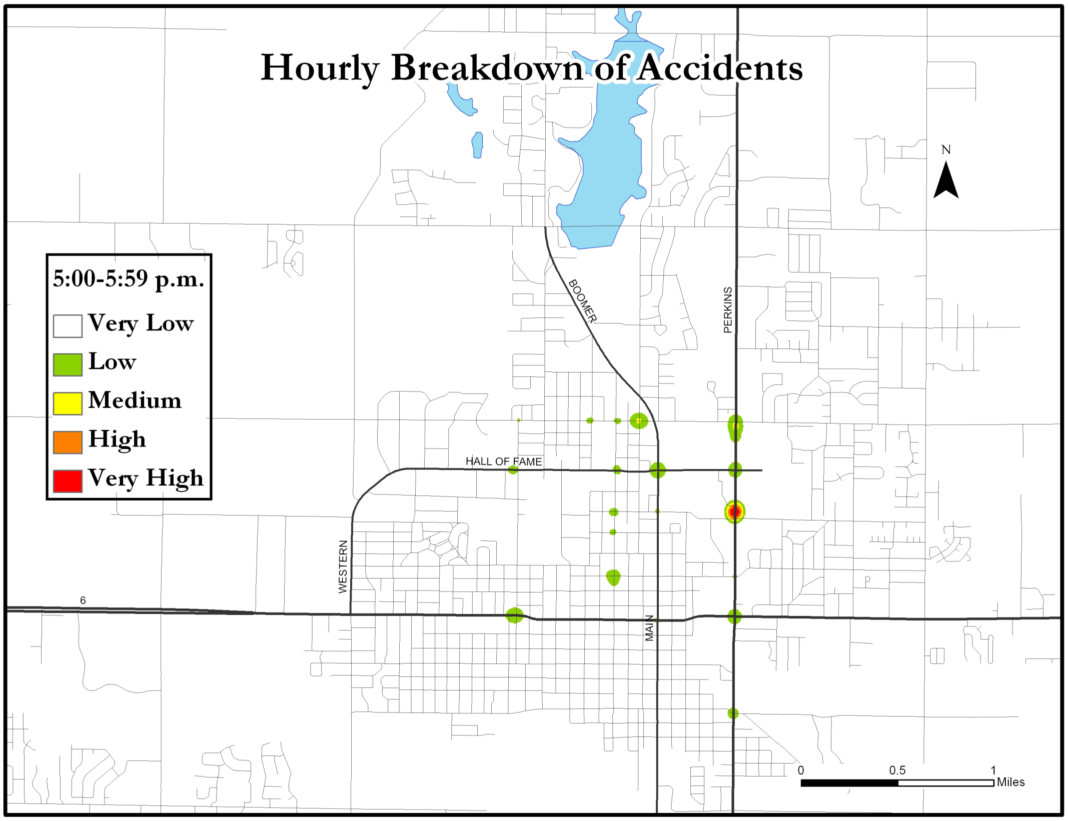


Appendix 24b. Looking northeast, 3-D densities from 4:00-4:59 p.m



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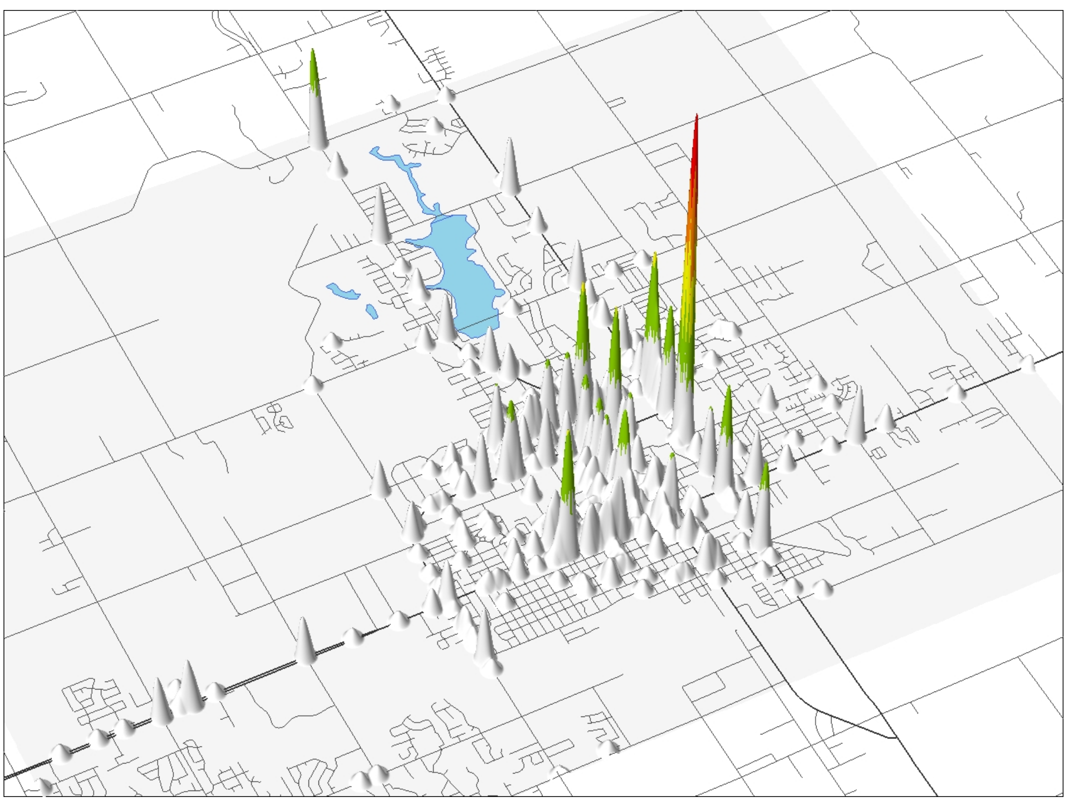
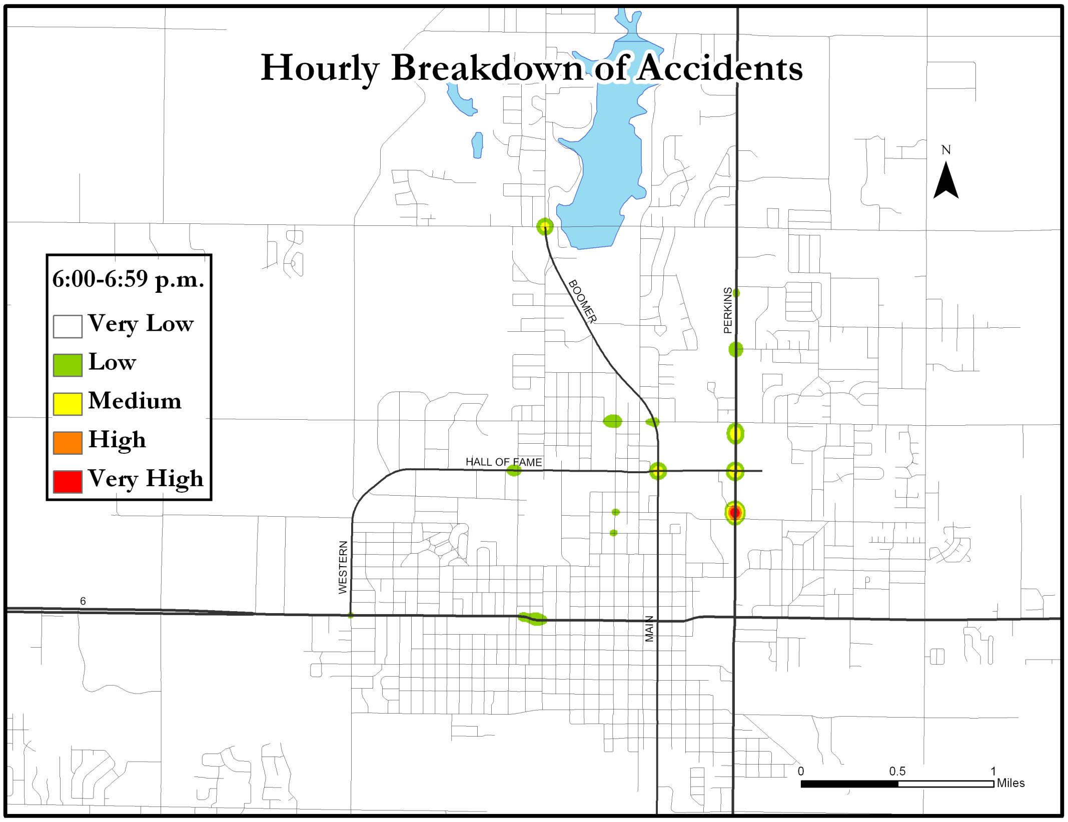


Appendix 25b. Looking northeast, 3-D densities from 5:00-5:59 p.m.



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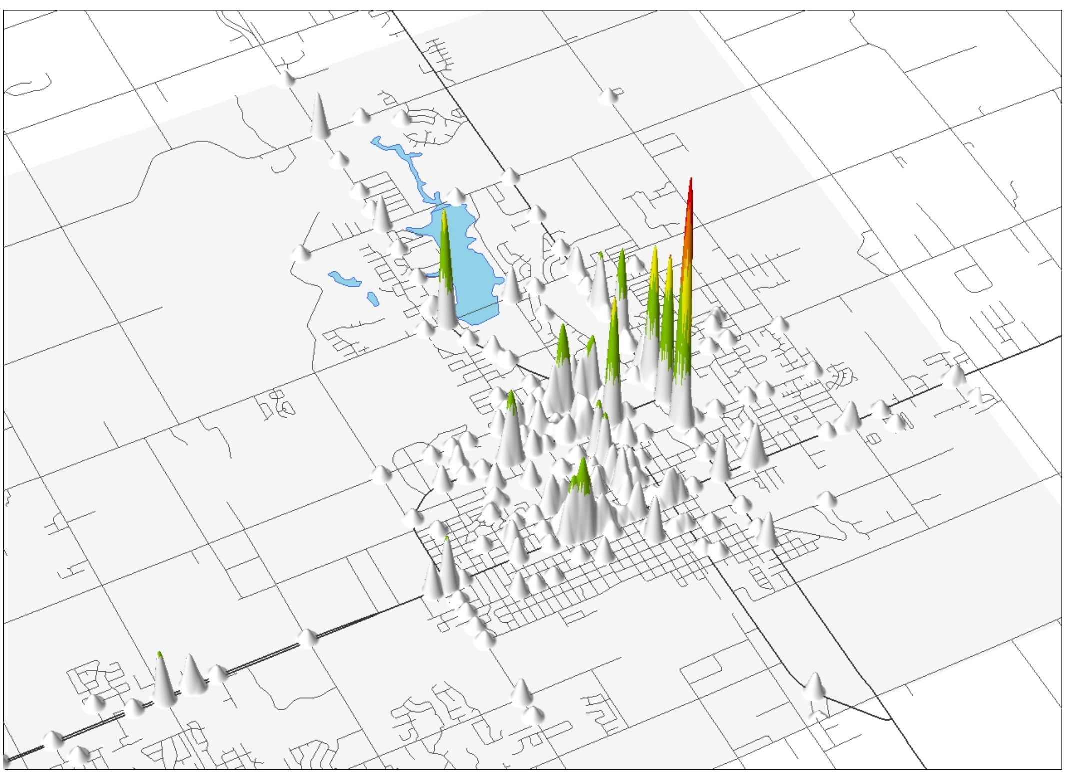
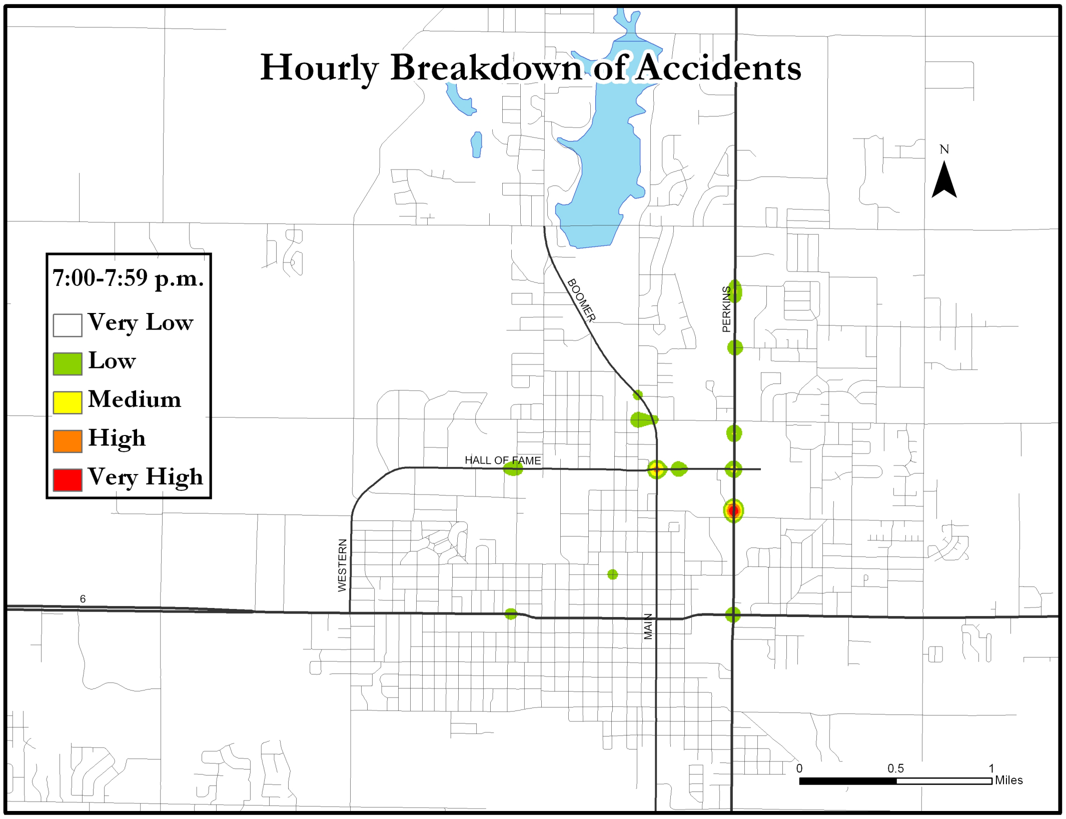
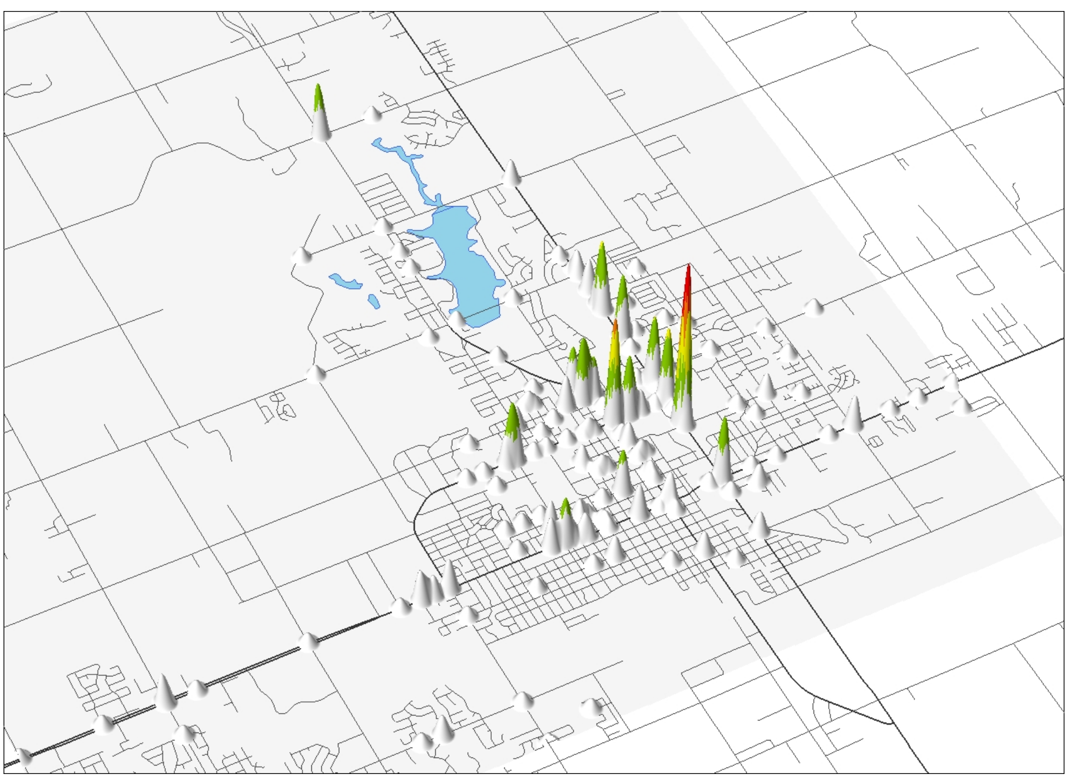


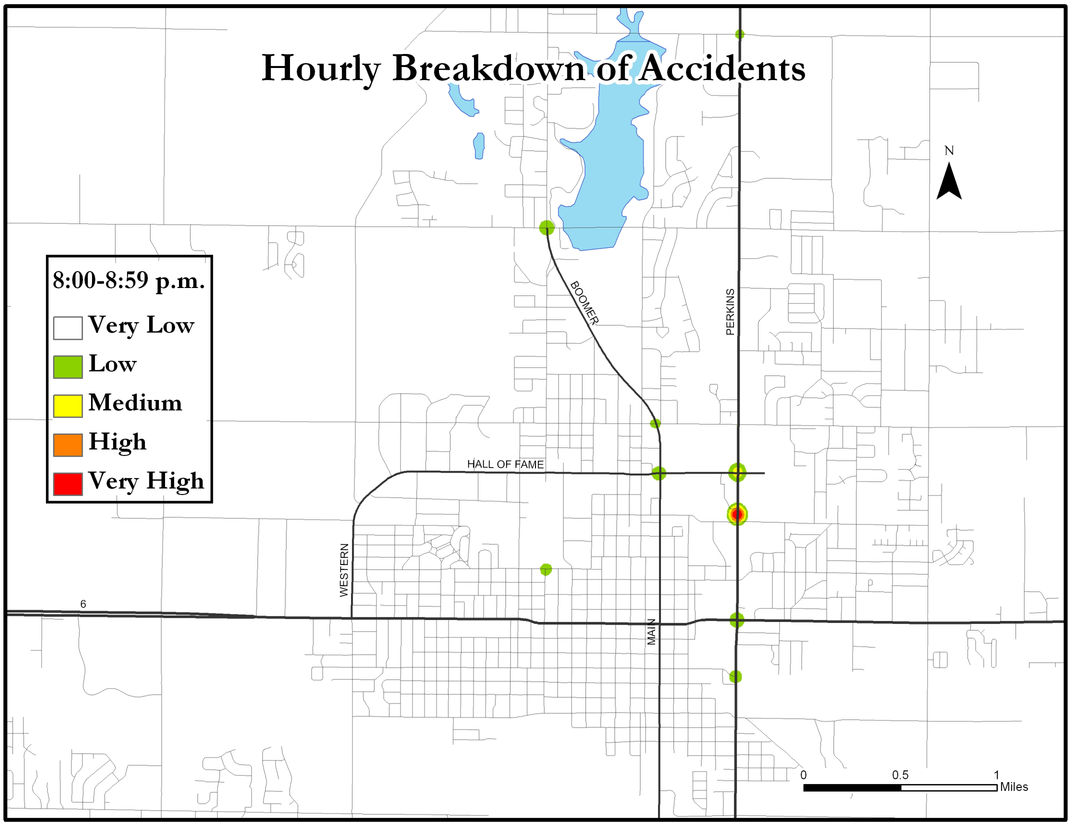
Appendix 26b. Looking northeast, 3-D densities from 6:00-6:59 p.m.



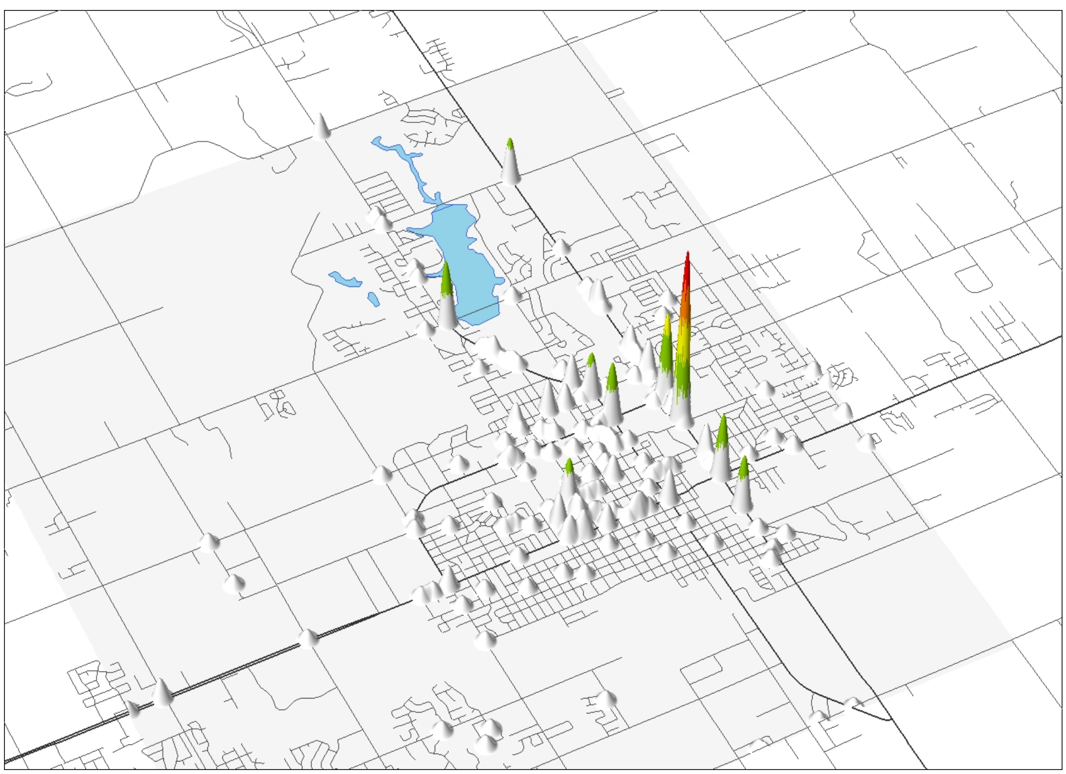
Appendix 27a.



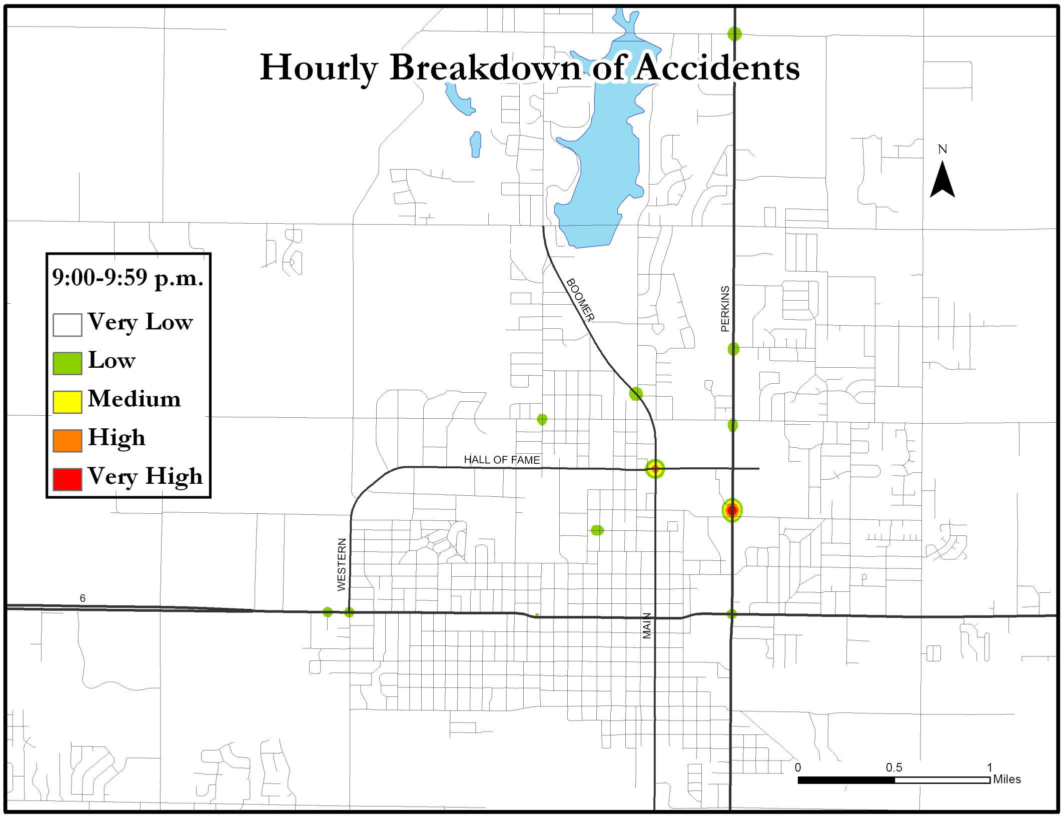
Appendix 27b. Looking northeast, 3-D densities from 7:00-7:59 p.m.



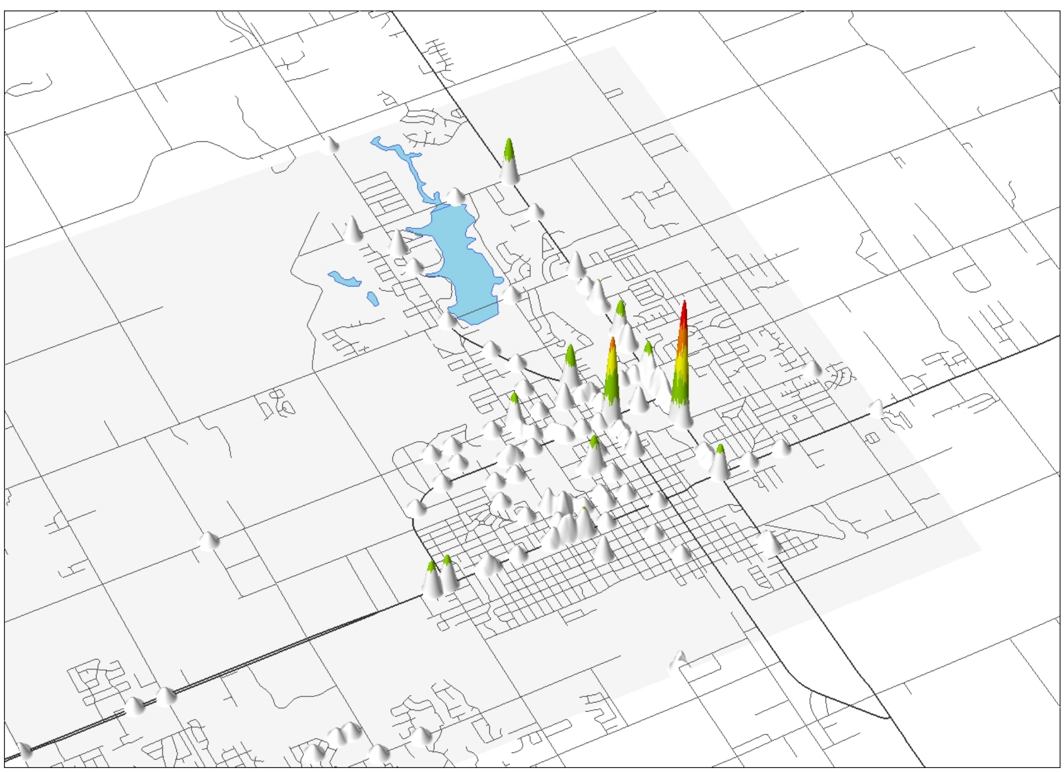
Appendix 28a.



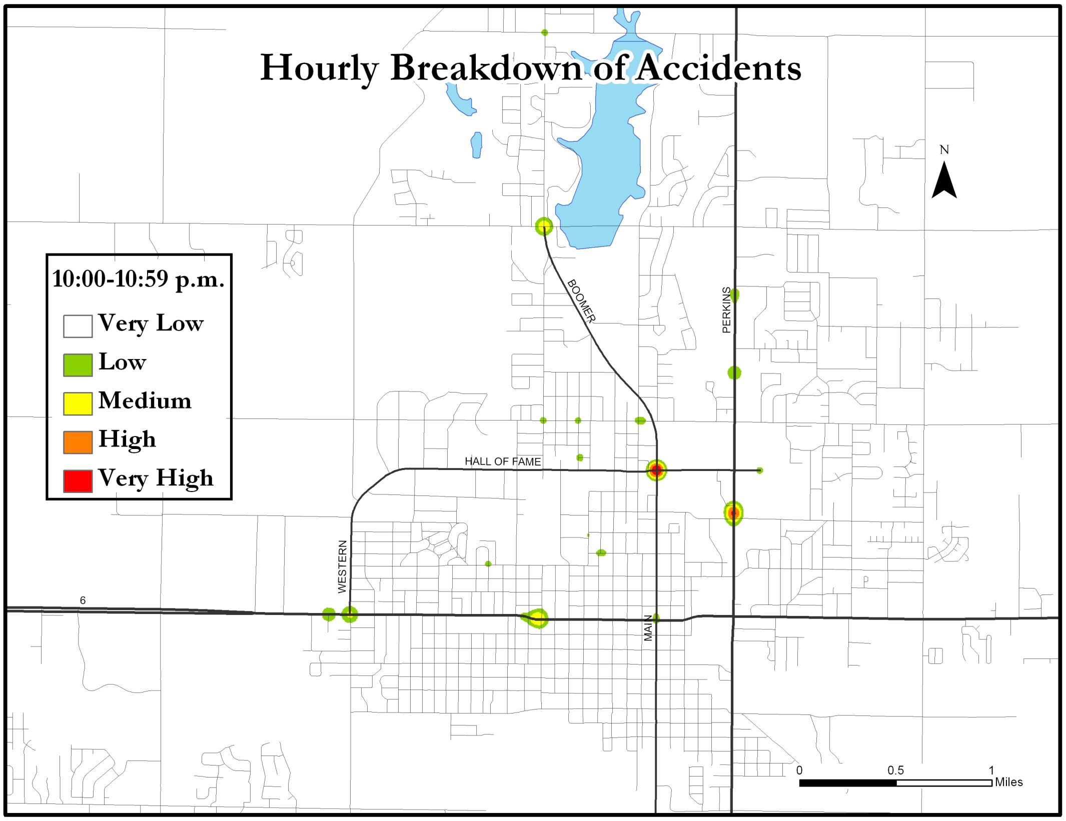
Appendix 28b. Looking northeast, 3-D densities from 8:00-8:59 p.m.



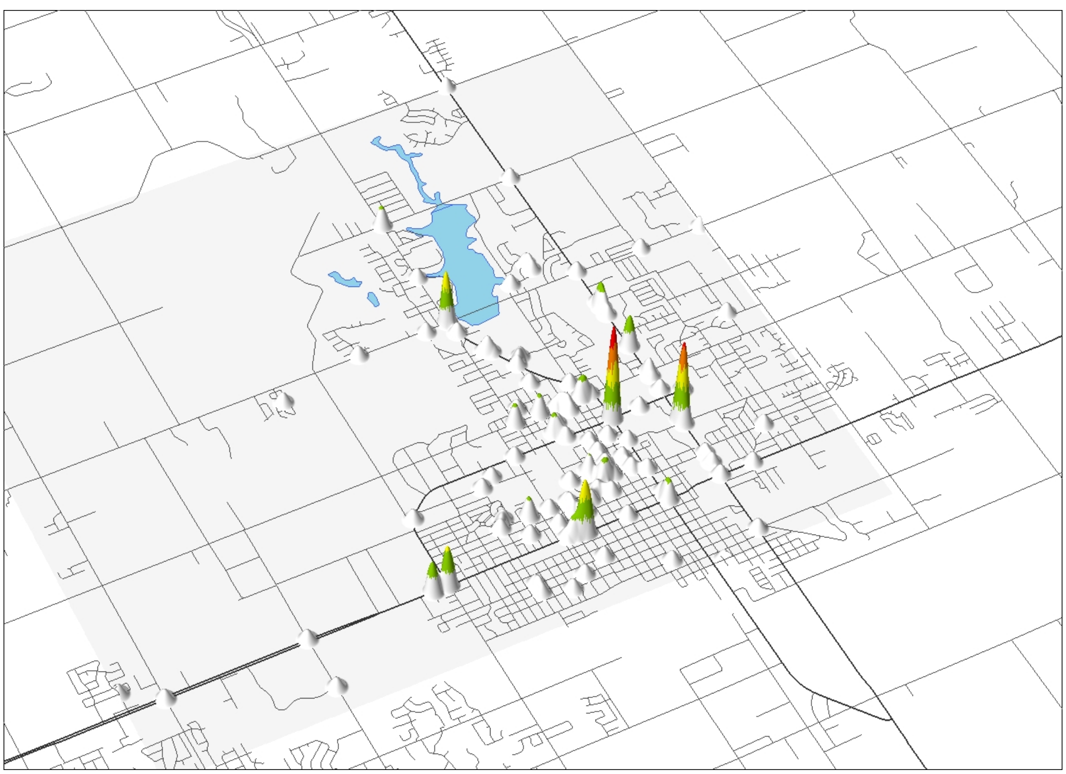
Appendix 29a.



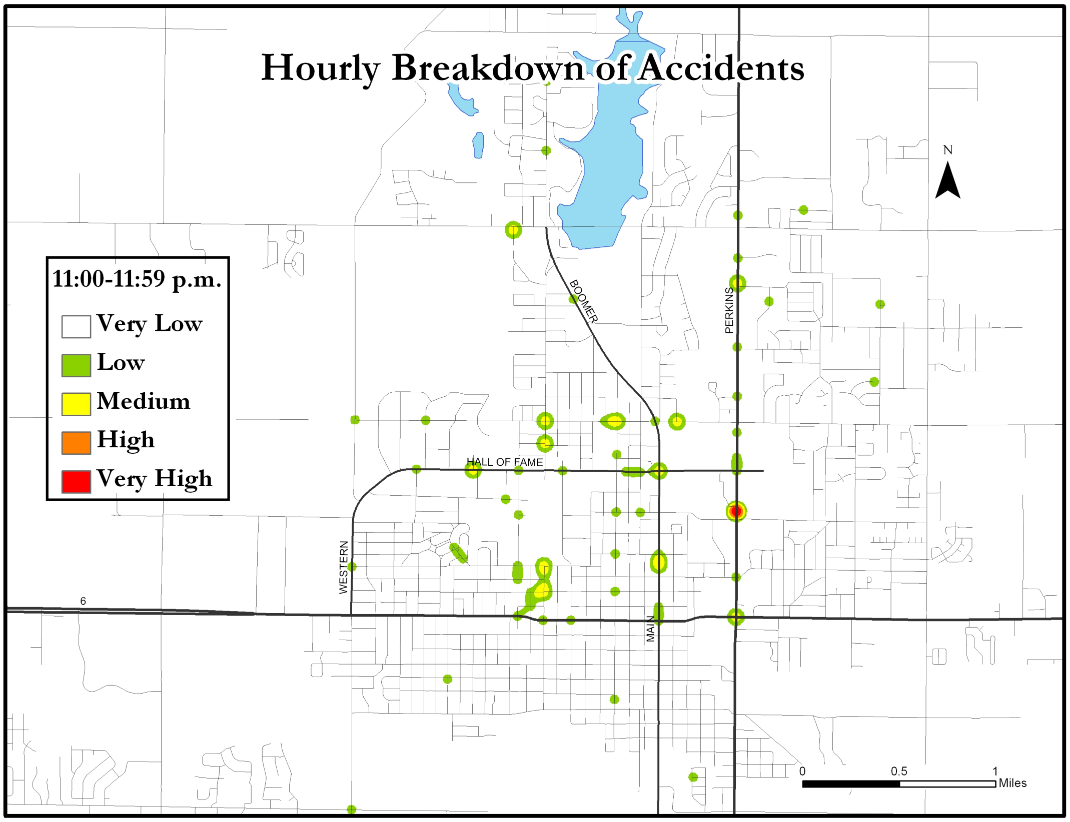
Appendix 29b. Looking northeast, 3-D densities from 9:00-9:59 p.m.



Appendix 30a.



Appendix 30b. Looking northeast, 3-D densities from 10:00-10:59 p.m.



Appendix 31a.

Appendix 31b. Looking northeast, 3-D densities from 11:00-11:59 p.m.

VITA

Alston Paul Hicks

Candidate for the Degree of

Master of Science

Thesis: DISCOVERING SPATIAL AND TEMPORAL PATTERNS OF TRAFFIC ACCIDENTS IN STILLWATER, OKLAHOMA

Major Field: Geography

Biographical:

Education: Received Bachelor of Science degree in Geography from Oklahoma State University, Stillwater, Oklahoma in December, 2007; Completed the requirements for the Master of Science in Geography at Oklahoma State University, Stillwater, Oklahoma in December, 2009.

Experience: Employed by Oklahoma State University, Department of Geography as a Physical Geography teaching assistant, 2008-2009.

Professional Memberships: Association of American Geographers

Name: Alston Paul Hicks Date of Degree: December, 2009

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: DISCOVERING SPATIAL AND TEMPORAL PATTERNS OF TRAFFIC ACCIDENTS IN STILLWATER, OKLAHOMA

Pages in Study: 99 Candidate for the Degree of Master of Science

Major Field: Geography

Scope and Method of Study: The purpose of this study was to establish a greater understanding towards spatial and temporal patterns of traffic accidents in Stillwater, Oklahoma through the use of a GIS. Traffic accidents from 2001 through 2008 were represented through various visualization methods in ArcGIS to support the idea that geovisualization influences an increased understanding of patterns with accidents in the city.

Findings and Conclusions: Traffic accidents are not random. Spatiotemporal patterns of accidents exist within the city of Stillwater, Oklahoma. Accidents are influenced by patterning of daily and seasonal social activities, as well as weather events. Deeper insight of traffic accidents in the city is gained through crash mapping and using different 3-D visual representations of the data in a GIS. Hot spots in the city reveal when and where concentrations of accidents cluster at specific locations. Geovisualization of traffic accidents acts as a compass to help navigate police and transportation planners to road areas needing safety reform, a benefit to the city.

ADVISER’S APPROVAL: Dr. Allen Finchum