Lightning Safety: Suggested Guidelines to Reduce the Risk of Strikes

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Certification Statement

I hereby certify that this paper constitutes my own product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions, or writings of another.

Signed: ____

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Abstract

Several firefighters have been affected by lightning strikes in the United States during the past several years. Oakland Park is located in Florida which is recognized as consistently experiencing the most lightning strikes in the United States. The problem is that Oakland Park has frequent lightning strikes, increasing the risk of a firefighter being struck by lightning. The purpose of this research is to determine which operating guidelines can be instituted to reduce the likelihood of Oakland Park firefighters being struck by lightning. Descriptive analysis was utilized to answer the following research questions: 1. What are the risks of lightning strikes in the Oakland Park area? 2. What activities do firefighters perform that place them in jeopardy in reference to lightning strikes? 3. What safety guidelines are being used by other organizations to reduce lightning strike hazards? 4. What actions should Oakland Park Fire Rescue take to reduce the chance of firefighters being struck by lightning? A comprehensive literature review, interviews, statistical analysis, and a survey instrument were utilized to answer all of the research questions. The results indicate that Oakland Park firefighters operate in an area in the United States which places them at a greater risk for lightning strikes than most other areas in the United States. The nature of the work places firefighters at great risk in terms of experiencing lightning strikes. The recommendations of this paper include instituting operating guidelines which include the lowering of all aerial apparatus, reducing the number of personnel outside, and eliminating roof operations in lightning conditions. It is also recommended that the department purchase and utilize a lightning proximity warning system.

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Introduction

The city of Oakland Park is located in Broward County, Florida, which is near the southern tip of Florida. The city is just north of Miami, Florida, on the east coast of the state. Oakland Park encompasses seven square miles of area within three miles of the Atlantic Ocean. Lightning strikes are common occurrences in the city.

The National Oceanic and Atmospheric Administration (NOAA) has reported that, as of September 1, 2009, 31 people were killed by lightning strikes in the United States and that, in 2008, a total of 28 people died due to lightning strikes. In addition, hundreds of lightning related injuries occur every year (NOAA). The National Fire Protection Association (NFPA) reports that Florida leads the nation in the number of lightning deaths and in lightning flashes per square mile. There were a total of 71 lightning related deaths in Florida between 1997 and 2006; there were 26.3 flashes per square mile on average in Florida between 1996 and 2005 (National Fire, 2008). The most current information, distributed on December 18, 2009, which covers the period of 1996 to 2008, available from Vaisala, who maintains data from the National Lightning Detection Network, indicates that Florida has a lightning flash density of 25.3 strikes per square mile. The number of lightning-caused fatalities in Florida has remained fairly consistent; data for the period 1999 to 2008 indicates that Florida led the nation with 70 fatalities (R. Holle, personal communication, January 5, 2010).

The problem is that Oakland Park, Florida experiences frequent lightning strikes, thus increasing the risk of firefighters being struck. The purpose of this research is to determine what operating guidelines can be instituted to reduce the likelihood of Oakland Park firefighters being struck by lightning.

This research will utilize descriptive methods to answer the following research questions:

1. What are the risks of lightning strikes in the Oakland Park, Florida area?
2. What activities do firefighters perform that place them in jeopardy in reference to suffering lightning strikes?
3. What safety guidelines are being used by other organizations to reduce lightning strike hazards?
4. What actions should Oakland Park Fire Rescue take to reduce the chance of Oakland Park firefighters being exposed to lightning strikes?

Background and Significance

Oakland Park Fire Rescue's mission statement is "To be a high performance team that provides quality, compassionate, and efficient fire suppression, prevention and emergency medical services." The department motto is "Our Family Helping Your Family" (City of Oakland Park).

In support of Oakland Park Fire Rescue's mission statement and motto, the department employs 70 personnel in three divisions: Operations, Administration, and Prevention. Oakland Park Fire Rescue (OPFR), in Broward County Florida, utilizes three fixed fire stations, each of which houses one suppression apparatus and one rescue vehicle. The suppression units include a squirt and a quint, which are both aerial apparatus and a standard pumper. Each of the suppression units and all three of the rescue apparatus vehicles are full Advanced Life Support (ALS) units. OPFR also has a rescue boat and an Emergency Medical Services (EMS) cart, which can be staffed by personnel from the rescue or suppression units or by staff called in for special situations. OPFR also utilizes mutual aid agreements with surrounding cities and Broward County to provide additional resources, specialty teams, and/or apparatus such as for handling hazardous materials and for technical or air rescues, when requested. Figure 1 illustrates the layout of Oakland Park and the locations of the three fire stations as defined by the Geographic Information System (GIS) in Oakland Park. The rings around each station indicate a 1.5 mile radius circle and show the current coverage overlap. This layout of overlapping coverage and placement of stations within 1.5 miles of nearly all parts of the city affords the opportunity to send multiple units to any address in the city within minutes.

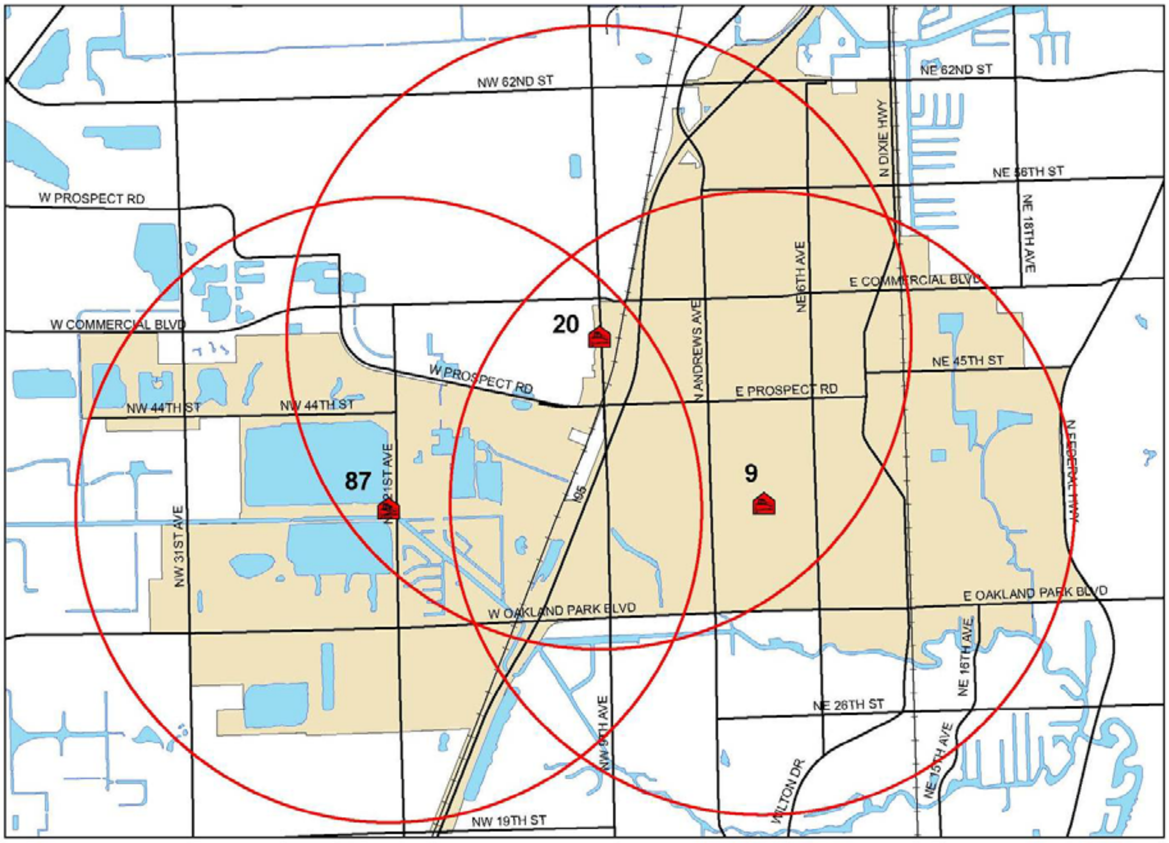

Figure 1 .

The city of Oakland Park covers about nine square miles and has two major railroad lines, the Florida East Coast (FEC) and Chessie Seaboard Expanded (CSX), bisecting the city. Oakland Park is also bisected by a major South Florida Interstate highway, I-95. Approximately 20% of the city is zoned commercial or industrial, with the remainder being residential (City of Oakland Park). The population of Oakland Park, as of the latest census, is 37,950, with a median age of 39.9 and median household income of $44,051 (U.S. Census Bureau). Since the latest census (in 2000), the population has increased to 42,151, a growth rate of 36.87%. Oakland Park has approximately 250 sunny days per year; it has 120 stormy days per year, producing 59.8 inches of rain per year. The average rainfall for the remainder of the United States is 36.6 inches per year (Sperling's Best, 2009).

Oakland Park units responded to more than 4,500 fire-rescue calls in the 2008 fiscal year. Emergency Medical Services (EMS) calls composed nearly 85% of those calls. Oakland Park experiences an average of 3.66 structure fires each month (Villasov, 2009). Overall, the number of structure fires has been declining in both raw numbers and in dollars lost per fire during the past several years. A growing effort in terms of fire code enforcement, plan reviews, and public education has helped Oakland Park to reduce the amount of fire losses.

The Oakland Park Fire Rescue Prevention Division has two fire inspectors, one assistant fire marshal, one fire marshal, and one administrative secretary. All of the staff in the Prevention Division, with the exception of the administrative secretary, are also certified as firefighters and emergency medical technicians or paramedics.

Oakland Park Fire rescue, through its continuing efforts to improve fire prevention, has not suffered a fire-related death in more than seven years and has not had a line of duty death in its history (Villasov, 2009). However, one Oakland Park firefighter has been struck by lightning while performing firefighting operations. The firefighter was a volunteer firefighter for a neighboring community before work for the city of Oakland Park. While touching a fire truck he was hit by lightning, but suffered no permanent injuries. Florida has an average of 25.3 flashes of lightning per square mile and ranks first in the country for the number of strikes per square mile and lightning deaths per year (Ahrens, 2008). There were 424 lightning deaths in the United States between 1999 and 2008; of these, 16%, or 70 deaths, occurred in the State of Florida (Holle, 2009). If the 424 lightning deaths were to be distributed evenly across all fifty states, the result would be 8.48 deaths per state; however, Florida residents and firefighters are clearly more likely to be struck than those who live in other states. With the disproportionately high number of lightning strikes in Florida and the necessity for firefighters in Florida to frequently work in conditions in which lightning strikes are likely to occur, it is more a question of when will one of them be struck by lightning rather than of will one be struck by lightning.

The United States Fire Administration (USFA) has developed a five year strategic plan for fiscal years 2009-2013 with the following goals:

1. To reduce risks at the local level through prevention and mitigation.
2. To improve local planning and preparedness.
3. To improve the fire and emergency services' capability for response to and recovery from all hazards.
4. To improve the fire and emergency services' professional status.
5. To lead the nation's fire and emergency services by establishing and sustaining USFA as a dynamic organization (United States Fire Administration, 2009).

This research is focused on working toward accomplishing USFA goal numbers one and three. Focusing on goal number three first, lightning striking and injuring or killing a firefighter would have lasting and profound effects on Oakland Park Fire Rescue. In order to adequately and safely respond to and recover from all hazards, firefighters must have a reasonable degree of safety and also have the least amount of mental stress. If a firefighter were to be struck by lightning and be injured, that would not only diminish or eliminate that individual's capability for response and recovery, but would likely affect several other firefighters emotionally. Needless to say, the death of a firefighter would be an irreparable loss.

As a side benefit to researching how lightning awareness and protection can benefit firefighters, this study can be used to address goal number one. The safety guidelines developed during this research could have benefits for the residents of Oakland Park as well as reduce the risk of lightning injury through prevention.

In addition, this research relates to the United States Fire Administration’s five year operational objectives, which were established in 2002; they include:

1. Reducing by 25% the loss of life of those in the age group 14 years old and below.
2. Reducing by 25% the loss of life of those in the age group 65 years old and above.
3. Reducing by 25% the loss of life of firefighters.
4. Making sure that 2,500 communities will have comprehensive multi-hazard risk reduction plans led by or including local fire services.
5. Appropriately responding in a timely manner to emergent issues (National Fire, 2002).

This research is directed at accomplishing goal number three of the United States Fire Administration’s operational objectives for 2002. As unlikely as a lightning strike affecting a firefighter may seem to be, every year, several firefighters in the United States are hit. The nature of the work frequently takes place outdoors during adverse weather conditions, increasing the risk of firefighters experiencing lightning strikes. This research will focus on finding ways to reduce injuries and the loss of life caused by lightning strikes on firefighters.

This research resulted directly from the Executive Development course, which is the first course in the Executive Fire Officer Program at the National Fire Academy. The APIE model of change management was discussed in the Executive Development course (FEMA, 2006). The

APIE model of change management refers to analysis, planning, implementation, and evaluation. To effectively address the dangers of lightning strikes affecting Oakland Park firefighters and to initiate steps to prevent this hazard. I will need to follow this change model within my organization.

Literature Review

A comprehensive literature review is provided to summarize and synthesize the arguments and ideas which are currently available related to lightning strikes and the prevention of injury or death as a result of a lightning strike. This literature review will focus on three primary areas: first, an evaluation of the dangers of lightning, the possibility of lightning strikes, the cause of lightning, and risk factors which contribute to individuals being struck by lightning; second, a review of the existing body of knowledge related to lightning safety as it relates to avoidance and early recognition; third, an examination of existing research on lightning strike prevention programs and policies in other agencies.

The National Weather Service indicates that lightning strikes and resulting injuries and fatalities are often misunderstood. It is widely believed that lightning strikes are typically fatal. However, only about 10% of people struck by lightning are killed; the other 90% suffer varying degrees of injury and disability. Many individuals struck by lightning who survive suffer nervous system injuries or neurological disorders. For some victims, these symptoms are mild or even unnoticeable; however, for some, they are debilitating (National Weather Service, 2009). There is a sufficient number of lightning strike survivors in the world to have formed an organization called Lightning Strike and Electric Shock Survivors, International (LSESSI). This organization was founded by Steve Marshburn Sr., who is a lightning strike survivor who lives in Jacksonville, NC (http://lightning-strike.org, November 24, 2009).

In the Paul Douglas book *Restless Skies*, lightning is described as an incredibly powerful phenomenon. The visible stroke of lightning is just one part of a complex set of events which culminates in the visible strike. Lightning is an extremely brief surge of negatively charged particles traveling from a cloud to the ground through a pencil-thin column of air molecules which have been ionized, or literally ripped apart. The first phase of lightning, which is not visible to the naked eye, is known as a stepped leader; this electrical impulse travels in a zigzag motion, taking steps of about 150 feet each (Appendix A, Figure 2). As this stepped leader nears the ground, it is met by streamers (Appendix A, Figure 3), which leap up from the ground and meet the stepped leader (Appendix A, Figure 4). When the stepped leader and the streamer meet, the circuit is complete, and there is a visible flash of lightning (Appendix A, Figure 5). Stepped leaders and streamers (sometimes called upward leaders) are visible light; however, they occur at a speed which cannot be viewed by the human eye. The step leader travels at 136,000 miles per hour, and the main stroke of lightning travels at about 61,000 miles per hour. The flash of lightning that people see is actually composed of multiple strokes (as many as 40) occurring along the same path; these strokes occur so quickly that they appear as only one flash to the human eye (Douglas, 2005). Ronald Holle, who is a meteorologist with Vaisala, indicates that the number of return strokes in a lightning strike is more typically 20. These multiple return strokes create the flickering effect often associated with a lightning strike. The National Lightning Detection network measures and records each of the return strokes in a lightning strike (R. Holle, personal communication, January 5, 2010). Lightning creates a channel of air which is heated to 50,000 degrees Fahrenheit within a millisecond. The explosive heating of the column of air creates a shock wave which moves at about the speed of sound causing what is known as thunder.

The National Weather Service has found that lightning can travel great distances. A general rule is that lightning can strike as a “bolt from the blue” up to ten miles from a storm. There have been several cases in which lightning has struck individuals at distances of up to 12 miles from storms who were on the other side of mountains. Recent research indicates that lightning can travel 60 miles or more horizontally in a cloud. The longest recorded stroke of lightning to date occurred over the Dallas-Ft. Worth area of Texas, and was measured at 118 miles long (National Severe Storms Laboratory, 2009).

The power of lightning is described in the book *Extreme Weather* by Michael Mogil. The true intensity of lightning, aside from the ability to heat air to five times that of the sun’s surface, is the incredible amount of electricity transferred during a lightning strike. A typical stroke of lightning can discharge 30,000 amperes of electricity at up to 1 billion volts, billions of watts, and with electron densities exceeding 1,022/ft. During a lightning strike, several kinds of energy are emitted, including visible light, radio waves, x-rays, and gamma rays (Mogil M, 2007). Seymour Simon, who is associated with the Smithsonian, further states that the energy emitted by a lightning strike in a split second is equivalent to as much power as there is in all of the electrical generating plants in the United States. A lightning stroke only lasts for a millionth of a second so the power over time ratio would yield only enough electricity to power a light bulb for about one month (Simon, 1997/2006).

Mary Ann Cooper, MD stated in an article in e-medicine that lightning has consistently ranked as one of the top three environmentally related causes of death and the second most common storm-related cause of death. Floods and flash floods are the most common cause of storm-related fatalities, and extreme temperatures are typically the most common cause of environmental injuries and fatalities. Some years, lightning kills and injures people more frequently than hurricanes, tornadoes, and earthquakes (Cooper, 2009).

Dr. Cooper explains that a lightning strike, while only pencil thin, can cause damage to objects and individuals who are not in the path of the direct strike. There are, in fact, six ways in which an individual can be killed or injured by lightning (Cooper, 2009). The cause of death and injury which most people associate with lightning strikes is the direct strike. A direct strike is one in which the visible stroke of lightning, which is the surge of electricity which occurs after a stepped leader connects with an upward leader, strikes an individual. This direct strike form of injury or fatality accounts for only about 3 to 5% of lightning-related casualties. A side splash is the second way in which lightning can injure or kill a person. Side splash occurs when lightning strikes an object, intensely energizing it; the object then emits electrical discharges. Side splashes account for about 30% of lightning-related injuries. The third cause of injury associated with lightning is contact voltage. Contact voltage occurs when an individual is touching an object that is struck by lightning. Contact voltage lightning injuries account for about 1-2% of lightning injuries. The fourth cause of lightning injuries is ground current effect. When lightning strikes the Earth, it seeks an electrical ground, and, while people consider the Earth to be the “ground,”, lightning needs an electrical ground. The soil which makes up the “ground” is, ironically, a poor conductor of electricity, so the lightning strikes the ground and then spreads out along the ground seeking a path to go deeper into the Earth. The enormous surge of current moving across the Earth in the area of the direct strike can travel for some distance before becoming grounded. Ground current effect is the leading cause of lightning related injuries, accounting for 40-50% of lightning-related injuries. The fifth cause of lightning injury is from a failed upward leader. A visible lightning stroke is the result of a stepped leader traveling downward from a cloud and connecting with an upward leader coming out of the ground. The upward and downward leaders are both invisible to the naked eye and often occur without making a connection. During most lightning strikes, several upward leaders come up from the ground in an area, trying to make a connection with a single downward leader (Ju & Walden-Newman, 2009). The phenomenon of secondary upward streamers is illustrated in figure 5 (Appendix A). It is, therefore, possible to be hit by an upward leader which never connects with a stepped downward leader. Lightning injuries which are associated with failed upward leaders account for about 20-25% of lightning injuries. The sixth and final cause of lightning injuries is trauma. The two types of trauma associated with lightning are blunt trauma, which occurs when a person is literally thrown by the strike of lightning, and barotrauma from being too close to the explosive force of the lightning.

Dr. Cooper states that injuries associated with lightning are primarily neurological. Most lightning strike victims are not directly struck; instead, the lightning is transmitted to them through another medium such as the ground, a tree, or other object; therefore, fewer than one third of lightning strike victims suffer burn injuries (Cooper, 2009).

Explaining to people that lightning is dangerous and can kill or injure a firefighter if struck is easy; convincing them that firefighters may actually be struck is much more difficult. Most people assume that the odds of a firefighter being struck by lightning must be near zero.

Michael Mogil writes that, on any given day, about 44,000 thunderstorms occur on planet Earth, with about 2,000 in progress at any moment in time. These storms produce lightning discharges at a rate of about 100 per second (Mogil M, 2007). Paul Douglas has reported that lightning flashes more than 3 million times a day on Earth and that it has also been detected on other planets. One in 86,000 strokes of lightning will actually hit a person and one in 345,000 strokes of lightning will be fatal. The average American is twice as likely to die from a lightning strike as from a tornado or hurricane (Douglas, 2005). According to the National Weather Service, it is estimated that, every year, 600 to 1,000 people in the United States are injured or killed by lightning strikes. As of September 22, 2009, a year to date total of 31 people in America had been killed by lightning strikes. It is important to note that all of the victims killed by lightning strikes in the United States in 2008 were outside when struck (National Weather Service, 2009).

The data provided by the National Weather Service likely includes information from more than ten years ago, when 50 to 75 people in the United States were killed by lightning each year. These high fatality rates upwardly skew the projection in terms of future fatalities, according to Ron Holle, a meteorologist with Vaisala. Mr. Holle indicates that fatality rates have been slowly decreasing, to the current range of 30 per year. An injury to fatality ratio of 10:1, meaning ten injuries for every one fatality, would be considered an acceptable estimate, as there is no way to document all lightning-related injuries, as some people are never treated. This would mean that, typically, about 330 people are injured or killed by lightning strikes every year in the United States (R. Holle, personal communication, January 5, 2010).

Marty Ahrens, who is associated with the Fire Analysis and Research Division of the National Fire Protection Association, wrote a paper about lightning fires, in which he indicated that, during the average year, 31,400 fires in the United States are caused by lightning. These lightning-caused fires result in 12 deaths, 57 injuries, and $213 million in property damage on average every year. It is important to note that these deaths and injuries are results of associated lightning-caused fires; storm data excludes lightning-caused fire deaths and injuries as they are considered indirect. Lightning ignites fires at all hours of the day, and nowhere in the world is exempt from the possibility of lightning strikes. Lightning strikes are considered random events associated with storms; however, there do seem to be trends in lightning which are interesting. Lightning-caused fires follow storm seasons in terms of frequency, so the first noticeable trend in terms of lightning strikes is the time of year lightning caused fires and strikes peak. April through September are the peak months for lightning strikes and lightning related fires, accounting for 94% of the annual fires. Another trend in reference to lightning strikes has to do with human nature: people spend more time outdoors on weekends as compared to times during the work week. Most lightning strike fatalities occur on Sundays, with the second most common day being Saturday. Table 1, below, illustrates that lightning strike fires tend to be concentrated in the afternoon and early evening hours of the day. The table shows that 61% of fires started by lightning occur between the hours of 2:00 p.m. and 10:00 p.m. The pattern for lightning strikes which do not cause fires is very similar to those percentages (Ahrens, 2008).

Table 1

Lightning Fires by Time of Day

Time of Day	**Percentage of Fires**
12 a.m. – 1 a.m.	3%
1 a.m. – 2 a.m.	2%
2 a.m. – 3 a.m.	2%
3 a.m. – 4 a.m.	2%
4 a.m. – 5 a.m.	2%
5 a.m. – 6 a.m.	2%
6 a.m. – 7 a.m.	2%
7 a.m. – 8 a.m.	2%
8 a.m. – 9 a.m.	2%
9 a.m. – 10 a.m.	2%
10 a.m. – 11 a.m.	2%

11 a.m. – 12 p.m.	2%
12 p.m. – 1 p.m.	3%
1 p.m. – 2 p.m.	4%
2 p.m. – 3 p.m.	6%
3 p.m. – 4 p.m.	8%
4 p.m. – 5 p.m.	9%
5 p.m. – 6 p.m.	10%
6 p.m. – 7 p.m.	9%
7 p.m. – 8 p.m.	8%
8 p.m. – 9 p.m.	7%
9 p.m. – 10 p.m.	5%
10 p.m. – 11 p.m.	4%
11 p.m. – 12 a.m.	3%

Marty Ahrens further indicates that not all states are equal when it comes to the frequency of lightning strikes. Florida consistently leads the nation in both the number of lightning strikes and total lightning deaths. Between 1997 and 2006, Florida experienced 71 lightning-related deaths. Annually in Florida, there has been an average of 26.3 flashes per square mile and 1,507,000 lightning strikes to the ground. Surprisingly, California had seven lightning-related deaths between 1997 and 2006. California averages only an annual .6 strikes per square mile and 91,000 strikes. California has cool water off shore, which does not supply the fuel needed for thunderstorms, which is why there are so few strikes in that state. Florida leads the number two state, Louisiana, for lightning strikes per square mile by 5.2 flashes per square mile. Colorado is number two in the rankings of lightning-related deaths, with 30 between 1997 and 2006 (Ahrens, 2008). While Florida is considered the lightning capital of the United States, it does not lead the world in lightning strikes. Rwanda, Africa holds the title of lightning capital of the world, with over 50 lightning strikes every square mile on an average year. The north and south poles of the Earth are almost never hit by lightning (Price & Barry, 2001).

Lightning poses a threat to every state in the United States and to nearly every place on planet Earth. Other planets, such as Jupiter and Venus have lightning storms on their surface. Space, may seem to be the only safe haven from lightning. However, recent discoveries of new types of lightning known as elves, sprites, and jets, which reach outward from clouds into space, have eliminated this once thought to be lightning-free zone (Simon, 1997/2006).

The overall odds of being affected by a lightning strike are much greater than most people think. The odds of winning the Florida Lottery are stated as one in 22,957,480 (http://www.flalottery.com, December 3, 2009); the odds of being affected by a lightning strike are much greater. Calculating the bottom line odds of an individual becoming a lightning strike victim involve making several calculations and using actual and estimated data. First, one must use the U.S. Census population of 2008, which is about 300,000,000. Then, one must factor in the number of actual U.S. deaths (58), actual injuries (540), the estimated (due to reporting errors) number of actual deaths (70), and the estimated (due to reporting errors) number of total injuries (540). Using the reported actual deaths and injuries, results in the odds of being struck in any given year as one in 700,000. If the estimated actual numbers of deaths and injuries are utilized instead of the actual numbers, the odds of being struck in any given year increase to one in 400,000. If one were to factor in the average life expectancy, which is estimated at 80 years, the odds of an individual being struck are one in 400,000 in any given year; then the odds of being struck by lightning in a lifetime becomes one in 5,000. Assuming that ten people will somehow be affected for every one person struck by lightning, the odds of being affected by a lightning strike increase to one in 500 (National Weather, 2009).

Table 2

Odds of Becoming a Lightning Victim

ODDS OF BECOMING A LIGHTNING VICTIM				
U.S. 2000 Census population as of 2008				300,000,000
Number of Deaths Actually Reported	58	Number of Injuries Reported	340	400
Estimated number of actual U.S. Deaths	70	Estimated number of actual Injuries	540	600
Odds of being struck by lightning in a given year (reported deaths + injuries)				1/700,000
Odds of being struck by lightning in a given year (estimated total deaths + injuries)				1/400,000
Odds of being struck in one’s lifetime (Est. 80 years)				1/5000
Odds one will be affected by someone being struck (ten people affected for every one struck)				1/500

Firefighters are not exempt from these statistics. A Google search for “firefighter hit by lightning” yields far more results than one might think. One result was from the *Mount Airy News*: on August 21, 2009, two Surry County, North Carolina firefighters were hit by lightning in separate incidents. The firefighters were operating on different scenes, but were affected by lightning strikes associated with the same storm. Both firefighters were struck indirectly by ground current effect; in each case, the actual point of contact of the lightning strike was about 100 feet from each of the firefighter's locations. Both firefighters survived their lightning strikes (Wood, 2009).

Another result, this one reported by *KMBC*.com, occurred on the morning of August 4, 2009, when a firefighter with the South Metropolitan Fire Department in Missouri was struck by lightning while taking an axe from a fire truck. Lightning apparently struck the fire truck at the exact moment the firefighter was reaching for the axe. The lightning splashed from the truck and injured the firefighter's hand. The firefighter was transported to a hospital, and recovered from his injuries. A tire on the truck blew, and it suffered significant damage to its electronics as a result of the strike (KMBC.com, 2009). Ron Holle stated that the firefighter in this case was probably affected by step voltage. Mr. Holle indicated that it is very dangerous when a strike occurs to a vehicle or the ground nearby at the time as when a person is touching both the ground and the vehicle (R. Holle, personal communication, January 5, 2010).

The *McClatchy-Tribune* reported that, on July 22, 2008, eight firefighters were struck by lightning while working at a fire in Caldwell County, North Carolina. The stroke in this case came from a distant storm, as the firefighters all reported that the sky above them was blue and calm. All eight firefighters had been taking a break while awaiting aerial support to help them fight a brush fire. Lightning hit a nearby snag, and traveled through its root system to the area where the firefighters were sitting. Each of the firefighters was thrown about ten feet, was knocked unconscious, and woke up unable to move. All of the firefighters were transported to hospitals, where they spent several days recovering from burn and neurological injuries. All of the firefighters in this case survived the lightning strike, but not all returned to fire fighting (McClatchy, 2008).

According to the *Daily News*, on May 24, 1999 in Palmdale, California, a U.S. Forest Service firefighter was struck by lightning while standing next to a cottonwood tree. The lightning apparently struck the tree and then splashed from it, striking the firefighter on his shoulder. Lightning continued to strike very close to paramedics who were treating the injured firefighter. Initially, the firefighter had a viable heartbeat, but he was pronounced dead at the hospital to which he had been transported (Coit & Bostwick, 1999).

Michael Mogil, the author of *Extreme Weather*, states that, contrary to popular belief, lightning can strike more than once in the same place. The Empire State Building in New York City was built to dissipate lightning strikes; it is struck more than 100 times every year (Mogil M, 2007). It is understandable that lightning will hit tall buildings more frequently than lower structures, but what is not understood is how it can hit a moving target with frequency. The world record holder for lightning strikes to a human is Roy Sullivan. Roy, a park ranger at the Shenandoah National Park, was struck by lightning seven times between 1942 and 1977. Six of the times he was struck by lightning he was at work, and once while fishing. He was nicknamed “Dooms,” “Sparky,” and the “human lightning rod” by his coworkers. Two of his rangers Stetsons, with lightning damage, are currently on display at the Guinness World Exhibit Hall.

The odds of a person being struck more than once are calculated using independent probability, which means that one must multiply the odds of a single strike exponentially. When the odds of being struck seven times in a lifetime are calculated, they come out to one in 2,187,000,000,000,000,000,000,000, but it did happen to Roy Sullivan. Ironically, the seven lightning strikes did not fatally injure Roy; he ended up taking his own life six years after his last lightning strike (Janiskee, 2008).

To completely understand a problem or threat, one must attempt to discover the cause; however, determining the cause of lightning poses a significant problem. Lightning is associated with storms and has even been encountered during sand storms, with no associated rain or moisture. Lightning has also been observed during volcanic eruptions, nuclear explosions, and even forest fires (Johnson, 2009). Meteorologists and scientists have several competing theories as to the cause of lightning, none of which can be definitively proven. With about four million lightning strikes per day on Earth and decades of electric field measurements having been taken inside thunderstorms, the answer should be apparent. As it turns out, all of the research has shown that no electric field large enough to produce a spark has been detected, even when precipitation is taken into consideration (Dwyer, 2008).

One of the more popular theories behind lightning is that warm updrafts simply carry positively charged particles into the tops of clouds, while negatively charged particles collect at the base of clouds or the ground. When the charge differential becomes great enough, there is a spark, or what is referred to as a stroke of lightning (Douglas, 2005).

Another theory holds that lightning occurs in thunderstorms because of collisions between ice particles and water droplets. According to this theory, water droplets are carried on updrafts to altitudes as high as 70,000 feet, which is well above the altitude at which freezing occurs. Water droplets freeze at that high altitude and begin to fall back toward the Earth, colliding with warmer water droplets which are ascending on the updrafts. The warmer water in the droplets which collide with the descending ice keeps the surface of the ice slightly warmer than the surrounding air, which causes the ice to turn into a soft hail known as graupel. Some scientists believe that this graupel is to blame for the electric charge needed for a lightning strike. As the graupel churns within the thunderstorm, it collides with multiple droplets of water or ice.

As these collisions occur, electrons are sheared off the rising particles and carried to the base of the clouds, while the positive ones continue to the top. This continues to develop, and the charge becomes greater and greater until there is an energy release known as lightning (McLendon, 2009).Of the mechanisms of lightning formation, the theory involving graupel, is very widely accepted by lightning researchers even though details on the exact cause are lacking (R. Holle, personal communication, January 5, 2010).

Many other theories are more complex, such as one involving cosmic rays. A Russian physicist, Alex V. Gurevich, theorizes, along with several other scientists, that the movement of high-energy cosmic rays originating from exploding stars light years away produces showers of energetic particles on Earth. These energetic particles form a conductive path that initiates lightning. The cosmic rays by themselves would not produce the needed reaction to cause lightning, so this theory is also based on the idea that storms give boosts to the cosmic rays through what is called runaway breakdown. While this theory sounds farfetched, x-rays and gamma rays are emitted prior to lightning strikes which lends credence to this theory (Dwyer, 2008).

Firefighters perform actions which place them at greater risk in terms of experiencing lightning strikes than other people. Three primary factors determine the statistical probability of a lightning strike hitting an object. The first risk factor for a lightning strike is the height of an object that might be hit. The second risk factor is the isolation of the object. The third risk factor is the narrowness of the object facing the cloud (Douglas, 2005). Other factors which also must be considered are the proximity to water and the presence of metal or pointed objects (Renner, 2002). When evaluating the risks associated with proximity to water and the presence of metal objects, it is important to remember that these are not risk factors for a strike, but rather for the conduction of electricity associated with a lightning strike. Lightning originates 15,000 to 25,000 feet above the ground and does not move toward an object until the last 150 feet. The flash then seeks a tall or isolated object, regardless of the material of which the object is made. Millions of trees are struck by lightning every year, and they are clearly not made of metal or water. The fact that lightning frequently strikes towers is related to the height, the pointiness, and isolation of these objects, and not to the fact that they are made of metal. The reason why metal objects and water should be evaluated in reference to a lightning strike safety assessment is because those objects are able to conduct the electricity from a lightning strike great distances (R. Holle, personal communication, January 5, 2010). The area in which one lives should also be included in a lightning strike risk assessment. Those who work in areas which have a greater amount of lightning strikes are obviously at an increased risk of experiencing lightning strikes than those in less lightning prone areas. Many of the tasks that firefighters perform place them directly in high risk categories for lightning strikes. NOAA lists objects and equipment which should be avoided in thunderstorms, which, ironically, include many tools of firefighters and activities that they perform. This includes staying off rooftops, not touching ladders, not touching large pieces of apparatus (such as fire trucks), and not touching water or water pipes (NOAA, 2009). Workers' Comp Insider lists firefighters as a group which has frequent too-close encounters with lightning (Ryan, 2009).

Not going outside during conditions which may produce lightning is the only sure way to remain safe; however, this is not practical for firefighting operations. Firefighters must frequently conduct operations in adverse weather conditions, mitigating emergencies which may very well have been caused by lightning strikes. Between 2002 and 2005, there were 31,400 lightning caused fires in the United States which fire department response was required. These lightning caused fires resulted in direct property damage of $213 million dollars and compelled firefighters to fight fires in known lightning conditions (Ahrens, 2008). Therefore, firefighters must evaluate what steps can be taken to reduce the risk of their being affected by lightning strikes.

The first step in avoiding lightning strikes involves the ability to predict where and when lightning may strike. Research is currently being conducted on forecasting lightning threats which involve what is called the cloud-resolving model simulation. This prediction method involves measuring the ice-phase hydrometer fields generated by regional cloud resolving numerical simulations. This prediction method is, however, in its fledgling stages and is being used as a starting point for better prediction methods (McCaul, Goodman, LaCasse, & Cecil, 2009).

Analyzing where lightning is currently striking can also be extremely useful in predicting locations of near term future strikes. The nation's central site of data collection related to lightning strikes is the National Lightning Detection Network. The National Lightning Detection network, NLDN, has installed over 100 sensors throughout the United States which instantly transmit data related to electromagnetic signals which are given off by lightning striking the Earth. The signals are sent via satellite to the Network Control Center in Tucson, AZ, which is operated by Vaisala Inc. Within a few seconds of a lightning strike, the information is analyzed and communicated to users all over the United States. The data is broken down to street level detail and is extremely accurate (NASA, 2009). The accuracy of the National Lightning Detection Network has been independently tested and verified by universities with cameras, towers, and rocket triggered lightning (in which a rocket is launched into a thunderstorm with a thin copper wire attached for the purpose of inducing a lightning strike) since the 1970s (R.

Holle, personal communication, January 5, 2010). At this point in time, the data is utilized by fire services for the purpose of fire cause and origin investigations only, and has not been expanded to real time lightning following to make decisions on firefighting practices on a given scene.

For most incidents, there is no computer access to permit watching lightning prediction models so the other lightning detection method currently available is a portable version. Several portable lightning detection units are available, such as the SkyScan EWS-PRO. This unit is the only professional grade lightning detection system which is portable and is reputed to be able to detect strikes over 40 miles away. The claims of SkyScan have not been proven, tested, or evaluated in any way at this time (R. Holle, personal communication, January 5, 2010). The unit features a rechargeable battery which lasts for more than seven days on a single charge. The unit is housed in a rugged, weather resistant case, and provides both audible and visual indications of lightning proximity. This portable unit and others like it provides filtering software which does not allow the unit to alert when the lightning is cloud to cloud. These units are ideal for applications in which the personnel are moved to different locations at different times, such as firefighters responding to calls (http://skyscanusa.com, October 6, 2009).

Perhaps the best protection in the form of early warning in today's fire service can be provided through phones or Blackberries. A group of Values Added Resellers (VARs) utilize Vaisala's National Lightning Data Network data to distribute current lightning information to portable devices all over the country. Current lightning strike data is transmitted to these devices so that users can have real time lightning data in reference to approaching storm systems. The resellers of this service charge varying monthly fees. This form of lightning detection and data distribution provides the most accurate lightning data available to date (R. Holle, personal communication, December 18, 2009).

Predicting a lightning strike and avoiding an impending strike are completely different. Lightning avoidance is not an easy task when conducting outdoor activities, and there are very few ways to limit the possibility of a strike. Buildings, power poles, and some traffic control systems are protected from lightning strikes through the use of lightning rods. Lightning rods are metal rods erected vertically on top of the site to be protected. The rod or rods are electrically connected to an earth ground by heavy wire. The lightning rod theoretically provides a cone of protection over the building or site under the lightning rod. The cone has an apex angle of about 45 degrees, so the height of the lightning rod is critical to the area it will protect (Gibilisco, 2006). Lightning rods are by no means a guarantee of lightning protection, and lightning will strike areas directly under lightning rods. In a recent study, lightning rods of several heights were evaluated for effectiveness over a 300 lightning strike period. It was observed that a lightning rod that was 131 feet tall was struck 237 times at the top, while 15 strikes occurred at lower levels of the rod and 48 strikes occurred on the ground within the cone of protection. As the lightning rod became taller, the performance improved; for example, a 328 foot lightning rod had 289 strikes at the top, seven strikes lower on the rod, and only four strikes on the ground in the area considered to be in the cone of protection (Zhang, Dong, He, Chen, & Zeng, 2009). One reason for lightning not always striking the highest object lies in the fact that, with each strike of lightning, there can be up to 20 return strokes. About half of the return strokes from a lightning strike will terminate at a location at other locations than the original strike (NASA, 2009).

It has been reported that a form of lightning protection for individuals is being developed by the military; however, no information on this protection is available as of yet. It has also been proven that footwear, clothing, and wetness has little to do with lightning protection; lightning travels miles through the air, so the insulation provided by a shoe or boot will be no challenge for a stroke of lightning to gap (Cooper, 2009). All of the research agrees that the only way to ensure safety or to really limit the possibility of a lightning strike is to remain indoors during lightning conditions. Since firefighters cannot stay indoors, the only other reasonably safe place to be is inside the enclosed cab of a fire truck (Holle, 2009). Dr. Martin A. Uman, a professor at the University of Florida Lightning Research Group, is one of the foremost lightning researchers in the country. Dr. Uman conducts lightning research at the 100 acre University of Florida Camp Blanding site outside of Gainesville. At camp Blanding, an average of five to six natural lightning strikes are studied every year. Because five or six lightning strikes are not enough to conduct in-depth research, the facility utilizes rockets with thin wires attached to induce 30 to 50 lightning strikes every year (http://www.lightning.ece.ufl.edu/, December 14, 2009).

Dr. Uman stated that there is no lightning rod and no actions that firefighters can take which will ensure their safety from lightning; he explained that the best place to be during a lightning storm is inside of a truck or a dwelling. He also stated that a raised ladder truck, while acting as a lightning rod, would not be effective in terms of reducing a lightning strike threat to firefighters. He stated that, while his lightning research is conducted inside a specially made trailer with pneumatic and fiber optic input coming from sensors outside, he still experiences errant strikes which go to unintended locations (Dr. M. Uman, phone interview, September 22, 2009).

Since lightning poses a risk to health and safety, many organizations have taken steps to reduce the risk of lightning strikes to personnel. The National Collegiate Athletic Association (NCAA), the Professional Golfers Association (PGA), the National Athletic Trainers

Association, many schools, and many other entities have developed comprehensive guidelines and policies to prevent lightning related deaths and injuries (NOAA).

A study by Ronald Holle reiterates the distinct advantages of being inside a fully-enclosed metal-topped vehicle during a lightning strike. The key element of this study as it relates to firefighters involves an evaluation of 76 events which occurred between 1980 and 2007 involving people inside fully enclosed, metal topped vehicles which were struck by lightning. During the 76 events, there were four fatalities and 77 injuries. While this sounds like a high incidence of injury and fatality, one must break down the incidents further to determine the true level of safety in terms of being inside this type of vehicle. In more than half of the events (40), the occupants of the vehicles struck by lightning reported no injuries at all. The injuries were typically minor.

It is also questionable whether the four fatalities can truly be attributed to lightning while the victims were inside enclosed, metal roofed vehicles. Two fatalities were reported when lightning struck a vehicle with occupants; the fatalities, however, were persons who were leaning on the outside of the vehicle. In another case the lightning strike caused the driver to crash, which caused the fatality. Another case, involved a bus without wheels which was being used as an office; the lightning’s mode of strike is questionable in this case.

The study also evaluated incidents which involved people standing in proximity to vehicles which were struck by lightning. This study was useful in terms of evaluating what would be likely to occur if a pump operator or firefighter were to approach the truck to remove equipment.

Of the 47 events which were associated with people near a vehicle in some fashion, 14 fatalities and 77 injuries were reported. This clearly indicates that standing in proximity to a vehicle is dangerous and frequently leads to injuries or fatalities when the vehicle is struck by lightning. This problem would certainly be far worse if the vehicle was a ladder truck with the ladder extended, acting as a lightning rod. This study concludes that one of the best protections which can be afforded firefighters is to be inside the protection of the enclosed, metal roofed cab of a fire truck (Holle, 2008)

A review of National Fire Protection Association (NFPA) standards indicates that several chapters involve lightning and protection from strikes. NFPA 780 is the standard for the installation of lightning protection systems; however, this standard discusses only the protection of structures, and not personnel (National Fire, 2004). NFPA 407 is the standard for aircraft fuel servicing; this standard is the only standard to recommend lightning protection for an individual. NFPA 407 (5.9) states that “fuel servicing operations shall be suspended where lightning flashes are in the immediate vicinity of the airport.” This standard also requires that written procedures be developed to control fueling operations related to lightning at airports (National Fire, 2006).

A few fire departments have developed policies with varying degrees of specificity for lightning protection of their personnel. Orange County Fire /Rescue in Florida has policy 3.2, which states that all non-emergency outside activities shall be discontinued when visible cloud to ground lightning appears to be in the general area (Orange County Fire, 2008). Departments in the Tampa Bay area of Florida have developed more detailed policies for operations during lightning storms, including halting ladder and roof operations, not using metal tools, keep personnel not engaged in operations in cabs of trucks, and pump operators staying in cabs (City of Seminole, 2009). Several departments in the Tampa area emphasize the element of removing non-essential personnel from the scene and keeping them inside the protection of enclosed cabs of the fire apparatus during lightning storms.

Procedures

This research study utilizes descriptive statistics to evaluate the risk of lightning strikes to firefighting personnel and what can be done to reduce those risks. All procedures focused on answering four research questions:

1. What are the risks of lightning strikes in the Oakland Park area?
2. What activities do firefighters perform that place them in jeopardy for experiencing lightning strikes?
3. What safety guidelines are being used by other organizations to reduce lightning strike hazards?
4. What actions should Oakland Park take to reduce the chances of lightning strikes affecting Oakland Park firefighters?

After determining that lightning strikes pose a threat to firefighters in Oakland Park, the first procedure involved conducting a literature review. The literature review was utilized to guide the research direction up to and including the formulation of survey questions. The literature review began at the Learning Resource Center (LRC) of the National Fire Academy in Emmetsburg, Maryland in August of 2009 while I attended the Executive Development course. The research conducted at the LRC was supplemented by additional resources such as interviews, Internet searches, and information that was gathered at the Broward County Regional Library.

The research conducted to answer question number one utilized data provided from Vaisala Inc., the central information center for lightning strike data in the United States; it had to do with evaluating the number of cloud to ground lightning strikes per square mile. The lightning strike data utilized was for the years 1996 to 2008. The author manually entered lightning strike density data from the entire nation (data set 1) and the State of Florida (data set 2) into a Microsoft Excel spreadsheet to facilitate data analysis. The data was then analyzed using descriptive statistics to determine the mean, mode, standard deviation, and confidence in each data set. To verify that the statistical difference was not coincidental or random, a t-test was performed. A t-test assesses whether the means of two groups are statistically different from each other and it specifically defines whether the difference is statistically significant. A t-test for means assuming unequal variances was performed with an alpha level of .05. This was tested against a null hypothesis that there is no statistically significant difference in lightning strike frequency between the state of Florida and the United States.

Research conducted to answer the second question consisted of direct observations of firefighters performing normal duties at fire scenes. The actions of the firefighters were evaluated against risk factors which were identified during the literature review to determine what actions increased the possibility of a lightning strike affecting a firefighter. The observations were conducted at a total of 47 incidents between September 1, 2009 and December 2, 2009 in the city of Oakland Park. The firefighters were not informed of the ongoing observations so as to avoid the Hawthorne effect, in which they would improve some aspect of their behavior which was being experimentally measured as a psychological response to being studied.

To answer the third research question, a survey of other fire service agencies was required. The survey which was created was guided in part by the literature review. The survey (Appendix B) consisted of 10 questions in a web-based format. All responses to the survey were collected by the web-based survey software maintained and administered by SurveyMonkey.com. The data collected was able to be analyzed with software on

SurveyMonkey.com or downloaded for further analysis, if necessary. An attempt was made to survey as many fire departments as possible by sending out the survey by mass email to the Florida State Fire College's A-List and all other fire department contacts available to the author. However, a true sample was not identified and, for this study, the sample is a sample of convenience. Response to the survey was open from September 15, 2009 until December 1, 2009, with no periods of inoperability. One hundred two fire departments responded to the survey with their contact information (Appendix C). As of 2008, there were an estimated 30,170 fire departments in the United States (U.S. Fire, 2009). The sample size obtained is well below the .05 alpha level required for a sample size to meet academic or scientific standards, as the population size in this case is the total number of fire departments. If a 5% margin of error in the sample were to be utilized at a 95% confidence level with 30,170 fire departments, a minimum of 380 fire departments would need to be surveyed to create a valid sample. Therefore, the sample size is not of sufficient size to make inferences about the total population of fire departments.

The fourth research question regarding actions which Oakland Park can take to improve firefighter safety was grounded in the literature review and responses to the same survey used to answer question 3. Specific policies from other agencies were gained through requests from agencies that responded to the survey and discussed in the literature review. A feasibility study was compiled to evaluate possible alternatives and their probability for success and implementation.

Assumptions

A significant portion of the data utilized in this research is based on secondary data. It is assumed by the author that all of the data was collected in an honest, accurate, and unbiased fashion. The primary data which is presented, such as interviews and surveys, was submitted with the assumption that all of the respondents answered the questions honestly, accurately, and with no biases.

Limitations

This research is affected by several limitations. The primary limitation is a time constraint. There is a great deal of information which is scattered in locations which, when found, leads to new directions in terms of the research. The author faced a time limitation in reference to gathering this information and finalizing the research project. Limitations affecting data analysis are discussed throughout the literature review in reference to the manner in which the data was collected and presented. Another limitation is that not all respondents to the survey answered all questions, thus limiting the ability to cross reference responses to some questions. The survey is also limited by respondents who misunderstood questions and answered inappropriately.

Definition of Terms

Barotrauma: Physical damage to the body caused by a difference in pressure inside and outside the body ("Barotrauma," 2009).

Bolt: Traditional expression for a discharge of lightning. This term is not acceptable in scientific discussions since it has no definition. ("Thunderbolt," 2009).

Graupel: Refers to moisture which forms when supercooled droplets of moisture condense around a snowflake creating a ball of rime ice ("Graupel," 2009).

Mean: The arithmetic average of a set of values ("Mean," 2009).

Quint: Fire apparatus which serves the purpose of both a ladder truck and a fire suppression engine ("Quint," 2009).

R.I.T.: Rapid Intervention Team. Standby team of firefighters utilized for emergency firefighter rescue, if needed.

Squirt: Fire apparatus with an articulating water tower (Snorkel Fire, 2003).

Volt: Unit of electromotive force. Typical U.S. household voltage is 110 volts ("Volt," 2009).

Watt: Measure of energy conversion. One watt is equivalent to 1 joule of energy per second ("Watt," 2009).

Results

Calculations utilized to answer research question number one yielded the following findings. Results indicate that the overall mean average in the United States for lightning strikes is 8.064 per square mile for the years 1996 to 2008. In Florida, there is an average of 25.3 lightning strikes per square mile in a year. In performing the two sample t-test assuming unequal variances to verify that these statistics were significant, the mean of the national average was measured against the mean of strikes per square mile in Florida. The t-critical value was 2.01 and the reported t-statistic for the two sample t-test is 20.91 at an alpha level of .05 (Table 3). Therefore, the null hypothesis that there is no statistically significant difference in lightning strike density between the state of Florida and the United States must be rejected. This means that there is a statistically significant increased risk of firefighters being affected by lightning strikes in Florida, in which the city of Oakland Park is situated.

Table 3

T-test

t-Test: Two-Sample Assuming Unequal Variances

	Lightning Strikes per Sq. Mile in Florida	*Lightning Strikes per Sq. Mile Nationwide*
Mean	25.3	8.064
Variance	0	33.96439184
Observations	50	50
Hypothesized Mean Difference	0	
df	49	
t Stat	20.91267394	
P(T<=t) one-tail	2.2671726	
t Critical one-tail	1.676550893	
P(T<=t) two-tail	4.5343326	
t Critical two-tail	2.009575199	

The second research question was answered through direct observation of firefighters performing normal activities. Of the 47 incidents between September 1, 2009 and December 2, 2009 in the city of Oakland Park which the author observed, 36 occurred in weather conditions which were conducive to lightning. The behavior of the firefighters observed changed when they conducted operations which occurred at times when lightning was a threat. However, the only change noticed involved attempts to avoid rain rather than the possibility of a lightning strike, and some of these actions actually placed the firefighters in greater danger of strikes while trying to avoid the rain. One piece of essential lightning safety advice which is frequently stated by the lightning safety community is “Pay attention to the lightning, not the rain” (R. Holle, personal communication, January 5, 2010). It was observed that, in attempting to avoid rain, on four occasions, firefighters sought shelter under objects, which placed them at a greater risk for being affected by lightning strikes. On several occasions, personnel were observed engaged in activities such as carrying or raising ladders, carrying pointed objects, and standing on roofs.

The table below shows firefighter activity which increased the risk of experiencing lightning strikes. It is important to remember that current guidance from experts indicates that the category of outside of vehicle with no assignment is the most critical one. While other actions may increase risks in terms of experiencing lightning strikes, the only truly safe place to be is inside the cab of an enclosed truck. In some of these cases, functions such as those of Rapid Intervention Teams (RIT) could have been accomplished by leaving the team inside a vehicle, rather than exposing them to the threat of lightning strikes.

The other categories demonstrate behavior which increases the risk of experiencing strikes, but stopping those activities only improves the safety of firefighters and reduces the threat of lightning strike injury if the firefighters were to move to safe locations inside buildings of significance or in the enclosed cabs of fire trucks. The figures below are numbers of occurrences, and, in some cases, they involved multiple firefighters engaged in the stated activities.

Table 4

Firefighter Observations

Firefighter activity	**Number of times activity was conducted in clear weather**	**Number of times activity was conducted in lightning prone conditions**
Carrying a metal ladder	3	7
Climbing metal ladder fixed (on truck) or portable	1	7
Carrying pointed metal object such as pike pole.	5	12
Standing on roof or elevated position	2	6
Making/maintaining contact with an object which posed a lightning strike hazard	15	22
Standing or walking in area of standing water	0	9

Firefighter activity	**Number of times activity was conducted in clear weather**	**Number of times activity was conducted in lightning prone conditions**
Standing in proximity to an object which posed a lightning strike hazard, including pump operator at pump panel	13	34
Outside of vehicle Having no assignment, which required personnel to be outside vehicles **(THIS IS A CRITICAL OBSERVATION)**	**9**	**15**
Occupying a position which was dangerous due to overhead objects such as flag poles or trees	4	12
Total number of times firefighters were observed performing activities which would place them in danger of a lightning strikes	**52**	**124**

These observations indicate that firefighters routinely perform activities which place them at an elevated risk for experiencing lightning strikes. Activities were noted without regard to whether the activity was necessary or not. While some of these activities could be avoided, it is noted that not all could be without causing extreme fire loss. A determination of an acceptable level of loss vs. risk was not made during these observations.

To determine what other fire departments are doing to reduce lightning strike hazards, a convenience survey of other departments was conducted. Responses from the survey are presented in tabular form for presentation only. The survey as it was posted on-line, viewed, and taken by respondents is presented in Appendix B. The first two questions in the survey were demographic questions which were presented so that trends could be analyzed and used for cross reference purposes.

Table 5

Survey Question 1

Which best describes your type of department?		
Answer Options	**Response Percent**	**Response Count**
Volunteer	3.0%	3
Career	75.2%	76
Combination	21.8%	22
Industrial	0.0%	0
Military	0.0%	0
Other (please specify)	0.0%	0
	answered question	**101**
	skipped question	**1**

Table 6
Survey Question 2

Population served by department		
Answer Options	**Response Percent**	**Response Count**
Under 2,500	2.0%	2
2,501-10,000	6.9%	7
10,001-25,000	10.9%	11
25,001-75,000	31.7%	32
75,001-150,000	25.7%	26
Over 150,000	22.8%	23
	answered question	**101**
	skipped question	**1**

The third question in the survey involved contact information for those who completed the survey and is presented in Appendix C. This information was collected so that the author could contact survey respondents who answered questions in a way which would require follow ups.

The first question directly related to lightning strike activity was question 4, which gathered information about lightning strike victims as it related to each department.

Table 7
Survey Question 4

Have you ever had a lightning strike victim who was:				
Answer Options	**Yes**	**No**	**Cannot recall**	**Response Count**
A resident in your community?	72	15	13	100
A visitor to your community?	44	19	28	91
A member of your organization?	15	62	13	90
Other (please specify)				2
			answered question	**101**
			skipped question	**1**

Statistically, this indicates that 71.3% of departments which responded to this survey had residents of their communities who were victims of lightning strikes; 47.8% of the respondents to this survey also indicated that visitors to their communities had been victims of lightning strikes. The most important statistic realized from this survey is that 16.7% of responding departments reported that one of their own members had been a victim of a lightning strike. An additional 14.4% of the respondents could not recall whether a member of their organization had been the victim of a lightning strike. When cross referenced, of the departments which had a member struck by lightning, 93.3% also had a resident struck and 75% had a visitor struck by lightning in their community. Of the 15 departments which had members struck by lightning, 86.7% were career departments and 13.3% were combination departments. All of the departments reporting lightning strikes to members served populations greater than 25,001. Departments which indicated they had members of their communities struck by lightning included all population ranges.

Question 5 of the survey was designed to determine whether responding departments already had lightning strike-related policies or procedures in place. This survey question allowed respondents to select multiple answers if they had more than one appropriate response.

Table 8
Survey Question 5

Does your department have any of the following with respect to lightning safety? Check all that apply (If possible, please forward a copy to JohnP@oaklandparkfl.org)		
Answer Options	**Response Percent**	**Response Count**
Standard Operating Procedures (SOPs)	14.9%	15
Standard Operating Guidelines (SOGs)	8.9%	9
Any written guidelines for lightning safety	3.0%	3
Training on lightning safety	24.8%	25
None	54.5%	55
Other (please specify)	6.9%	7
	answered question	**101**
	skipped question	**1**

In reference to this question, 54.5% of responding departments indicated that they had no lightning protection policies, procedures, guidelines, or training in place. An important cross question analysis related to this question in the survey reveals that, of the 15 fire departments which responded to this survey indicating that one of their members had been struck by lightning, 33.3% responded "None" to this question. When analyzing departments which reported that a resident had been the victim of a lightning strike, 51.4% responded that they had no policies, guidelines, or training on lightning strike prevention.

Question 6 on the survey was designed to obtain the specifics of the types of policies, procedures, and guidelines that departments reported in question 5. The question offered respondents several choices of policies and procedures which were identified as the most common to reduce the threat of a lightning strike.

Table 9

Survey Question 6

What policies, guidelines, or instructions related to lightning safety exist in your department? (Check all that apply)		
Answer Options	**Response Percent**	**Response Count**
None exist	51.5%	52
Lower ladder trucks	25.7%	26
No/Limited personnel on roof	21.8%	22
No/Limited ladder contact	19.8%	20
No/Limited drafting operations	2.0%	2
Active reduction of personnel on scene outside of vehicles	26.7%	27
Other (please specify)	14.9%	15
	answered question	**101**
	skipped question	**1**

Two statistical findings in relation to this question are extremely relevant. First, 51.5% of the respondents to this survey indicated that they had no policies or procedures in place in reference to lightning safety. Second, and most importantly, only 26.7% of the respondents to this survey indicated that they had policies, procedures, or instructions which would actively reduce the number of personnel on scene outside of their trucks. Of the departments which responded that they had a policies, guidelines, or instructions on active reduction of personnel on the scene during lightning conditions, only 25% reported that they have ever had a member struck by lightning.

Question 7 was designed to determine whether fire departments had and utilized lightning proximity warning systems. The first part of the question asked whether the department owned a lightning warning system, and the second part determined usage practices.

Table 10

Survey Question 7

Does your agency have a lightning proximity warning device?				
Answer Options	**Yes**	**No**	**N/A**	**Response Count**
Does your department have a warning system?	12	87	2	101
Is it used regularly?	11	18	50	78
			answered question	**101**
			skipped question	**1**

Only 11.8% of fire departments which responded to this survey indicated that they owned lightning proximity warning devices of any kind. Only one department which owns a lightning detection device does not use it regularly. All of the departments which indicated that they have

a lightning proximity warning devices serve populations greater than 10,001. Of the departments which responded to the survey indicating they have lightning proximity warning devices, only 8.3% indicated that they had ever had a member of their organization struck by lightning. In reference to this question, 17.1% of the departments which responded indicating they did not have lightning proximity warning devices also indicated that members had been struck by lightning.

Question 8 of the survey measured how important each department considered lightning safety. This question was designed for cross reference and to determine an overall attitude toward lightning safety.

Table 11

Survey Question 8

How important would you consider lightning safety to be to your department?		
Answer Options	**Response Percent**	**Response Count**
Very	49.5%	50
Somewhat	37.6%	38
Not Important	5.0%	5
Not a Consideration	1.0%	1
Had not considered it until I received this survey	6.9%	7
	answered question	**101**
	skipped question	**1**

Of the respondents to this survey, 49.5% indicated that they consider lightning safety to a very important consideration. Fully 87.1% of the respondents indicated that lightning safety was at least somewhat important, whereas 12.9% of the respondents indicated that lightning safety was either not important or not a consideration. Of the departments which indicated that lightning safety was either very important or somewhat important, 37.1% had members who had been struck by lightning. However, of these same departments which indicated that lightning safety is important, 50.6% have no safety guidelines in place to enhance lightning safety. Additionally, only 29.2% of the departments which felt that fire safety was important had policies in place which actively reduced the number of personnel on scene outside the protection of fire trucks.

Question 9 of the survey was open; it asked respondents to explain what they thought could be done to improve lightning safety for firefighters. Seventy-four respondents replied to this question with suggestions.

Table 12

Survey Question 9

What do you think could be done to improve lightning safety for firefighters?	
Answer Options	**Response Count**
answered question	**74**
skipped question	**29**

Number	**Response Date**	**Response Text**
1	**Oct 5, 2009 7:30 PM**	Add proximity devices, policies, and training.
2	**Oct 5, 2009 7:47 PM**	Generate practices and follow SOPs & SOGs
3	**Oct 5, 2009 7:59 PM**	By participating in this survey, it may shed information concerning mistakes or progressive thinking about this life-threatening problem. It is my hope that someone will share their experience, and, as a result, we will all benefit.
4	**Oct 5, 2009 8:08 PM**	Common sense
5	**Oct 5, 2009 8:09 PM**	Awareness

6	**Oct 5, 2009 8:10 PM**	A significant incident
7	**Oct 5, 2009 8:11 PM**	????
8	**Oct 5, 2009 8:13 PM**	Awareness
9	**Oct 5, 2009 8:13 PM**	More education and training; standard guidelines as best practices
10	**Oct 5, 2009 8:13 PM**	Include in the basic safety plan minimum standards and at the department
11	**Oct 5, 2009 8:14 PM**	Develop written safety SOGs and utilize local park system lightning detectors.
12	**Oct 5, 2009 8:16 PM**	More awareness and training. Unfortunately, while in the rescue mode, we perform and try to avoid lightning. However, when it comes to practical training, the training officer should be accountable to discontinue the exercise.
13	**Oct 5, 2009 8:16 PM**	Use as much common sense as possible, along with standard risk-benefit analysis.
14	**Oct 5, 2009 8:16 PM**	Develop economical mobile lightning proximity devices.
15	**Oct 5, 2009 8:17 PM**	Early detection, training, and emphasis
16	**Oct 5, 2009 8:18 PM**	Safety awareness
17	**Oct 5, 2009 8:20 PM**	Good common sense by the OIC for the safety of his/her personnel when lightning is in the area. Education for personnel on dealing with lightning in the area.
18	**Oct 5, 2009 8:22 PM**	Greater awareness and understanding of the hazards, which can be accomplished through a focused training and education effort.
19	**Oct 5, 2009 8:25 PM**	SOPs
20	**Oct 5, 2009 8:29 PM**	Awareness training, and limited outside activities
21	**Oct 5, 2009 8:30 PM**	Develop SOGs to address operations during thunderstorms.
22	**Oct 5, 2009 8:33 PM**	Increased awareness and good judgment by all responders.
23	**Oct 5, 2009 8:36 PM**	Reduce exposure
24	**Oct 5, 2009 8:52 PM**	Awareness and devices
25	**Oct 5, 2009 8:54 PM**	Better officer adherence to limiting personnel outside during close-by strikes
26	**Oct 5, 2009 9:08 PM**	Not sure; I haven't really thought about it.
27	**Oct 5, 2009 9:14 PM**	Minimize exposure when outside during storms.
28	**Oct 5, 2009 9:45 PM**	Additional training in indications on lighting, as well as providing a warning system
29	**Oct 5, 2009 10:42 PM**	Use devices to warn of oncoming lightning to help crews to make decisions when working in possible dangerous situations.
30	**Oct 5, 2009 11:56 PM**	SOP/SOGs or any written guidelines
31	**Oct 6, 2009 12:04 AM**	Template SOPs to adopt or review.
32	**Oct 6, 2009 12:55 AM**	Training for lightning awareness and education, perhaps an SOG.
33	**Oct 6, 2009 11:07 AM**	Establish guidelines or protocols.
34	**Oct 6, 2009 11:27 AM**	Provide yearly lightning training before the start the height of lightning and provide written policies.
35	**Oct 6, 2009 11:54 AM**	Training and education

36	Oct 6, 2009 12:08 PM	Better situation awareness and safety measures taken by the OIC.
37	Oct 6, 2009 12:12 PM	Standard procedures for fire service
38	Oct 6, 2009 12:13 PM	Continual training and reinforcement of the hazards related to lightning strikes. The complexity of emergency response and the exposure to lightning is a difficult situation since many of the emergency requests are due to lightning strikes (structure fires, fire alarms, actual lightning strikes with humans requiring EMS).
39	Oct 6, 2009 12:17 PM	More awareness on the dangers and how to recognize high lightning probability
40	Oct 6, 2009 12:21 PM	Well, now that you have brought it up, I think I will work on some guidelines. I assumed common sense would play a major role with this subject, but your survey has enlightened me for some reason.
41	Oct 6, 2009 12:29 PM	Establishment of SOGs
42	Oct 6, 2009 12:38 PM	General awareness/scene safety training...i.e., risk\benefit
43	Oct 6, 2009 12:46 PM	More awareness, education, and grant program to fund lightning proximity devices
44	Oct 6, 2009 1:16 PM	Train on and review the SOP on a regular basis.
45	Oct 6, 2009 1:54 PM	Awareness is probably the biggest factor. Firefighters still need to function on the fire ground, but should be aware of weather conditions and follow the incident command prompts for safety.
46	Oct 6, 2009 1:59 PM	Lightning proximity warning device. We currently rely on commercial weather/lightning reports.
47	Oct 6, 2009 2:04 PM	I think that limiting exposure to lightning through some of the methods you have listed above may be the most effective.
48	Oct 6, 2009 2:07 PM	Awareness training
49	Oct 6, 2009 2:22 PM	Self-awareness
50	Oct 6, 2009 2:55 PM	Strom tracking; more defined SOGs & SOPs; lightning strike training scheduled on a regular basis, both tactically and medically.
51	Oct 6, 2009 2:58 PM	Warning system hooked to our MDTs
52	Oct 6, 2009 3:17 PM	In addition to informing firefighters, we need to also keep the public aware of the dangers. In the end, they both learn.
53	Oct 6, 2009 3:25 PM	Training on lightning safety
54	Oct 6, 2009 3:46 PM	A General Operating Guideline would be a good start. If I'm not mistaken, there are also some lightning awareness programs out there as well that could be taken into consideration.
55	Oct 6, 2009 3:47 PM	Awareness.
56	Oct 6, 2009 5:56 PM	Develop SOP and train on it.
57	Oct 6, 2009 6:05 PM	Awareness of problem and what safety measures to take in the event of a lightning storm.
58	Oct 6, 2009 6:43 PM	Awareness will be the best improvement.
59	Oct 6, 2009 6:47 PM	The use of proximity warning devices
60	Oct 6, 2009 6:54 PM	Standard procedure with a national model for all

		departments to use
61	Oct 6, 2009 7:08 PM	Education
62	Oct 6, 2009 7:45 PM	Provide classes, training, policies
63	Oct 6, 2009 7:56 PM	Maintaining situation awareness as it relates to the weather
64	Oct 6, 2009 8:38 PM	Training & education
65	Oct 7, 2009 12:02 PM	Awareness of external environment
66	Oct 7, 2009 7:35 PM	Maintain situational awareness
67	Oct 7, 2009 11:41 PM	Insist that company officers exercise as good a judgment as possible and think risk vs. benefit when operating in a storm.
68	Oct 12, 2009 12:31 PM	Having lightning proximity small enough to be installed on command vehicles which does not give a lot of false positives.
69	Oct 12, 2009 7:39 PM	Every fire department should have a lightning safety protocol in place.
70	Oct 12, 2009 8:10 PM	Ensure low profile
71	Oct 14, 2009 4:19 PM	Have better awareness for all personnel
72	Oct 14, 2009 7:47 PM	Provide training and early warning detection.
73	Oct 16, 2009 2:28 PM	I'm not an expert, so I have no idea.
74	Dec 22, 2009 2:09 PM	Lightning detection systems at drill sites and stations. Consider portable for events, etc.

Awareness, common sense, early warning, and training were recurring themes which appeared in the responses. The most valuable safety measure identified in the literature review of limiting firefighter exposure by keeping them inside vehicles as much as possible was identified directly in only three responses. Response #60 is worth additional consideration, as this is where I would like this research to lead. Several respondents also indicated that awareness was a critical event in having fire departments increase their lightning safety. Several of these departments also indicated that the simple fact they had received the survey prompted them to increase their lightning safety awareness.

Question 10 of the survey was an inquiry to determine whether departments had policies they would be willing to share. This information was cross referenced with respondents who indicated they did have such documents, and these departments were contacted to obtain copies of their policies.

Table 12
Survey Question 10

If you have any written SOG, SOP, or other guidelines related to lightning safety, would you be willing to share them?			
Answer Options	**Answer Options**	**Response Percent**	**Response Count**
Yes	Yes	79.2%	80
No	No	20.8%	21
answered question	*answered question*	*101*	**101**
skipped question	*skipped question*	*1*	**1**

Policies were obtained from departments which had them and were willing to share same; these policies cover a wide range of lightning safety guidelines. Of the 80 departments which indicated they would be willing to share their lightning safety guidelines, only 25 actually indicated that they had policies or guidelines. Discussions with these departments revealed that even fewer had actual written policies or procedures. It was further determined that several of the departments which did have written policies and procedures were in the Tampa area of Florida and had already used each other's policies related to lightning safety to create their own. The policies which were unique were limited to two ends of the spectrum, one which required a "common sense" approach; the other specifies in more detail the steps to be taken. The best policies included language which restricted the number of personnel outside of trucks during lightning conditions.

In evaluating the fourth research question, I compiled a feasibility study to evaluate and measure actions that Oakland Park Fire Rescue could take to increase lightning safety. Actions with a high feasibility could be implemented with low or no cost and little effort if approved by fire administration personnel. Moderate feasibility actions would involve costs and/or more significant time commitments from fire administration and could not be implemented immediately. Low feasibility actions stand little chance of ever being realized due to high costs, extensive time commitments, or other limiting factors. Actions with low feasibility ratings are not bad ideas, and may, in fact, be very good ideas; however, they stand little chance of coming to fruition due to external factors which cannot be overcome at this point in time. These low feasibility items should always be reconsidered when the circumstances of the department change, allowing them to be considered as being in moderate or high feasibility rankings.

Table 13

Feasibility Study

Action	**Feasibility**	**Comments**
Institute a policy which limits the number of firefighters outside of trucks in lightning conditions.	High	This type of policy would offer the best protection for firefighters.
Institute a policy which restricts fire fighter actions such as carrying ladders, roof operations, etc	High	While these policies will help, they are not as effective as a policy which limits exposure.
Institute a policy which would cease all outdoor operations when lightning conditions are present in all cases.	Low	While this policy would provide the greatest safety factor, it would result in a great property and possibly life loss.
Institute a policy which would cease all outdoor operations when the endangered property is of	Moderate	Difficult to define and specify the go and no-go break.

Action	Feasibility	Comments
negligible value or is already completely lost.		
Institute a policy which would cease all outdoor operations during training exercises when lightning is a threat.	High	This policy would eliminate placing firefighters in danger of a strike when not necessary.
Purchase and use a device which is linked to the National Lightning Detection Network.	Moderate	Extremely Accurate. Cost varies. Initial cost is for unit which can receive information; in some cases, this can be a phone. Ongoing monthly subscription service cost is about $169.00.
Purchase and use a portable lightning proximity warning device such as the SkyScan EWS-PRO.	Moderate	The unit costs $805.00, and the only recurring cost is maintenance. The unit is not the most accurate lightning detection system.

Discussion

The results of this research clearly show that Oakland Park firefighters are at a higher risk for suffering lightning strikes than the national average. Awareness of the dangers associated with lightning strikes needs to be focused on scenes where this danger exists.

Lightning is considered to be deadly; however, research has found that lightning strikes to humans are fatal only about 10% of the time; the remaining victims suffer varying degrees of injuries (National Weather Service, 2009). While not being killed by a lightning strike sounds like a benefit, the reality is that the injuries caused by lightning strikes are often debilitating. The fact that only 10% of lightning strikes are fatal also causes the problem to be under-reported because it is often not newsworthy if they are not fatal. When considering all of the possible causes of environmental injury or death, it is difficult to believe that lightning has consistently ranked among the top three causes. In a typical year, lightning kills and injures people more frequently than hurricanes, tornadoes, and earthquakes (Cooper, 2009). Lightning also has the ability to reach out great distances, striking objects and people up to 12 miles away (National Weather Service, 2009). It is also widely believed that one must be directly hit by a stroke of lightning to be injured or killed; this could not be further from the truth. There are six ways in which a stroke of lightning can harm people including: direct strike, side splash, contact voltage, ground current effect, failed upward leader, and barotrauma (Cooper, 2009).

The first research question asked *What are the risks of lightning strikes in the Oakland Park area?* Globally, there are 44,000 thunderstorms on any given day and 2,000 in progress at any given time (Mogil M, 2007). This means that, globally, there are about 3 million strokes of lightning on Earth. According to the most recent data, 330 people in the United States are injured or killed by lightning strikes every year (R. Holle, personal communication, January 5, 2010).

The national average number of lightning strikes per year is 8.064 per square mile. Oakland Park is in the state of Florida, which has an average of 25.3 lightning strikes per square mile annually. These numbers were analyzed with a T-test; it was determined that, with a 95% confidence level, Florida has a statistically significant increased risk of lightning strikes compared to the rest of the country.

It is difficult to calculate what the exact odds are of one being affected by a lightning strike during his or her lifetime. The odds of winning the Florida Lottery are one in 22,957,480; however, the odds of being affected by a lightning strike during a lifetime are estimated at one in 5,000 (Holle, 2008). When considering the fact that Oakland Park encounters about three times the national average number of lightning strikes per square mile every year, one must adjust the odds of being affected upward accordingly.

Reviewing news articles and searching the Internet led to the discovery that firefighters are struck by lightning at a rate which far exceeded initial expectations. In recent times, several firefighters have been struck and some killed by lightning while operating at fire scenes. It is important to note that, in all of the cases of lightning strike deaths or injuries in 2009, firefighters were outside of their vehicles when struck. In fact, research clearly reveals that the inside of a vehicle with an enclosed metal roof cab is one of the safest places in which a firefighter can be during a thunderstorm (Holle, 2008).

All literature reviewed and all of the data studies that the author conducted indicate that firefighters in Oakland Park, and anywhere else in Florida, are at a significantly increased risk for suffering lightning strikes when measured against national averages. Lightning density maps provided in Appendices D & E, as well as interviews with experts in the field of lightning research support this finding (R. Holle, personal communication, December 18, 2009).

Research question number two focused on evaluating the activities which firefighters perform that place them in jeopardy in terms of lightning strikes. The nature of the job often leads firefighters directly into the paths of lightning strikes. In the average year, 31,400 fires in the United States are caused by lightning (Ahrens, 2008). Frequently, firefighters respond to these fires and conduct their operations outdoors while lightning activity is still present. The safest place to be during a lightning strike is inside a building of significance or a vehicle with an enclosed metal roof. When conducting firefighting operations, it is not possible to completely avoid going outside, but some actions that firefighters take unnecessarily increase their risk of being exposed to lightning strikes. Activities and or factors identified in the literature review which increase an individual's chance of being struck include the height of a person or object, the amount of isolation of object or person, and how narrow or pointed a surface is. Contact with metal objects and contact with water were identified as factors which could facilitate the movement of electricity associated with a lightning strike, but those substances do not attract lightning (R. Holle, personal communication, January 5, 2010). In conducting firefighting operations we frequently are involved in activities which mirror these risk factors. When firefighters conduct roof operations, they become the highest object in that location, and, thus, increase the risk of being subject to lightning strikes. The hazard of height may be amplified by having personnel operate from elevated platforms which would place them atop a 100 foot tower.

Contact with metal objects is another frequent aspect of firefighting. Carrying ladders, pike poles, and other tools increases the risk of firefighters being struck by lightning. The most obvious risk factor that firefighters encounter is contact with water. As water is the firefighter's weapon of choice in battling fires, it often accumulates in lower areas which are frequently traversed by firefighters engaged in combat activities. NOAA has compiled a list of objects, equipment, and activities which should be avoided during thunderstorms; they are always present in typical fire attack scenarios. NOAA's list includes staying off rooftops, not touching ladders, avoiding contact with large pieces of apparatus (such as fire trucks), and not touching water or water pipes (NOAA, 2009).

Observations of firefighters performing their normal routines confirmed that firefighters frequently perform acts which place them at greater than average risk of suffering lightning strikes. While not performing the activities which are considered risk factors for lightning strikes is not possible in the firefighting profession, it is certainly possible to reduce the exposure to them. The most critical activity which firefighters could perform to increase the lightning safety factor involves reducing the number of non-essential personnel outside of apparatus. Oftentimes, RIT and other functions could be performed from inside the safety of enclosed vehicles.

Research question three asked *What safety guidelines are being used by other organizations to reduce lightning strike hazards?* The literature review indicated that many sporting agencies such as the PGA, LPGA, NCAA, as well as many schools have adopted guidelines to create lightning safety protocols. Most of these organizations' guidelines include complete cessation of outdoor activities when lightning is present (NOAA). While this is certainly the safest course of action, it will not work in practical application for the fire service. To perform firefighting duties, some outdoor activities are necessary. In surveying other fire departments to determine guidelines which may already exist, I found that very few departments have written guidelines. Of the departments which had policies on lightning safety, most include the basics of lowering aerial apparatus and limiting roof operations. Several departments in the

Tampa area of Florida have more comprehensive procedures which include the critical element of limiting the number of non-essential personnel outside of apparatus.

Lightning detection was an element identified in the literature review as a possible safety feature which could be beneficial to the fire service. Several different versions of lightning detection equipment which would be suitable for fire service application were identified. SkySkan produces a model which is portable and has user selectable ranges. This model has an upfront cost of about $800.00 and ongoing maintenance costs. The most accurate lightning detection, however, is data which is collected and transmitted by the lightning detection network. Vaisala, a private company, records lightning strikes all over the United States and transmits this data to remote users in real time. The data transmitted can be used on Blackberries, portable computers, or computers already on fire apparatus for other purposes. The cost of this service varies, depending on the vendor utilized for data service. This form of warning is, beyond doubt, the most accurate lightning data available to the fire service at this time. Research indicates that, while this service could provide a safety factor for the fire service, most departments use the service only for the purpose of fire investigations. The data collected by Vaisala is archived, allowing investigators to view exact locations and time ranges to determine whether lightning had been a possible cause of a fire. Expanding the use of this data would certainly lead to safety gains related to lightning strikes on fire grounds.

Research question four asked *What actions should Oakland Park take to reduce the chance of lightning strikes affecting Oakland Park firefighters?* The author’s recommendations are presented in the next portion of this research report; however, in reaching these recommendations, several considerations had to be made. While absolute lightning safety would be an ideal, a consideration had to be made that, in order to adequately perform the job, some level of risk must be accepted by firefighters. Therefore, staying indoors or inside trucks during all storms is not a viable solution.

It was determined through the literature review and on the basis of my findings that the threat of a lightning strike affecting Oakland Park firefighters is very real and that safety measures should be established. There is no policy which can be written, no SOP utilized, and safety measure used which will guarantee lightning safety on the fire ground; however, there are ways to improve the level of lightning safety on a daily basis. With the threat of lightning strikes in Florida triple the national average, it would be prudent for Florida fire departments to lead the way in instituting measures which will keep firefighters as safe as possible from that danger. Technology has evolved to a level so that all departments have early warning lightning detection within their reach. Convincing departments that there is a need for this type of equipment is more of a challenge. Fire departments that have had members struck by lightning are keenly aware of the advantage that this equipment offers and frequently have it on all command vehicles. As the technology has evolved and become more accurate and more real time, the cost has come down. Portable units and even information on phones is now available.

It is important to remember that the best information gained from the literature review and from my findings indicates that avoidance is the best way to avoid lightning strikes. The safest place to be during a lightning storm is inside a building of significance or the cab of an enclosed vehicle with a metal roof. Every effort should be made on the fire ground during lightning storms to keep as many personnel as possible inside trucks. If personnel are inside structures or cabs of apparatus, then the threat of lightning strikes affecting personnel is greatly reduced. Reducing other lightning strike threats will help, but will not be nearly as effective as reducing the number of targets. The best course of action would be to develop the following philosophy: if the fire or person to be saved is beyond hope and there is no other reason to risk personnel, stay inside the apparatus.

Recommendations

Oakland Park firefighters are at a greater risk in terms of suffering lightning strike injuries/fatalities than the national average. This research has concluded that some form of lightning strike safety measures need to be in place for Oakland Park firefighters. The purpose of this research study is to determine what operating guidelines can be instituted to reduce the likelihood of Oakland Park firefighters being struck by lightning. The following recommendations are a direct result of the findings of this research study:

1. It is recommended that Oakland Park Fire Rescue develop a policy related to lightning safety at structure fires which incorporates the following elements:
    a. All personnel not on active assignment should stage inside apparatus when lightning is in the area.
    b. The driver/engineer should remain inside the vehicle when possible if lightning is in the area.
    c. The R.I.T. team should stage inside a vehicle when lightning is in the area.
    d. No roof operations should be conducted when lightning is in the area.
    e. All aerial apparatus should be lowered when lightning is in the area.
    f. Ladders should neither be carried nor erected when lightning is in the area.

The primary focus of this policy should be to limit the number of firefighters outside the protection of fire apparatus. It is established that having all personnel remain inside apparatus would be the safest course of action to prevent lightning strikes from affecting operating personnel; however, this is not possible when conducting necessary operations. The intent is to limit, whenever possible, the hazards most frequently associated with lightning strikes affecting personnel.

2. It is recommended that Oakland Park Fire Rescue develop a policy related to lightning safety at non-structure fires which incorporates the following elements:
    a. Incident commander should use a risk/benefit analysis to determine the value of property at risk vs. the safety of firefighters, with lightning safety as a major consideration if lightning is in the area.
    b. If outside operations are undertaken, only the minimum number of personnel should be utilized outdoors if lightning is in the area.
    c. If the fire is reachable, fire attacks should be attempted with all personnel operating nozzles from inside the protection of the apparatus if lightning is present.

The primary focus of this policy is to focus incident commanders' attention on the risks of lightning strikes and measure that against the value of the property involved, which would be lost if no outdoor firefighting operations were to be conducted. The secondary goal is to encourage incident commanders to seek alternatives to having personnel exposed to the dangers of lightning strikes when other options may be available.

3. It is recommended that Oakland Park Fire Rescue seek a grant to purchase an early warning lightning proximity device or, preferably, utilize data from the National Lightning Detection Network, which could be accessed on Mobil Data Terminals already in use on all apparatus.

The acquisition of access to early warning and lightning proximity cannot be understated in terms of importance. Access to this superior technology would require a subscription to live data from the National Lightning Detection Network. It is realized that, on many scenes in which Oakland Park firefighters operate, the warning parameters of any device would alert those on the scene to the existence of unsafe conditions; even just the knowledge that the device is going to indicate an unsafe condition, when activated, will cause incident commanders to make lightning safety a consideration in their planning. The simple presence of a device of this type should raise awareness of lightning safety on every operational scene.

4. It is recommended that Oakland Park Fire Rescue develop a training program which focuses on lightning safety, and offer this training to all personnel on an annual basis.

The policies, procedures, and equipment utilized in the other recommendations will have little value if they are not accompanied by and implemented through training. Training and awareness have been clearly identified as two of the leading factors in terms of improving lightning safety for firefighters. The training on lightning safety should be comprehensive and generalized to include multiple situations. It should be presented annually to both reinforce the information on existing personnel and educate new personnel who have not had the training in the past.

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Appendix A

Stages of a Lightning Strike

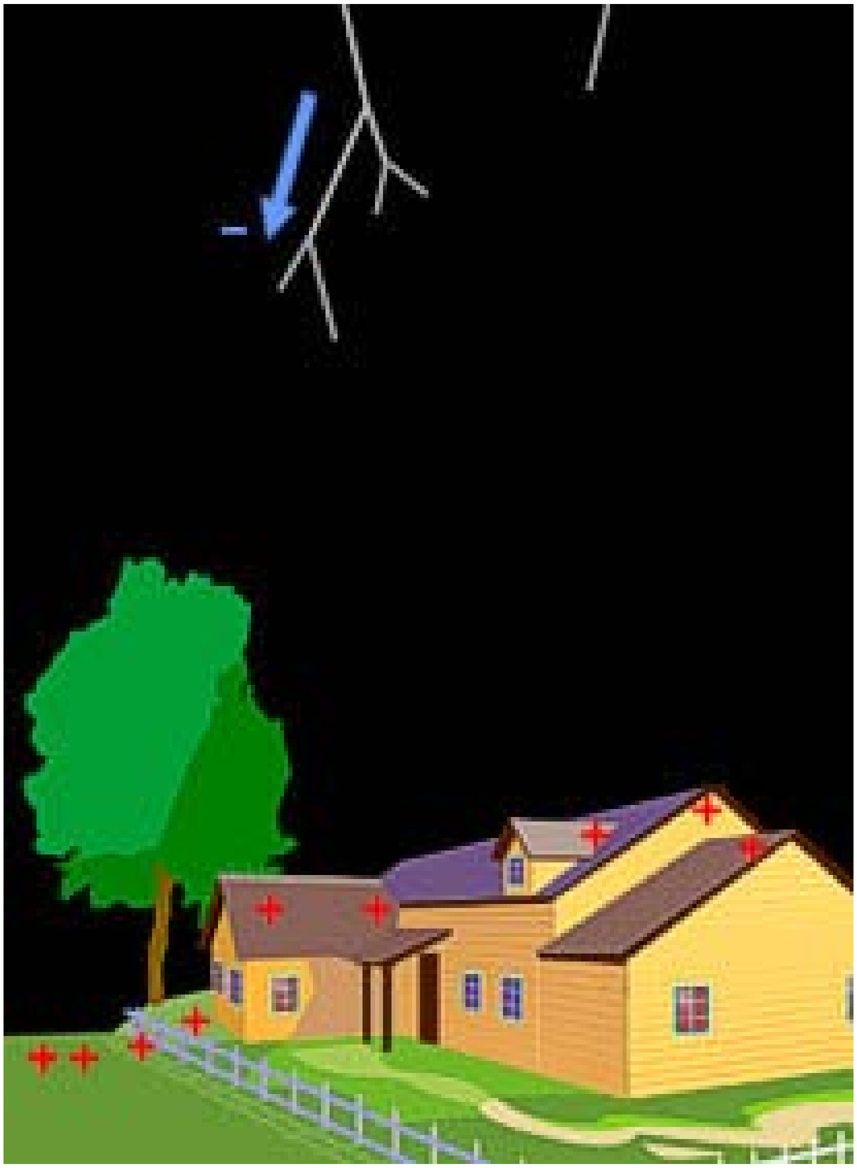


Figure 2. Stepped Leader (not visible).

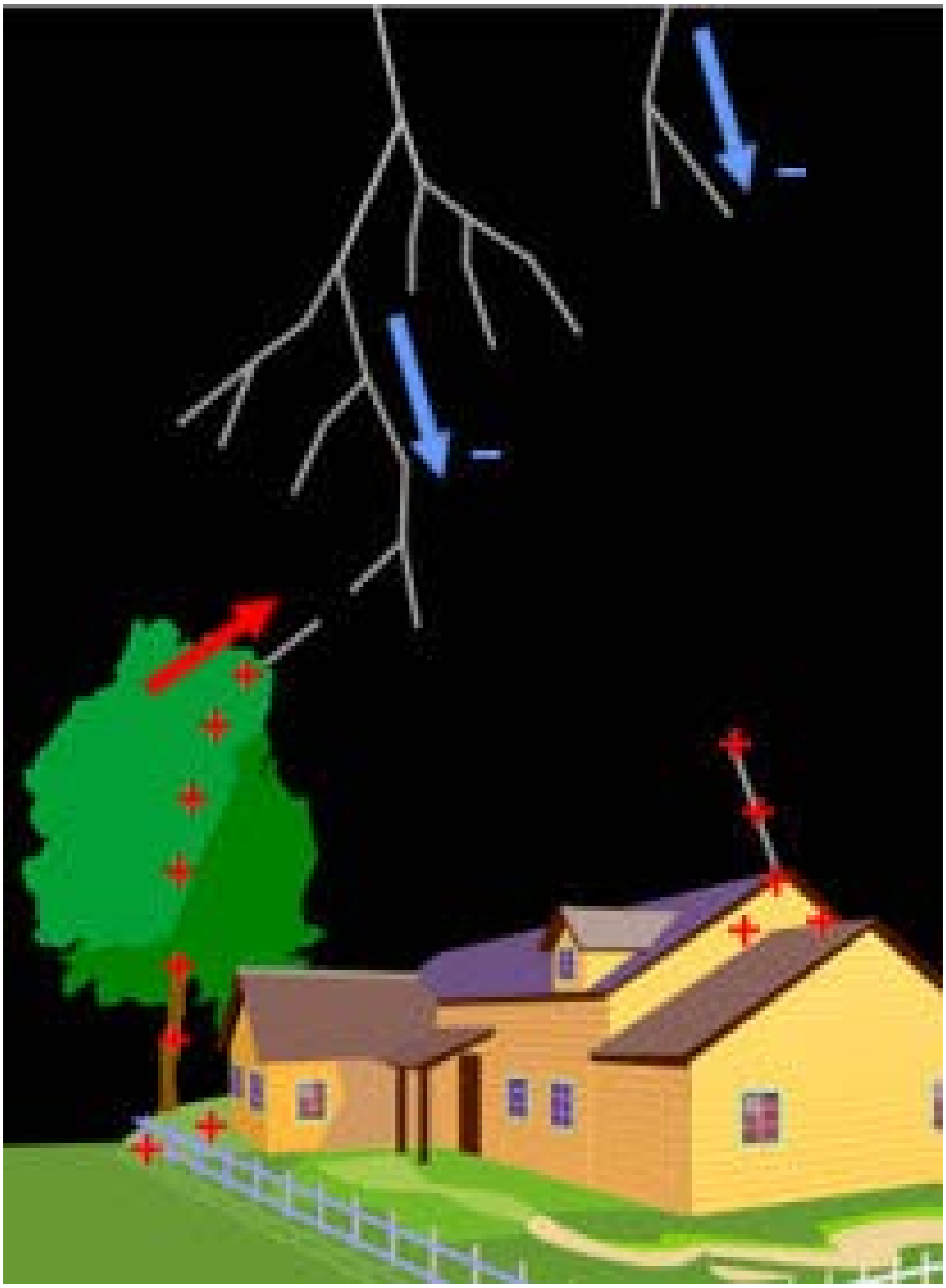


Figure 3. Upward Streamer or Leader (not visible).

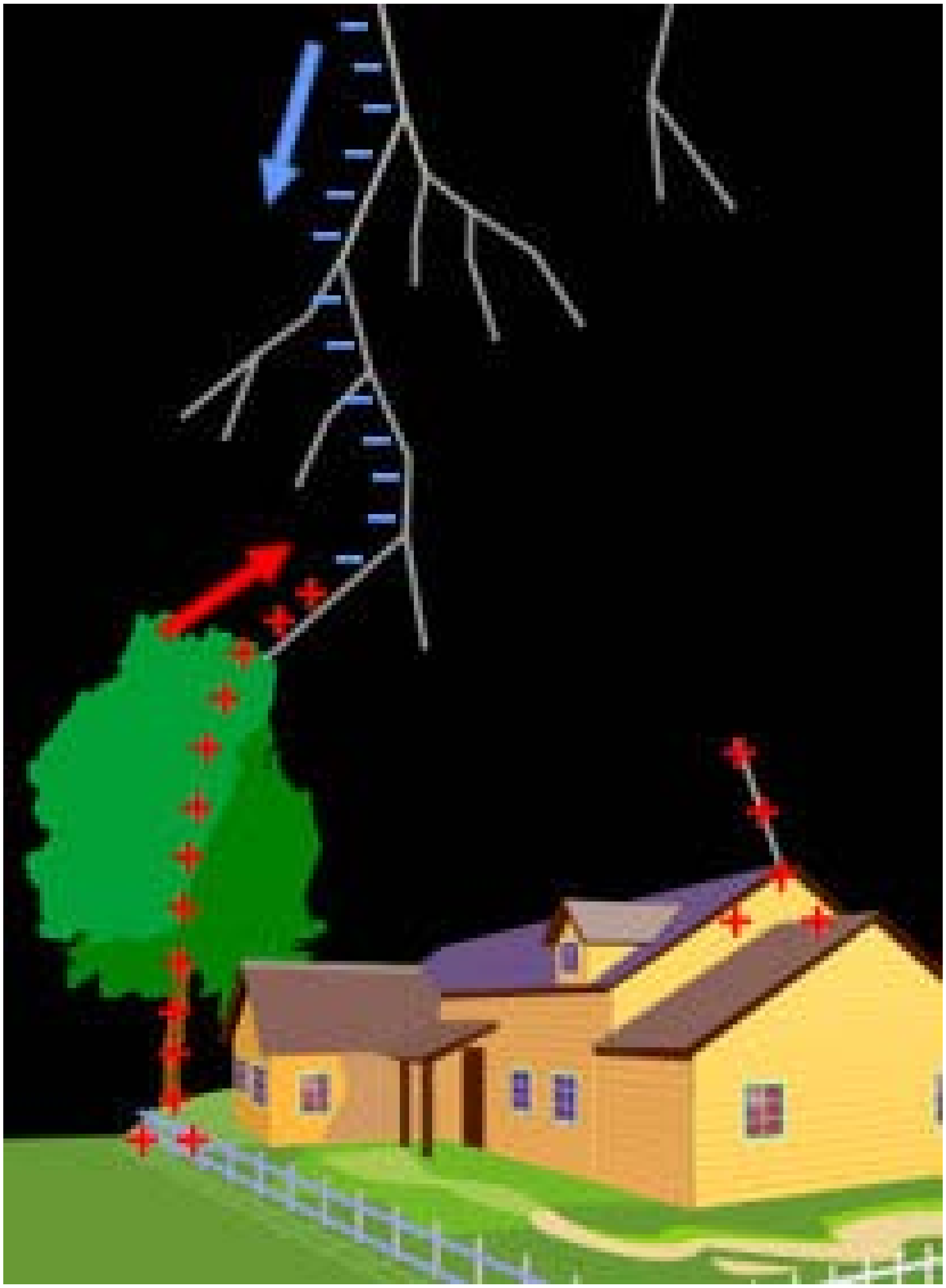


Figure 4. Channel Established When Stepped Leader Connects to Upward Leader or Streamer (not visible).

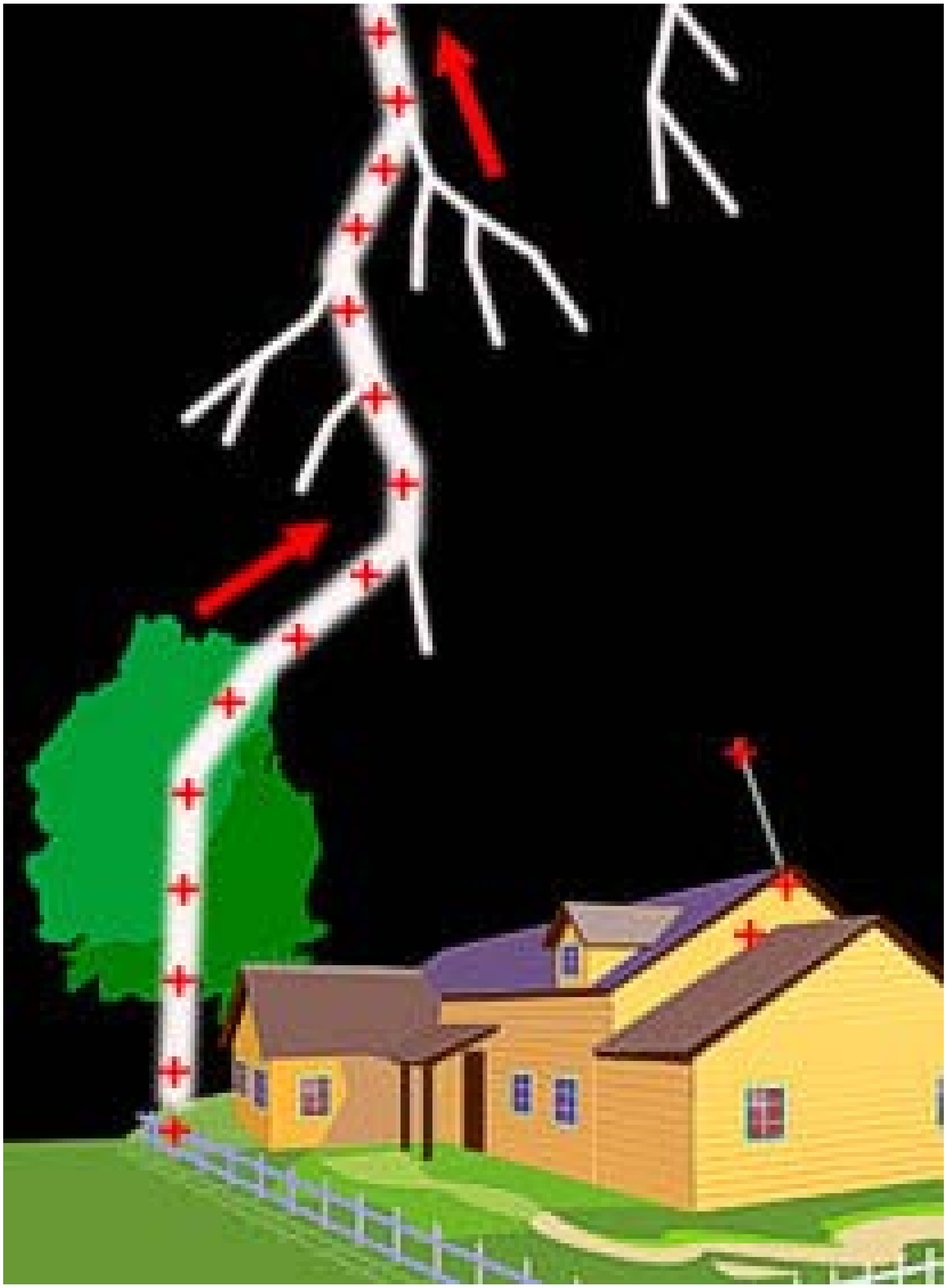


Figure 5. Return Stroke (visible lightning).

Appendix B

Survey Instrument

Purpose of survey

Dear Fire Department Representative,

Thank you for taking the time to complete this short survey. The results will be utilized in an applied research project for the EFO program at the National Fire Academy. The results of your input on this survey and associated research will help to keep Firefighters safe.

I appreciate your time and thank you.

10 Question Survey

*** 1. Which best describes your type of department?**

- ◯ Volunteer
- ◯ Career
- ◯ Combination
- ◯ Other (please specify)
- ◯ Industrial
- ◯ Military

*** 2. Population served by department**

- ◯ Under 2,500
- ◯ 2,501-10,000
- ◯ 10,001-25,000
- ◯ 25,001-75,000
- ◯ 75,001-150,000
- ◯ Over 150,000

*** 3. Your departments name and location**

Name:
Company:
Address:
Address 2:
City/Town:
State:
ZIP:
Country:
Email Address:
Phone Number:

*** 4. Have you ever had a lightning strike victim who was:**

	Yes	No	Can not recall
A resident in your community	◯	◯	◯
A visitor to your community	◯	◯	◯
A member of your organization	◯	◯	◯

Other (please specify)

*** 5. Does your department have any of the following with respect to lightning safety? Check all that apply (If possible please forward a copy to JohnP@oaklandparkfl.org)**

- [ ] Standard Operating Procedures (SOPs)
- [ ] Standard Operating Guidelines (SOGs)
- [ ] Any written guidelines for lightning safety
- [ ] Training on lightning safety
- [ ] None
- [ ] Other (please specify)

*** 6. What policies, guidelines, or instructions related to lightning safety exist in your department? (Check all that apply)**

- [ ] None exist
- [ ] Lower ladder trucks
- [ ] No/Limited personnel on roof
- [ ] No/Limited ladder contact
- [ ] No/Limited drafting operations
- [ ] Active reduction of personnel on scene outside of vehicles
- [ ] Other (please specify)

*** 7. Does your agency have a lightning proximity warning device?**

	Yes	No	N/A
Does your Department have a warning system?	☐	☐	☐
Is it used regularly?	☐	☐	☐

*** 8. How important would you consider lightning safety to be to your department?**

- ◯ Very
- ◯ Somewhat
- ◯ Not Important
- ◯ Not a Consideration
- ◯ Had not considered it until I received this survey

9. What do you think could be done to improve lightning safety for firefighters?

*** 10. If you have any written SOG, SOP, or other guidelines related to lightning safety would you be willing to share them?**

- Yes
- No

Appendix C

Survey Respondents

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Tamarac Fire Rescue	City of Tamarac	6000 Hiatus Road	Tamarac	FL	33321	jeffmo@tamarac.org	954-597-3800
Pembroke Pines Fire Department		9500 Pines Boulevard	Pembroke Pines	FL	33024	lbarneszargo@ppines.com	954-435-6700
Oakland Park Fire Rescue	Fire Prevention	5399 N. Dixie Highway	Oakland Park	FL	33334	Brucew@oaklandparkfl.org	954-630-4546
Greg Hoggatt	Orlando Fire Dept	400 S Orange Ave	Orlando	FL	32801	gregory.hoggatt@cityoforlando.net	407-246-3992
Tampa Fire Rescue		808 E Zack St.	Tampa	FL	33602	michael.gonzalez@tampagov.net	813-274-7520
Punta Gorda Fire Department		1410 Tamiami Trl	Punta Gorda	FL	33950	rhancock@ci.punta-gorda.fl.us	941-575-5538
Don Petito	Flagler County Fire Rescue	1769 East Moody Blvd.	Bunnell	FL	32110	dpetito	386-313-4255
Orange City Fire Department	City of Orange City	215 N. Holly Ave	Orange City	FL	32763	ourorangecity.com	386-7755460
Washington DC Fire & EMS	1923 Vermont Ave. NW		Washington	DC	20001	bruce.faust@dc.gov	(202) 727-3298
Palm Beach Gardens Fire Rescue		10500 N. Military Trail	Palm Beach Gardens	FL	33410	pbergel@pbgfl.com	531-799-4300
Marc Anderson	South Walton Fire District	911 N. CR 393	Santa Rosa Beach	FL	32459	manderson@swfd.org	850-267-1298
Palm Beach Gardens	Fire Rescue	10500 North Military Trail	Palm Beach Gardens	FL	33410		

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Donald R. Adams, Sr.	Lehigh Acres Fire Control and Rescue District	636 Thomas Sherwin Avenue South	Lehigh Acres	FL	33974	donalda@lehighfd.com	239.303.5300
Coral Springs Fire Department		4108 NW 120th Ave	Coral Springs	FL	33065	fdrjb@coralsprings.org	954-346-1354
BSO Fire Rescue		2601 W. Broward Blvd	Ft. Lauderdale	FL	33312	stephen_krivjanik@sheriff.org	954-831-8240
Coral Gables Fire Rescue		2815 Salzedo St	coral gables	FL	33134	mstolzenberg@coralgables.com	3054605536
South Walton Fire District		911 CR 393 North	Santa Rosa Beach	FL	32459	wwatts@swfd.org	wwatts@swfd.org
Hollywood		2741 Stirling Rd.	Hollywood	FL	33312	msteele@hollywoodfl.org	954-967-4248
John Tomaszewski	Delray Beach Fire-Rescue	501 W. Atlantic Ave.	Delray Beach	FL	33444	tomaszewski@ci.delray-beach.fl.us	561-243-7420
Gainesville Fire Rescue		1025 NE 13th St	Gainesville	FL	32601	northcutwk@cityofgainesville.org	352-334-5078
City of Naples		355 riverside cir	Naples	FL	34102		
North Bay Fire Control District		1024 White Point Road	Niceville	FL	32578	gdjordan@northbayfd.org	850-897-3689
Plant City Fire Rescue		604 E. Alexander Street	Plant City	FL	33563	gshiley@plantcitygov.com	813-757-9131
Edward L. Prime III, EFO	Indian River County Fire Rescue	4225 43rd Ave	Vero Beach	FL	32967	eprime@ircgov.com	772-226-3860
Anthony Smith	Escambia County Fire Rescue	6575 N W St	Pensacola	FL	32505	asmith@co.escambia.fl.us	850-475-5530
Department of Public Safety	Macclenny Fire Rescue	118 E Macclenny Avenue	Macclenny	FL	32063	chiefdugger@cityofmacclenny.com	904-259-0975

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Robert F Bacic	Fort Lauderdale Fire Rescue	2200 Executive Airport Way	Ft Lauderdale	FL	33309	rbacic@fortlauderdale.gov	9548283623
Kevin Easton	Sarasota County Fire Department	400 N. Beneva Rd.	Sarasota	FL	34232	keaston@scgov.net	941-861-2181
Hollywood		2741 Stirling Rd	Hollywood	FL	33312	raspinall@hollywoodfl.org	954.967.4404
W.J. Trinder Sr.	Jasper Fire Rescue Department	208 W. Hatley Street	Jasper	FL	32052	fcbt301@yahoo.com	386-792-2211
Baton Rouge Fire Department		8011 Merle Gustafson Dr.	Baton Rouge	LA	70807	sshelton@brgov.com	225-354-1430
Chief Lawrence Nisbet	Bayshore Fire Rescue	17350 Nalle Road	North Fort Myers	FL	33917	chief@bayshorefire.org	239-543-3443
David Ezell	Bradenton Fire Department	1010 9th Ave W	Bradenton	FL	34205	david.ezell@cityofbradenton.com	(941)708-6233
Palm Coast Fire Department		1250 Belle Terre Parkway	Palm Coast	FL	32137	gforte@ci.palm-coast.fl.us	3869862300
Christopher J. Weir EFO	City of Port Orange Department of Fire & Rescue	1090 City Center Blvd	Port Orange	FL	32129	cweir@port-orange.org	386-506-5905
Guy Keirn	Pinellas Park FD	11350 43 St N	Pinellas Park	FL	33762		7275410713
Lakeland Fire Department		701 E. Main Street	Lakeland	FL	33810	klastinger@verizon.net	863-581-7749
Bob Markford, EMS Chief	Palm Harbor Fire Rescue	250 West Lake Road	Palm Harbor	FL	33709	rmarkford@palmharborfd.com	727-683-1649
Port Orange Fire Rescue		1090 City Center Blvd	Port Orange	FL	32119	kburgman@port-orange.org	3865065903

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Byron Teates	East Manatee Fire Rescue	3200 Lakewood Ranch Blvd.	Bradenton	FL	34211	bteates@emfr.org	941-751-5611
Terry Tokarz	Seminole Fire Rescue	9199 113th Street North	Seminole	FL	33772	ttokarz@myseminole.com	727-393-8711 Ext. 207
Larry Morabito	Citrus County Fire Rescue	3600 W. Sovereign Path	Lecanto	FL	34461	larry.morabito@bocc.citrus.fl.us	352-527-5406
Randy Keirn	Lealman Fire District	4360 55th Avenue North	St Petersburg	FL	33714	rkeirn@lealmanfire.com	727-526-5650
Brian Tucker	Sumter County Fire Rescue	910 N Main St	Bushnell	FL	33513	Brian.Tucker@sumtercountyfl.gov	
Palm Beach Fire Rescue		300 North County Road	Palm Beach	FL	33480		
Scott Cooper	Polk County Fire Rescue	8822 Colonial drive	Winter haven	FL	33884	rescue96us@yahoo.com	813-917-7924
Panama City Fire Department	600 East Business Hwy. 98		Panama City	FL	32401	jprater@pcgov.org	850-872-3055
Jo-Ann Lorber	Fort Lauderdale Fire-Rescue	528 NW 2 Street	Fort Lauderdale	FL	33311	JLorber@fortlauderdale.gov	954-828-6809
Clay County Fire Rescue		1 Doctors Dr.	Green Cove Springs	FL	32043	richard.knoff@co.clay.fl.us	904 284-7703
North Port Fire Rescue		4980 City Center Blvd	North Port	FL	34286		
Pompano Beach Fire Rescue		120 SW 3 ST	Pompano Beach	FL	33060		
Deerfield Beach Fire Rescue		1441 FAU BLVD	Deerfield Beach	FL	33441	mhefferon@deerfield-beach.com	954 571-7585
Scott Lane	Englewood Fire Department	516 Paul Morris Dr	Englewood	FL	34223	lane@englewood-fire.com	941 474-3311
Boynton Beach Fire		2080 High	Boynton Beach	FL	33426	carterr@bbfl.us	561-742-6339

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Rescue		Ridge Rd					
City of Plantation		550 NW 65 Ave	Plantation	FL	33317	rpudney@psd.plantation.org	954-797-2150
Brett Pollock	West Manatee Fire Rescue District	6001 Marina Drive	Holmes Beach	FL	34217	brett.pollock@wmfr.org	941-741-3995
Craig Radzak	Sanford Fire Department	1303 French Ave	Sanford	FL	32771	radzakc@sanfordfl.gov	407.688.5040
Oakland Park Fire Rescue Department	2100 N.W. 39th Street		Oakland Park	FL	33309	donaldw@oaklandparkfl.org	954-630-4547
Kenneth A. Price Jr.	West Manatee Fire Rescue	6001 Marina Drive	Holmes Beach	FL	34217	andy.price@wmfr.org	9417413900
Chip Branam		2709 E. Hanna Ave	Tampa	FL	33610	cbranam26@yahoo.com	813-272-6600
City of Okeechobee	Fire Department	55 SE 3rd Ave	Okeechobee	FL	34974	hsmith@cityofokeechobee.com	863-467-1586
Chief Dave Downey	Miami-Dade Fire Rescue	9300 NW 41 Street	Miami	FL	33178	david.downey@miamidade.gov	786-331-4202
Fort Lauderdale	Fire	528 NW 2 St	Ft Lauderdale	FL	33311	Theiser@fortlauderdale.gov	954-828-6831
Ponce Inlet F/R		4680 S. Peninsula Drive	Ponce Inlet	FL	32127	mnoone@ponce-inlet.org	386-322-6720
City of Oldsmar Fire Rescue		225 Pine Av N	Oldsmar	FL	34677	smcguff@ci.oldsmar.fl.us	813-749-1200
Gainesville Fire Rescue		1025 NE 13th Street	Gainesville	FL	32601	1025 NE 13th Street	3523345065
James Warman Deputy Chief	Largo Fire Rescue	PO Box 296	Largo	FL	33779	jwarman@largo.com	727-587-6714
George Bessler	City of Seminole Fire Rescue	9199 113 St	Seminole	FL	33772	gbessler@myseminole.com	72 393-8711

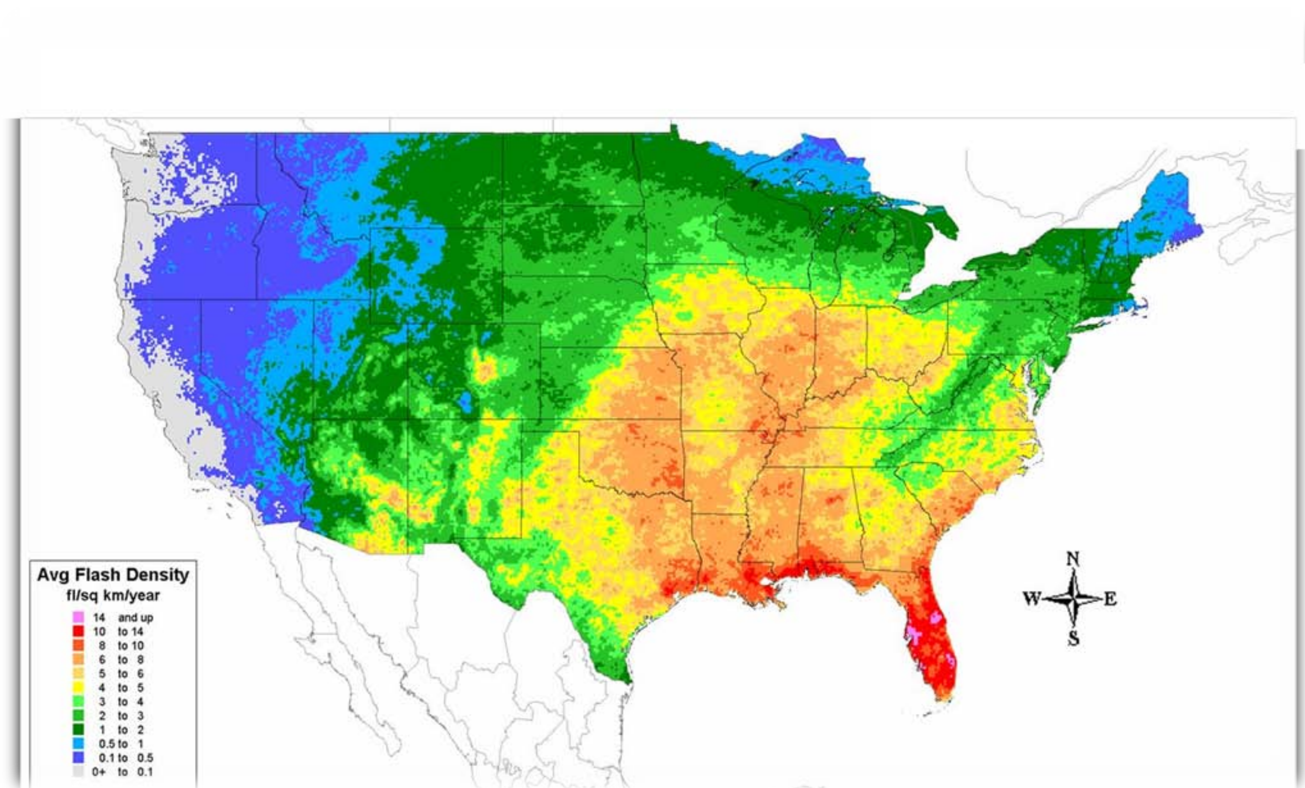
Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
City of Fort Walton Beach FD		5 Hollywood Blvd. NE	Fort Walton Beach	FL	32548	kperkins@fwb.org	850-833-9566
Brian Stoothoff	Ocala Fire Rescue	410 NE 3 St	Ocala	FL	34470	bstoothoff@ocalafl.org	(352) 629-8306
David Kilbury	Clermont Fire Department	439 W Hwy 50	Clermont	FL	34711	dkilbury@clermontfl.org	(352) 394-7662 E. 213
Lon Cheney	Haines City Fire & Rescue	138 N 11th St.	Haines City	FL	33845	lcheney@ci.haines-city.fl.us	(863) 421-3612
Ormond Beach FD	City of Ormond Beach		Ormond Beach	FL	32174	jarrell@ormondbeach.org	386-676-3270
Joe Campfield	Dunnellon Fire Rescue	12014 S. Williams St.	Dunnellon	FL	34432		
Mike Dutton	Fort Walton Beach FD	#5 NE Hollywood Blvd.	Fort Walton Beach	FL	32548	mdutton@fwb.org	850-833-9564
Greensboro Fire Department	Fire Station 11	2602 South Elm-Eugene Street	Greensboro	NC	27406	mark.schmitt@greensboro-nc.gov	336-279-1411
Gene Prince	city of Gainesville Fire Rescue	1025 NE 13 St	Gainesville	FL	32601	princehe@cityofgainesville.org	352-334-5078
Joe Hessling	North Naples Fire	1885 Veterans Park Dr	Naples	FL	34109	jhessling@northnaplesfire.com	239-552-1331
Assistant Chief Keith Frank	Quincy Fire Department	906 Vermont St	Quincy	IL	62301	kfrank@quincyil.gov	217-242-4594
Seminole Tribe of Florida	Seminole Tribe Fire Rescue	30280 Josie Billie Hwy	Clewiston	FL	33440	robertlevy@semtribe.com	954-605-7899
Ariel Villarreal, Bureau Chief	Martin County Fire Rescue	800 SE Monterey Road	Stuart	FL	34994	avillarr@martin.fl.us	7722885710
City of High Springs		205 NW 1st. Ave	High Springs	FL	32643	hsfirechief01@windstream.net	386-547-7293

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Greg Anglin	City of Melbourne Fire Dept.	1500 Hickory St.	Melbourne	FL	32901	ganglin@melbourneflorida.org	321-674-5866
Town of Davie		6901 Orange Drive	Davie	FL	33314	http://www.davie-fl.gov	954-797-1213
Orange County Fire Rescue, Florida		6590 Amory Court	Winter Park	FL	32792	brett.wasmund@ocfl.net	407-836-9809
Melbourne Fire Department		1500 Hickory Street	Melbourne	FL	32901	jsunday@melbourneflorida.org	321-674-5866
David Mixson	Largo Fire Rescue	PO Box 296	Largo	FL	33779	dmixson@largo.com	727-587-6714
Clay County		1 Doctors Drive	Green Cove Springs	FL	32043		
Tampa Fire Rescue		808 E. Zack St.	Tampa	FL	33602		813-274-7011
Iona McGregor Fire District		6061 South Pointe Blvd	Fort Myers	FL	33919	welliott@ionafire.com	239-433-0660
Miami-Dade Fire Rescue		9300 NW 41 St	Doral	FL	33178	ulloag@miamidade.gov	786-331-4811
Largo Fire Rescue	City of Largo	201 Highland Ave	Largo	FL	33770	swillis@largo.com	727-587-6714
Sanford Fire Department		1303 S. French Ave	Sanford	FL	32771	fiorettv@sanfordfl.gov	407-688-5046
Hutchinson Fire Department		18 E. B Ave	Hutchinson	KS	67501	jholland@cox.net	620-663-7882
Bloomington Fire Department		10 W 95th Street	Bloomington	MN	55420	lmccarthy@ci.bloomington.mn.us	
Clayton Blankenship	Hayward Fire & Emergency Services	13730 Hwy. 40	Keystone	SD	57751		
Winter Park Fire Rescue		343 W. Canton Ave.	Winter Park	FL	32789	pmccabe@cityofwinterpark.org	407-599-3606
Lauderhill Fire Rescue		1980 NW 56th Ave	Lauderhill	FL	33313	mceletti@lauderhill-fl.gov	954-730-2950

Name:	Company:	Address:	City / Town:	State:	ZIP:	Email Address:	Phone Number:
Reno County Fire Dept District #8		10111 S Alstead	Hutchinson	KS	67501	strainthebrain@aol.com	
Michael Calderazzo	El Paso Fire Department	8600 Montana	El Paso	TX	79925	CalderazzoMV@elpasotexas.gov	915-771-1003
Tampa Fire Rescue		808 e. Zack St.	Tampa	FL	33602	dennis.jones@tampagov.net	813.274.7011

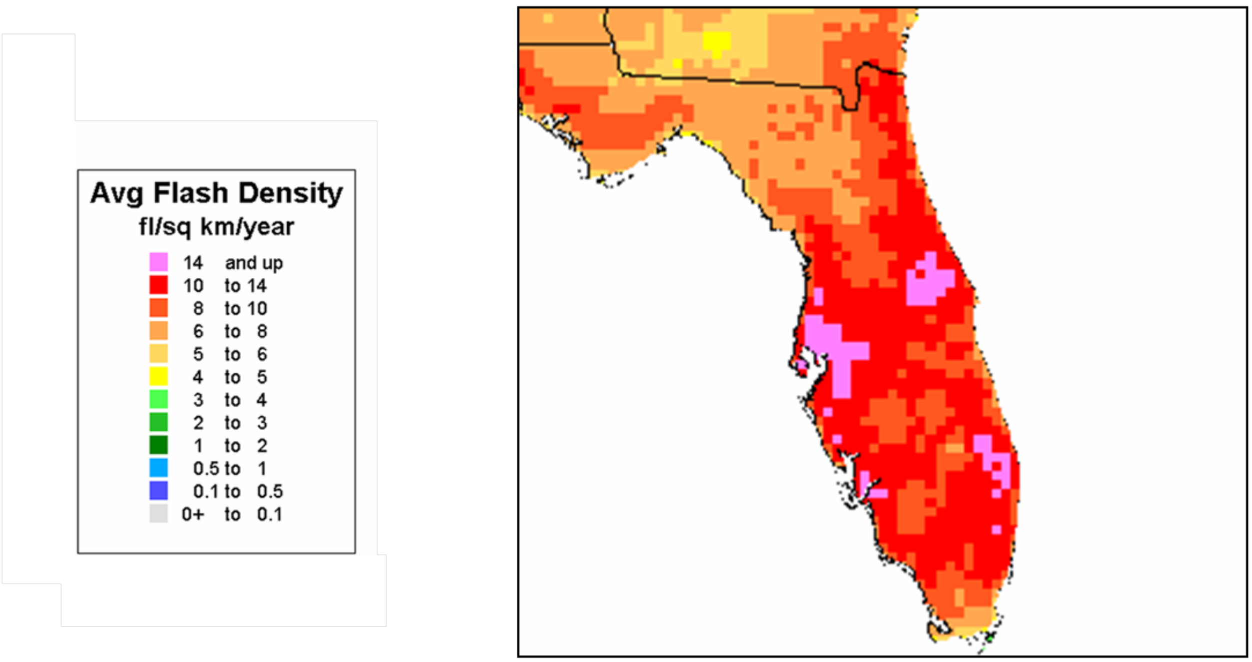
Appendix D

National Lightning Density Map



Appendix E

Florida Lightning Density Map



Author Note

On several occasions, I have been asked how I came up with the idea for this research project. Lightning has fascinated me ever since I was a child growing up in a state which has more lightning strikes per square mile annually than any other state. My parents would sit with me on the back porch of our home in Plantation, Florida, and watch the powerful and spectacular show that lightning would perform on summer nights on a regular basis. One night, when I was a young teenager, I encouraged a visiting friend to venture into the backyard to watch an approaching lightning storm. My friend looked at the sky and made a wise decision to stand in the doorway to observe the storm. As I stood in my backyard challenging, God to show me a great stroke of lightning, I scanned the sky for the best show. Lightning was flashing in the distance and some of the strokes were truly impressive. My desire to see an impressive stroke of lightning strike was soon fulfilled. I saw a fine bright spot of light to the south and, at the same time, heard a sound which was like a combination of ice settling in a cooler and a hiss. The fine spot nearly instantaneously transformed into a pure white light all around me and the sound changed to that of an explosion. I realized immediately that the lightning had struck either me or very close to me. I immediately attempted to conduct a survey of my condition. My first realization was that I could not see anything; however, I knew that I was not dead. Everywhere I looked I could see nothing but pure white light. I turned in circles in my yard trying in vain to see anything besides the pure white and I smelled ionized air. I wondered whether I had been struck and was now blind.

Thankfully, within one to two minutes, my world returned to normal; my vision was restored, my body was intact, and I knew that I had not been struck directly. My friend was gone; retreating well into the safety of the house. Rain had begun to fall.

At the time, I did not know how close I had come to a direct strike, but two or three days later, a tree in our backyard about forty feet from where I had been standing started to die. Further examination of the tree revealed that it had been the victim of a lightning strike, no doubt the strike I had witnessed

That close call with lightning taught me several lessons, including not to tempt God and to have respect for the awesome power of lightning. I am still fascinated with lightning; however, I also understand the terrible consequences associated with lightning striking a person or other living thing. It is my hope that the lesson I learned as a teenager can be used now to help protect my fellow firefighters.