SPATIAL ANALYSIS OF SURVEYED PERCEPTIONS OF SAFETY, CRIME, AND LIGHTING: A COLLEGE CAMPUS CASE STUDY

A Thesis
by
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ABSTRACT

SPATIAL ANALYSIS OF SURVEYED PERCEPTIONS OF SAFETY, CRIME, AND LIGHTING: A COLLEGE CAMPUS CASE STUDY
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With recent crime incidents at universities highlighted through the media, campus safety is of increasing importance to universities today. This research examines spatiotemporal relationships between surveyed perceptions of safety, reported incidents of crime, and exterior campus lighting using Appalachian State University's campus as a case study. Appalachian is a mid-major southern university located in the northwestern mountains of North Carolina with an enrollment of over 16,000 undergraduate and graduate students. During the 2009 spring semester 758 surveys were administered on Appalachian's campus aimed at better understanding places that students perceive to be unsafe, on-campus during the daytime and nighttime.

Respondents were asked to mark three daytime and three nighttime points where they felt unsafe and weight each point. They were also asked to briefly explain their perceptions and what could be done to improve these locations. Of those surveys administered, 696 were considered viable for this study. A geographic information system (GIS) was used to

digitize data from these student surveys into digital points. Spatial density analysis tools were used to convert these points into an enhanced campus perception of safety density surface. These point data were also analyzed with spatial statistics tools in the CrimeStat application to examine relationships between sexes, location of housing, perceived unsafe areas, and other spatiotemporal characteristics.

In order to assess the relationship between perceptions of unsafe areas and actual locations of crime, the perception points were compared with actual campus crime locations as well as the spatial extent of exterior illumination. The campus crime data was collected from the online log for the 2008-2009 academic year, divided into daytime and nighttime crime, and digitized into points using a GIS. Each point was weighted based on severity and spatial density analysis was used to generate an enhanced campus crime density surface.

Further spatial analysis was completed using CrimeStat to examine spatial clustering relationships between daytime and nighttime crime events. Exterior illumination was also examined to help validate the perception survey results. Lighting data for the macro light sources was gathered from computer aided design (CAD) data on landscape lighting as well as for large security poles. Additional lamppost location data was gathered utilizing six-inch color aerial photography. These points were enhanced with buffers to examine the predicted illuminated areas around each pole and for the entire campus area. This data was overlaid onto the density surfaces to examine relationships between lighting, nighttime crime, and perceptions of unsafe areas.

The daytime perception data yielded results primarily and unexpectedly related to foot-traffic and transportation safety while the nighttime data related to more classic safety concerns at points located across the entire campus and their relation to lighting extent. The

perception data clusters were layered and an intersect procedure used to extract areas of similarity within the study's subgroups (e.g., male/female, east/west/off campus). Results from this study suggest a high level of clustering of perceptions of unsafe areas but these do not necessarily correlate with areas in which crime actually occurs. However, there were similarities between poor lighting conditions and unsafe perceptions.

Additional data analysis illustrated expected outcomes such as females were much more likely than males to be cautious on-campus and travel much less frequently during the nighttime. Other analyses indicated that perception does not necessarily relate only to where a person resides, for example, students who resided on the western portion of Appalachian's campus perceived the central and eastern areas of campus to be less safe than their own areas. Results from this study may potentially be used to create a safer real and perceived environment for students at Appalachian as well as offer a more focused crime prevention régime for police. This study's framework and methods could also be implemented in planning other college campuses or in an urban planning context such as in downtown revitalization or neighborhood redevelopment projects.

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Chapter 1
Introduction

Appalachian State University is a mid-major southern university with a main campus student population of over 16,000 and a supporting faculty and staff of over 2,100. Due to the increasing popularity of Appalachian and goals set by the University of North Carolina system, the student population is expecting continued growth over the next several years. This influx in interest as well as an enhanced transportation network to larger cities in the region has also aided the growth of students and visitors to Appalachian.

This rise in student population at Appalachian has been accompanied by increased crime rates. Annual college campus crime statistics are mandated by the Jeanne Clery Act (Crime Awareness and Campus Security Act of 1990) to be released to the general public in the fall of each academic year. According to Appalachian's 2009 Yearly Crime Report (Appendix A), the 2008 - 2009 increase in actual crime has been in forcible sex offenses, burglaries, motor vehicle theft, and larceny. While larceny had significant growth, all other categories experienced only a slight increase. Additionally, there was an increase in forcible sex offenses in 2005, larceny in 2007, and burglary in 2006/2007. Since 2005 most events have decreased or normalized, but the heightened concern over these events has continued.

Crime prevention and improving campus safety is an issue that is increasingly in the media. Society seems to view places of higher learning as places that are relatively safe; in actuality, American campuses are open cities. In recent history there have been several nationally prominent college campus violence events. The first was the massacre at Virginia

Tech University which stunned the nation and made academic institutions take notice of the potential for violent crimes on campus. Less than a year later a similar event took place on the campus of Northern Illinois University. In addition to these very public events, campuses are experiencing small scale events of varying types of crime on a daily basis.

Prior research (Eck et al. 2005, Harries 1999; Kelling and Coles 1996; Newman 1996) suggests a relationship exists between environmental design, perceptions of safety, and crime rates. This study will further advance the knowledge of the relationship among these three factors, using Appalachian as a case study. The knowledge gained in this study may help Appalachian become a safer place and it could also be applied to environmental design and safety in other public areas such as parks, shopping centers, and downtown corridors.

According to research done thus far, there are also few studies on mapping exterior lighting using a Geographic Information System (GIS) and on creating spatial models to examine crime and its correlation to lit areas and people's perceptions of crime (Getis, et al. 2000). Additionally, there is little research into quantifying student victimization and campus crime levels beyond macro studies, so there are gaps in the field requiring further investigation (Fisher et al. 1998). Currently, there is an interesting combination of literature on crime on college campuses, lighting, safety, mapping crime, people's perspectives on crime, and campus design for safety. However, interestingly enough, there is a void of integration of these components such as an individual's perspectives on safety on their college campus, lighting, and crime on campus, while a map of perceptions of student fear was created in 1981 at the University of North Carolina at Chapel Hill (Richard Kopec, "UNC Co-Ed Anxiety Map," 1981, Geography Department), few studies have examined fear on college campuses. Even more so, there is yet no research focusing on how to visualize these topics spatially through GIS modeling.

In the post Virginia Tech and Northern Illinois era that we live in, safety and designing safer areas for the public are important functions of urban planning and public safety. To further study an individual's perceptions of safety, crime, and external lighting, this case study will examine the three previously mentioned topics at Appalachian. The model created was composed of a layer for each of the following: survey results from students on their perception of unsafe areas during the daytime and nighttime on campus, crime events that have taken place on campus and outside of buildings during the 2008-2009 academic year, and the estimated on campus external lighting distribution. Additional data was included such as emergency blue light phone locations and an indoor crime count per building.

It is expected that this model will show an intricate and meaningful relationship between where people feel unsafe, where crime is taking place, and where there is low lighting. The model should also give a clearer picture of where different types of crimes are taking place at Appalachian. Statistical operations were also performed to further show any clustering of perceptions of unsafe areas and crime. These statistics are derived from the CrimeStat and SPSS statistical packages.

The methods used for this research rely on statistical and GIS methods that have been used for years but are now being applied to a subject using a relatively novel methodology involving three layers. The first layer was derived from a public survey of students at Appalachian. This survey asked respondents to give standard descriptive data as well information on whether or not they live on or off campus, and if they live on campus which dorm do they live in. They were then asked to mark three point locations on a map of Appalachian's campus in places where they felt unsafe and rank them one to three for daytime locations based on their perceptions. Then they were asked to mark three more point locations on the same map of Appalachian's campus in places where they felt unsafe during the nighttime and rank them A, B, or C based on their perceptions. This data was digitized and attribution given to each point. The data was rasterized to show areas on campus where people feel the most unsafe. This data has yielded a tremendous amount of information because it can be disaggregated and additional studies can be performed, for example, on areas where males feel unsafe, females feel unsafe, or where people that live off campus feel unsafe.

The second layer is the crime layer, based upon the university's police department data on every event that they respond to. These can range from a nuisance violation to more serious crimes. This data was gathered for the 2008-2009 academic year and digitized into a GIS layer. Each point was given attribution for the date the crime took place, the time of the crime, the location of the crime, and the severity of the crime. This data was then rasterized, giving us a representation of where crime has historically taken place and at what level of severity.

The third layer is the lighting layer, based on mapping of each light pole on Appalachian's campus. The type of light source was identified in the attribution and proximity buffers were created based on estimated pole spacing. This buffer layer represents the estimated illuminated areas on the campus.

These layers were placed into a GIS where they were examined through a variety of mathematical and statistical operations. The result was a series of maps that show models of the campus depicting different correlations between the crime data and the survey data, or other combinations of data, or all three data sets combined. Nearest neighbor analysis was performed on the point data to assess the clustering of point locations. CrimeStat (Levine 2010) was also used to process nearest neighbor hierarchical cluster values to further develop the understanding of the data gathered. Finally, the visualizations produced with GIS offered a new way to perceive crime that has taken place and the diurnal variations of campus crime. Additionally, correlations between the areas illuminated on Appalachian's campus and places where people feel unsafe were also visualized. The following chapters will discuss the data, analyses, and results of this research in greater depth.

Chapter two examines the literature on the subjects of geography and place, lighting, environmental design, Crime Prevention Through Environmental Design (CPTED), crime and campus safety, GIScience, and geographic visualization for crime analysis. Chapter three further presents the geography of the study area and Appalachian's campus. This chapter also discusses the methods used for the data gathering techniques and analyses of the layers previously discussed. Chapter four examines the analyses and results for each of the data layers gathered. Chapter five discusses possible reasons for the results discovered and this chapter concludes with three specific areas highlighted in the daytime as being unsafe and four specific areas highlighted at nighttime as being unsafe based on the survey respondent's perceptions. Chapter six concludes the thesis with a discussion of future work and the broader implications and knowledge gained from this study.

Chapter 2
Literature Review

Place and the Geography of Perception

The concept of place represents one of geography's five major themes and is the foundation for the research and methodology of this study. Place is best examined with a framework that is structured around epistemological pluralism. This is because place is examined in multiple geographic subfields as well as in many other academic disciplines. Place has long been explored in an attempt to understand varying processes at the macro and micro scale as well as giving distinctive characteristics to these areas (National Research Council 1997). Place also incorporates people's experiences, values, and their perceptions, which are all critical components of this study.

According to the National Research Council (1997), research on place has shown that people follow "typical patterns" in certain environments resulting in the distinctive characteristics of place, a component of both human and physical geography. These patterns and places can be compared to others thus clarifying geographic variability, but, as indicated by the National Research Council (1997), geographic variability must take into account processes that cross boundaries of different areas such as crime that happens in a community and crime on a college campus within that community. This also shows the interdependencies of place within even a relatively small geographic area.

Nested within the broad geographic theme of place is the concept of the anchor point (Rossmo 2000). Anchor points play a critical role in people's lives, in their perception of places, and with their mental maps (Golledge and Stimson 1997). An anchor point is the most important place or places in a person's life; most often they are people's home or place of work (Rossmo 2000). These often spatially fixed places are not the same for criminals. As pointed out by Rossmo (2000), a criminal's anchor point may be a certain street or it could be similar to that of a homeless person, constantly changing. Most importantly, understanding a criminal's or a non-criminal's anchor point is critical to deciphering crime patterns and mental maps.

Mental maps are a representation of a person's environment and thus a function of a person's perception of safety and the environment in which he or she lives (Saarinen 1976). These maps are formed in people's minds based on their interactions within their routine activity spaces and the memories created from these nearly constant interactions (Golledge and Stimson 1997; Rossmo 2000). However, as Gould and White (1986) point out, people cannot retain the infinite amount of information that we observe daily; therefore we have mentally created screens that separate pertinent information from information that we can forget. For example, when examining perceptions of campus safety, Wilcox, Jordan, and Pritchard (2007) have found that females' perceptions and fears during daytime and nighttime far exceeded males' in their study examining certain criminal offenses. This illustrates one of many examples of how humans screen out certain information and thus create their own perceptions based on the individual's sex and society's enforcement of certain criminal patterns towards females. It also gives an example of Saarinen's (1969) description of how the decision making process is dissimilar from one person to another, consequently causing variations in perceptions.

Matei (2000) describes people's mental maps and perceptions as having a push/pull effect on decisions: comforting areas are seen as attractions and discomforting areas are seen as repellents. His study further pushes the mental map and spatial perception boundary by including the influence of the media on these factors. The media acts as an information pipeline that distributes data constantly in the popular forms of television, newspaper, internet, and radio. These information sources strongly influence a person's perception of a place and therefore, his or her mental map. If the media depicts a region, area of town, or social space as violent or dangerous, then people's mental maps and perceptions will be altered to avoid these areas (Matei 2000). Fear often changes mental maps and perceptions of an environment. However, changing a perception or mental map away from fearful or negative notions, toward more positive images, can be more difficult (Gould and White 1986). One way to positively affect a person or group's mental map is through better planning, lighting, and environmental design. In negatively perceived areas these may be some of the best tactics for altering fearful mental maps or perceptions.

Lighting, Environmental Design, CPTED, and the Built Environment

Lighting in urban environments serves multiple roles. Typically, its main role is to light streets for safer transportation. Beyond just lighting the streets, it also serves as a method of crime deterrence, a safety aid, and sometimes even as an aesthetically pleasing addition to the community. Many studies have been conducted on lighting in the built environment. Some of these studies are more quantitative and financial in their methodology and others are more qualitative, focusing on how people feel about having more or less lighting.

One of the first people to realize the effects of environmental design and good lighting was the famed urbanist, Jane Jacobs. According to Stuart Meck (2005), Jacobs realized good lighting lets the eye account for more of one's surroundings and encourages people to go outside because, in order to be safe, sidewalk areas must be usable for both the daytime and the nighttime, serving as a type of multimodal use. Jacobs (1961) also believes that lit areas like sidewalks bring about pride in a neighborhood and surrounding areas, thus reducing crime because people are keeping watch over their community and neighborhood. However, even if more individuals take pride in their community and watch out for it, controlling crime is a difficult task. There is only so much legislation and planning that can be done because at some point, crime is going to happen, and it is the crime analyst/planner's responsibility to mitigate and prepare for its impacts.

Oscar Newman's studies of environmental design and crime prevention in his work, *Creating Defensible Spaces*, used by the U.S. Department of Housing and Urban Development (1996), helped move these concepts to the forefront of urban planning. The primary concept behind a defensible space is to reorganize and redesign the physical areas that are not as safe into areas that are defensible and attractive. This would entice people to be more proactive in self-policing which would, sequentially, reduce crime. Additionally, Kelling and Coles' Broken Windows Theory (1996) also relates to the mitigation of crime and environmental design relationship. Kelling and Coles (1996) found that the existence of neighborhoods in disorderly conditions correlated to a fearfulness of crime from residents. If an area is poorly lit, not very visible, run down, and people are not proud of the space then people will become fearful of that space, and it will become a crime magnet.

Since lighting creates a sense of pride and promotes a sense of community, it is critical that light is included into defensible spaces. Including thoughtful light designs in new construction in commercial, industrial, and residential settings is a critical component of a defensible space. Light can be a tool to affect our emotions. Improved lighting has been a popular strategy for bettering community safety and reducing fear of crime for over a century (Pain et al. 2006). Certain patterns and light strengths can be used to create shadows of the unknown or high wattage lighting can be used to light an area up like an athletic field. According to Mellard (1997), a lighting plan should include continuous illumination, unexpected lighting, and shadows to create an intimidating effect on people that may have no reason to be on a piece of property or specific area. People are afraid of shadows because they represent the unknown. Criminals could fear the security or police officer that may be standing in that shadow. Mellard (1997, 42) says that shadows can be incorporated into a lighting plan to “disorient an intruder and even make it easier for an officer to apprehend the criminal.” Zahm (2004, 535) poses an interesting question: “is it possible to reduce crime and fear without just creating ‘brighter’ lighting?”

Incorporating all of these techniques into a lighting plan at the micro level is beneficial. Mellard (1997) conducted a study at twelve high schools: six were lit very brightly at night and six were left in the dark. According to Mellard (1997, 38), “Contrary to what one might expect, the six schools that were brightly illuminated experienced an increase in crime and vandalism, while the six left in darkness experienced the same level of crime as before.” It appears that the bright light attracted nuisance criminals to the sites. Bright light may even make the criminal’s job easier by providing a “work” environment with favorable visibility (Mellard 1997). Farrington and Welsh (2002) also report that better lighting could, in certain situations, increase the possibility for crime by bringing more people to the same space and increasing visibility of victims and their possessions.

CPTED (International CPTED Association 2010) is an effective design standard and tool set for preventing crime and dealing with some of the aforementioned issues. Part of the CPTED concept is to examine foreseeable danger, similar to a risk analysis, then take a nonpolitical stance so as to rise above partisan beliefs, and finally to manage the criminal risks (Parnaby 2006). The CPTED concept is one of risk management as people that practice CPTED work to prepare clients for potentially devastating criminal situations. CPTED should seek mutual understanding between all people involved. However, it seems that involving the CPTED logic is often rejected by designers and planners due to increased planning time and resource expenditures. However, there are projects where one can see an underlying CPTED methodology.

For example, consider the Beverly Hills, California shopping district. Downtown Beverly Hills was looking to attract more shoppers and nightlife as activity moved away from the downtown shopping district into newer retail areas. Part of the concept was to increase the area’s pedestrian safety. As Jane Jacobs (1961) has described before, lively streets and sidewalks are safe places. One of the steps taken by Beverly Hills was to widen their sidewalks to encourage more foot traffic, thus attempting to have pedestrians act as crime deterrents through their presence. They also implemented new lighting. Smartly, the city “designed the lighting for both roadway and sidewalk lighting in a modular format so additional lights or signs can be added as needed” (Dombrowski 2005, 32). One can see the CPTED idea employed in this situation. Risks were identified, planned for, and thus mitigated against.

The City of Chicago undertook a similar project in their back alleys. The Green Alley Project utilizes many green concepts including permeable, high albedo pavement, and dark sky lighting (Lynch 2007). The dark sky lighting is not initially sought after as a crime deterrent. However, since it is focusing light down and out and not in every direction, more wattage is being efficiently used to illuminate the human environment. In turn, light pollution is decreased as well. Rome, Italy is also undertaking a similar project. Rome is looking to dim light, but shine all of the light down through the use of dark sky lighting. According to the article, “Romans Reach for The Stars” in the *New Scientist* (2005), this will save Rome up to forty percent on its lighting bill. This plan and the Chicago plan are great examples of multimodal environmental design. The concept of environmental design is being used to eliminate several problems through a series of projects and applications.

Of course, there is skepticism to lighting and crime. Research suggests that improved lighting does not necessarily prevent crime; it just lessons people’s fears (Herbert and Davidson 1994; Clark 2002). Obviously, light is beneficial for detecting and recognizing people, but how does one recognize a threat? This concept refers back to Mellard’s ideas about implementing a varied light design by using techniques such as intermittent and unexpected lighting. A function of Clark’s (2002) work on lighting focused on how the media has, in the name of crime prevention, influenced increasing street lighting in quantity and brightness. In the 1990s United Kingdom leaders were convinced by a broad pro-lighting movement to install brighter exterior lighting to aid in the reduction of crime (Clark 2002). However, in early 2002 studies were conducted on street crime in the United Kingdom that revealed a twenty-eight percent increase in crime, thus showing inconsistencies with the potential preventative effects of increased lighting (Clark 2002).

In Clark's (2003) second work on outdoor lighting and crime, he continues to dissect the need of excessive lighting. One such example was the Boston suburb of Lexington, Massachusetts. Lexington installed approximately 3,600 street lights. In the early 1990s the leadership of Lexington decided to turn off every other light and if people complained then their individual light was turned back on. Over time 1,300 street lights had been left off. Clark (2003) followed up with the Lexington trial and found that ten years later about forty percent of the town's original number of street lights turned off were still not operating. Subsequently, the Town of Acton has also applied similar methods to save money by enacting a twenty-year freeze on new street light installations (Clark 2003). This helps to demonstrate that lighting quantity is not always the answer to quelling people's fears; sometimes it is beneficial to be more strategic in light placement.

Clark (2003) also discusses the relationship between population, crime, and lighting. Given the enormous size of crime and population datasets and the information the data offers; positive spatial correlations intertwined with positive temporal correlations show lower crime rates in darker areas. Interestingly, lighting demands coupled with community growth are causing power disruptions at night (Clark 2003). The negative correlation, long held by crime prevention practitioners that brighter lighting inhibits crime is showing trends towards being incorrect because of the substantial volume of criminal activity conducted during daylight hours (Clark 2003).

Light attracts people, so why install a brighter light when it is only going to allow criminals to see what they are doing that much better? Some consider the best way to prevent and/or deter crime is to practice solid crime mitigation through environmental design and lighting is a component of environmental design. For example, Newman's (1996) concept of defensible spaces comes from studying two similar high-rise public housing facilities, Pruit-Igoe in St. Louis and Cabrini-Green in Chicago. From these and other studies, he concluded that a defensible space must have zones of territorial influence where people can have a sense of territoriality. Surveillance opportunities for residents allowing for common areas to be seen and self-policed must be present and lighting is a function of this surveillance. Finally, Newman (1996) concluded that there must be a certain image and ambiance to the structures, which is to say that the structures and their interiors should not have an institutional feeling. These areas should be just as welcoming as any others. The ability to manipulate lighting plays a role in creating these feelings. Again, Mellard (1997) says that a lighting plan should include continuous illumination, unexpected lighting, and shadows to create an intimidating effect. Including these lighting features into a defensible space is an effective way to help deter crime and deliver a sense of safety.

In order to have a better effect on deterring crime, decision makers need to use environmental design and lighting techniques. A common misconception is that lighting alone will deter crime. However, this seems to be untrue. There are many ways to improve crime prevention, such as increasing police presence and improving lighting. People-centered designs can work hand-in-hand with crime prevention and environmental awareness. Meck (2005) discusses how our current neighborhoods and most newly developed neighborhoods are still being designed with the post World War II mindset of a wife staying at home and being able to look out over an area of the neighborhood and keep watch, which is a function of Newman's (1996) idea of surveillance. This concept focuses on designing our neighborhoods and urban areas to be automotive and building-cost friendly and does not take into consideration the on-the-go lifestyle of a modern family. If neighborhoods are built to be more people friendly then communities will end up with more guardians in those neighborhoods because people will want to live there and thus not solely relying on police officers. These “guardians” will be concerned neighbors, neighborhood watch associations, or just people who are driving or walking by and observe something that is out of place and/or dangerous.

Communities need better designing to build these human centric environments. Lighting should be addressed as a function of crime prevention and safety. While dimming or altering lights could be beneficial, people will not want to cut them off all together. Communities must also still be mindful of nontraditional situations such as handicapped individuals. This also applies to college campuses because their demographics are changing towards a more diverse, non-typical age range as older persons return to college to start new careers or gain an advantage in existing companies (Kressley and Huebschmann 2002).

Both Kelling and Coles (1996) and Newman (1996) have had their environmental design techniques implemented and have had some success. As society, researchers, and designers continue to build on their environmental design successes, our cities and neighborhoods will become safer and have more healthy environments to live in, thus reducing crime and its threats. Jacobs (1961) has also had success with her planning and environmental design theories. Her idea of busy streets and sidewalks during daytime and nighttime making for a safer place to live is correct. However, it is the interaction between environmental design and the residents of an area that make a city, neighborhood, or even a college campus a safer, less crime ridden area, and turns it into a better place to live.

Crime and Campus Safety

Criminal activity occurs, whether we like it to or not. In our current, declining economic state, there has been a resurgence of crime. An example of this is the very public and prearranged ambush, robbery, and murder of a Brinks Armored Car officer at 10am on Monday, December 15, 2008 in front of the Old Navy store at Greensboro, North Carolina's Friendly Shopping Center (Elmquist and Wise, "Robbery resembles ambush, police say." *News & Record*, 17 December 2008). An event like this has not happened before in recent Greensboro history. Across the nation crime is occurring in more unusual areas as people become more economically constricted. Some of this crime can be avoided by increasing police presence or changing security procedures. However, sometimes the best way to suppress crime and increase people's safety is through implementing a change in environmental design and analysis of crime.

Campus crime and safety has become a function of community safety and crime prevention regimes because college and university campuses are seen more and more as a component of the community and less as a secure ivory tower because of recent watershed events. Two events that come to mind are the shootings at Virginia Tech University in Blacksburg, Virginia and the shootings at Northern Illinois University in DeKalb, Illinois. However, there is little research into quantifying student victimization and campus crime levels beyond macro studies, so there are some gaps in the field (Fisher et al. 1998). Fisher et al. (1998) discusses the demographic characteristics of crime victims on college campuses by examining the National Crime Victimization Survey (NCVS). A critical component in campus crime victims is age; the younger the student, the more likely they are to be victims of a crime (Fisher et al. 1998). The other components indicated by Fisher et al. (1998) were a student’s “single” relationship status and the increasing number of students per campus, all components of a constantly refreshing pool of potential crime victims.

A key component of campus crime and safety is students’ lifestyles. Fisher (1995) expresses that most often, when college students are victims of crime, the person responsible for committing the crime against them is typically fellow a student. Research has been conducted on the theory that routine activities are associated with victimization. Therefore, some more dangerous lifestyles and types of daily routines are associated with more crime activity than others (Tewksbury and Mustaine 2003). Not surprisingly, Tewksbury and Mustaine (2003) explain that lifestyle factors contributing to crime events and victimization tend to revolve around alcohol and drug use as well as social activities away from students’ anchor points or homes that last into the night.

Fisher et al. (1998) explains crime events and victimization in four categories that are discussed below: 1) proximity to offenders, 2) accessibility and exposure to crime, 3) attractiveness to the criminal (symbolic or valuable possessions), and 4) lacking guardianship to prevent the crime.

Proximity and exposure to crime or offenders is an intriguing component of crime theory when examined within the context of a college campus. This is because as students live and pass through a campus they are in situations that place them in close proximity to potential victimization by the sheer number of other people existing in the same space, just like in a dense urban environment (Fisher et al. 1998). Woven into the proximity of a student to crime is their exposure and vulnerability to crime. Youthful vigor and boredom are factors that often result in exposure that can often result in a propensity for criminal activity and/or becoming more exposed and susceptible to criminal events.

Further compounding this is dormitory living. Students and their possessions are on-campus around the clock for many months, thus presenting an abundance of high value items to be stolen (Fisher et al. 1998). Interestingly, Fisher et al. (1998) found that students were 2.1 times more likely to experience theft on-campus than off-campus, but the aggravated assault rate was 4.5 time higher off-campus than on-campus, and the sexual assault rate was found to be 1.4 times greater on-campus than off-campus. This shows that some types of crimes, and how close a student is to those higher crime rate areas, depend on their living locations and anchor points.

Target attractiveness, when examining the prototypical college student is simple. Most students who carry large sums of cash are significantly more likely to be assaulted (Fisher et al. 1998). Furthermore, a college student body comes with a certain amount of higher value personal belongings that may include: flat screen TVs, computers, laptops, money, credit cards, jewelry, expensive clothing, cars, CDs, smart phones, or MP3 players. Fisher et al. (1998) also points out that the number of potential targets changes every semester and gets constantly refreshed and reloaded every fall semester, thus supplying an almost endless supply of potential victims.

The final crime theory is capable guardianship. This is the prevention of crime through interpersonal and/or target hardening devices (Fisher et al. 1998). As explained by Tewksbury and Mustaine (2003), guardianship activity could include possessing a gun, mace, dogs, extra lighting, or locking doors. In the collegiate world this can be a difficult task, especially for many young students who have never had to really think about safety and protection. Fisher et al. (1998) gives reason to believe that students living on-campus may have a higher rate of victimization due to a lack of capable guardianship than their similarly aged counterparts living off-campus because of the dense clustering of young people, often failing with the simplest of tasks, such as not locking a door and leaving themselves with a greater risk of victimization.

College campuses have a certain level of responsibility that is now reinforced via court precedents and by state and federal legislation. The first is to inform students about campus criminal activity as well as offer greater police protection. Colleges now have a duty to warn students about known risks (Fisher 1995). This is often done via campus-wide e-mails, text messages, or warning sirens. Colleges have a duty to provide students with adequate security protection (Fisher 1995). The level of protection depends in part on the level of need and known risks. Colleges have taken a number of measures ranging from ID cards with magnetic strips to gain access to secure areas such as dorms or research facilities, to increasing the campus police/security force or their visibility.

The Crime Awareness and Campus Security Act of 1990, later renamed the Jeanne Clery Act, mandates that any postsecondary school that receives federal funding and financial assistance must distribute annual statistics on certain crimes including: murder, negligent and nonnegligent manslaughter, forcible and nonforcible sex offenses, robberies, aggravated assaults, burglaries, arson, motor vehicle thefts, hate crimes, and arrests/disciplinary referrals for liquor-law violations, drug-law violations, and illegal weapons possessions. They must also maintain a publicly accessible crime log, and give timely warnings about any crime that is listed above (Crime Awareness and Campus Security Act of 1990; Fisher 1995).

This federal act, signed into law in 1990, requires greater transparency and responsibility by college campuses and their security/police departments. Fisher (1995) found that although progress has been made in increasing student awareness, problems still exist in regards to actually decreasing crime rates. Some problems also exist with campuses not following through with the expectations and requirements of the Clery Act. In December 2006 Eastern Michigan University officials discovered the body of a student raped and murdered in her room (Lipka 2008). After two months of covering up the facts about the event, even to her parents, Eastern Michigan University announced the arrest and charging of another student for the rape and murder.

The United States Department of Education conducted an investigation into the crime and cover-up. They found that Eastern Michigan University was not properly following the Clery Act by failing to warn the campus and student body of a murder, not maintaining a campus crime log, and improperly reporting crime statistics. This report resulted in the firing of the top three university officials, including the president, and the highest fine ever imposed via the Clery Act, $357,500 (Lipka 2008). Cumulatively, the case cost Eastern Michigan University at least four million dollars in fines, settlements, severance packages, fees, and security improvements (Lipka 2008).

Campus crime awareness and prevention is an important part of a community's efforts to reduce crime. It is critical that college campuses work within their boundaries to prevent crime and educate students, faculty, and staff of potential problems or better personal safety tactics. However, it is critical to acknowledge that college campuses no longer stand alone like an island in a community or an untouchable ivory tower. While a campus boundary does exist on paper, to a potential criminal (student or non-student), boundaries have no meaning because very few campuses are gated and protected. Thus, it is important to keep under consideration the transient population and crime that may spill over from the community into a campus when creating a campus crime protection regime.

GIScience and Geographic Visualization for Crime Analysis

Crime analysis has become a vital tool to both federal agencies and local police offices. For example, Getis et al. (2000) focuses on the capabilities and potentials of GIScience techniques currently being used for crime analysis and crime research. Additional papers from the United States Department of Justice, Office of Justice Programs (Harries 1999; Eck et al. 2005) focus on techniques used to examine and analyze crime and hot spots through more advanced crime mapping techniques.

In 1999 the University Consortium for Geographic Information Science (UCGIS) met in Minneapolis, Minnesota to discuss the effects and possibilities of GIScience in an array of subfields within the science. At the 1999 summit an important discussion area was crime analysis because of increasing crime rates and the increased capabilities of technology to analyze and create solutions for criminal activity. GIScience has since risen to the forefront of crime analysis for many reasons.

Firstly, the cost of new technology is decreasing. This decrease in costs has led to an increase in technology availability which has led to the integration of GIS capabilities into police departments with fewer resources. This technology allows for a greater clarity and insight into the criminal activity patterns and their underlying causes in a community or region (Badurek 2007). Most importantly, this technology has led to a reduction in crime where applied. These novel perspectives on spatially oriented crime data does not necessarily detract from additional forms of data and analysis; rather it supports a richer analysis of the what, where, when, and who aspects of crime data (Pain et al. 2006).

As positive as all this seems, a study, highlighted by Getis et al. (2000), and completed in 1999 examined the digital mapping capabilities of police offices around the nation. The study found that the digital divide still exists, but officers do feel the technology would aid their efforts. The study found that only thirteen percent of departments surveyed actually used a GIS to aid their crime fighting efforts. It also found that the capabilities of a GIS are still being used at very basic levels for tasks like geocoding, digital pin mapping, service call locations, and some hot spot mapping. These are not necessarily poor uses of a GIS. However, these are a less powerful set of techniques and analyses compared to higher-end modeling and geographic visualization.

When the UCGIS decided to look deeper into the crime analysis subfield of GIScience, they made two conclusions. First, to a police department and to a police officer what matters the most is location, location, location. This is due to the apparent non-random nature of crime as an event in time and space, so everyone wants to know where the next crime will be taking place and equally important, why will it be happening? Second, a police department and a police officer want to better understand the criminals and their behavior. While this can be aided greatly by a psychologist, there can be a tremendous amount of information gathered from the spatiality of crime events.

Another part of the UCGIS summit was to look at institutions currently doing research in the subfields being discussed. The UCGIS found that universities and colleges, as well as Environmental Systems Research Institute, Inc. (ESRI), are doing research on crime mapping and analysis. A large federal agency working on the research is the Department of

Justice's (DOJ) Geographic Information Systems and Spatial Crime Analysis System which supports the National Institute for Justice, which houses a Crime Mapping Research Center and a Crime Mapping and Analysis Program. Additionally, the Federal Bureau of Investigation (FBI) utilizes extensive crime mapping technologies. Across the nation, National Community Demonstration sites exist in cities being used as examples and "guinea pigs" for crime mapping and analysis techniques. It is the aim of UCGIS to expand the number of institutions actively pursuing crime analysis research as well as to broaden the types of tools and techniques being used to analyze and examine crime data.

While research has been done, more needs to be accomplished in moving GIScience and crime analysis forward. A few research areas are GIS and society, computer power versus dataset size, spatial forecasting, prediction, projection, mapping the causation of crime, and spatial analysis in a GIS environment (Getis et al. 2000). These broad areas are just a smattering of the research topics in the field of GIScience and focused into the subfield of crime mapping. The National Institute for Justice has further examined how to analyze crime data to find hot spots through focused research as evidence in Eck et al's (2005) report on "Mapping Crime: Understanding Hot Spots."

GIS and society is a broad topic, but when focused on the crime analysis subfield it is an interesting way to join policing with the community in a public participatory GIS. It encourages greater partnership with the police force because the citizens can pinpoint areas they perceive to be dangerous or areas they feel safe in. GIS and society studies offer the opportunity to look at crime in a more regional level by combining smaller community datasets with larger state datasets. This data could be uploaded onto GoogleEarth™ to provide publicly available crime data. Additionally, a Really Simple Syndication (RSS) feed could be added to this mapping function to give the public the opportunity to be updated as crime occurs. As the crime event is logged, a point would be generated with attribute data and the hot spot map would be updated simultaneously to show the change.

Computing power is a critical function of quantitative GIScience and crime analysis, even in its fledgling stages in the late 1960's. As mentioned earlier, technology is getting more affordable with time, but the corollary is the datasets are getting larger and more detailed which requires greater computing strength to model and visualize these datasets (Lavalle, McConnell, and Brown 1967). This also poses an additional problem: if more computational power is needed to develop these models of detailed datasets then that computational power is being tied up doing mapping, and not on other vital police operations.

There is vast potential for three-dimensional applications in crime analysis as well. This requires additional computational and graphical power. This type of computational ability is not always the most affordable, but the "in-the-field" results are visible. Eck et al.'s (2005) hot spot mapping pamphlet, while an excellent foundation for hot spot mapping and spatial statistics, does not sufficiently go in depth into the computational requirements of spatial analysis or three-dimensional analysis. A simple Google™ search for "three-dimensional crime mapping" or "crime analysis and GIS" will render an array of advanced and modern map images that will give one a taste of what is possible in 2010.

Tied to spatial modeling is spatial forecasting, prediction, and projection. This is a critical component of effective crime analysis and mapping. Crime often has a natural cycle to it and can be spatially and temporally forecasted. Furthermore, these forecasts need to be recognizable by the type of crime based on the season of the year, time of day, and day of the week. This helps validate, model, perform quality control, and train the crime models. Additional data needs to be used, like surveillance data from street cameras that can help to provide additional perspectives on the environment. This type of data would allow for the inclusion of the temporal factor. At this point, a space-time model could be created that will offer an analysis of where and when crime is taking place as the day progresses.

What causes crime is a larger question than where and when a crime takes place. Understanding crime's causation can help lead to a greater understanding of the community, society, and their general health. There are many known factors to crime which include: low income community areas, poorly educated individuals, a history of juvenile delinquency, and unemployment (Harries 1999). What makes all of these factors spatially significant is location, and as such, their ability to be mapped. Using United States Census block groups, all of these factors can be mapped quickly and used for analysis at a more detailed level. How can these datasets be used to better understand the crime data that is already available? Some of this information can come from the criminals themselves and their records. This would lead to a greater understanding of the criminal population and where their actions are spatially distributed.

A better understanding of crime is critical to our communities and GIScience is a key component of that understanding. More investments should be made in furthering geospatial education and to examining crime in a spatial manner. Furthermore, GIScientists need to better understand additional spatial factors like economic health, modes of travel, and environmental design to help aid in understanding functions within the larger picture of crime. Finally, great strides need to be made to move this research from the university or government lab to the officer in the field. Our police forces should not be expected to research and develop new techniques; they should be released by universities or government authorities to the police departments in communities that need it the most, in a timely manner.

Vivid and accurate three-dimensional visualization of geographic data has been a goal for geographic information scientists. The current "gaming" computer platforms that boast high amounts of processing power, random-access memory (RAM), and graphics capabilities matched with a robust GIS platform and high definition monitors has allowed for a steady increase in the availability of three-dimensional geographic visualizations. This capability has been utilized in many arenas, ranging from mountain topography visualization to battlefield modeling to crime mapping and analysis. The utilization of three-dimensional visualization and GIScience in the fields of crime mapping and homeland security has recently come a long way.

It could be stated that the majority of three-dimensional visualization with geospatial data is performed on either an open source GIS like GRASS™, or is done using ESRI's ArcScene™ package. Either way, the foundation of three-dimensional analysis is the ability to take a raster data set and interpolate it into a wire mesh structure or a triangulated irregular network. This allows any other data to be draped over it so that it takes that substructure's three-dimensional form. There are other ways to visualize data three-dimensionally. Vector data can be extruded based on an attribute; for example, crime data can be extruded based on severity. In this case, a more severe crime will have a taller representation than a lesser crime in a three-dimensional visualization.

There is additional research on these applications conducted in the United States and abroad. An intriguing piece of work has been done by Markus Wolff in Cologne, Germany.

He and his colleague, Hartmut Ashe, are visualizing robbery densities in the three-dimensional environment. This team used the LandXplorer™ three-dimensional modeling software to do their studies. Cologne has approximately 22,000 buildings (Wolff and Ashe 2009) that were turned into three-dimensional models with roof lines. Using the wire frame of the city's topography, they were able to drape across it many different layers of their study. They also used spatial interpolation methods to further their examination of the city's crime.

Crime analysis and geographic visualization is an important and up-and-coming tool for many police departments. Currently, only well-funded large metropolitan police departments are using this technology. This type of analysis begun with push pin maps on the wall of the police department and now it has spring boarded into robust three-dimensional examination of criminal activity. The types of analysis run by Wolff and Asche (2009) are important to the greater understanding and furtherance of the field of three-dimensional analysis and visualization. For both the Appalachian study and the Wolff and Asche study, the next level of the visualization is the fourth dimension, or the temporal component. Temporality is one of the themes of this study and will help to focus the university or municipality's efforts even further and will hopefully result in a more true deterrence of crime.

This study examines all three of the topics discussed in this literature review. The study examines perceptions of safety, crime, and lighting together within the constraints of a college campus. This smaller microcosm of a more populous urban environment allows for greater model development, better focus on a more homogeneous demographic, and the potential for model implementation in a larger scale urban environment. In the following section, study area and methodological framework will be discussed and examined as it pertains to gathering perceptions of safety, crime data, and lighting data.

Chapter 3
Methods

Study Area

Founded in 1899 with fifty-three students as Watauga Academy, Appalachian State University has grown into a mid-major southern university. Appalachian's campus is located within the small college town of Boone, North Carolina. It has a main campus student population of over 16,000 and a supporting faculty and staff of over 2,100. Due to increasing popularity of Appalachian and goals set by the University of North Carolina system, the student population is expected to grow tremendously over the course of the next several years. This influx of students, as well as growing transportation networks to larger cities in the region has created a greater number of students and visitors at Appalachian.

The campus (Appendix B) is bound to the north by the Town of Boone's historic district and to the south by mountains with residential structures. To the west the campus is bound by mountains and more of the town's historic downtown area. To the east Appalachian is bound by a major highway, US 321. Furthermore, the campus is bisected, northeast to southwest by a four-lane road, Rivers Street. Rivers Street is a major collector for the Town of Boone's transportation system, allowing students, faculty/staff, buses, visitors, and business people access into the campus. This street creates the east and west halves of Appalachian's campus that will be referenced throughout the following sections of text.

A previous study on perceptions of safety found that "students and faculty may face a dual victimization risk, being vulnerable to crime committed by outsiders as well as insiders within the campus community" (Jennings, Grover, and Pudrzynska 2007, 193). Furthering this vulnerability is the copious number of complex variables that effect crime. This continues to point to the fact that examining campus crime and safety must be done through multiple lenses and focused into a model able to distribute the variables dependent upon criterion set for analysis.

Perceptions of Safety Survey

Survey Instrument

The survey instrument (Appendix C) used to gain a fuller perspective on student's perception of safety at Appalachian was designed to be simple yet thorough. The survey contained three to four demographic questions, depending on the answer of the third question. Following the demographic questions were the questions identifying the student's perceptions of safety. Attached to each survey was a map of main campus, including roads, sidewalks, major athletic facilities, and major construction projects. Each respondent was asked to mark on their survey map three places they felt unsafe during the day and three places they felt unsafe during the night. The respondent was asked to weight each point with a 1, 2, or 3 for the day and an A, B, or C for the night. 1 or A corresponded to the most unsafe feelings while 3 or C corresponded to feeling slightly unsafe.

Following the mapping component each respondent was asked to write two or three sentences about why they felt unsafe in these locations and finally, what they would do to change these locations to make them safer. Each survey took approximately ten minutes.

Survey Implementation

During the first quarter of 2009, 758 surveys were administered to undergraduate and graduate students at Appalachian. To facilitate a broad number and variety of students, campus contacts, professors, and clubs/organizations were used. The survey received good responses from the respondents and was commended regularly for taking a new approach to student and campus safety. Of the 758 surveys administered, only sixty-two (8.18 percent) were considered unviable because directions were not followed.

Survey Data Digitization and Modeling

Once the surveys were completed they were gathered in a central location, evaluated, and prepared for data entry. The first step was to cull and highlight the surveys. The surveys were placed into three stacks; completed properly, blank (i.e. the student had no perceptions of unsafe areas on campus), or incorrectly filled out. The incorrect surveys were counted, numbered, and set-aside. The blank surveys were counted and numbered as well but not included in the model. The properly completed surveys were evaluated. The three places marked on the map for daytime perceptions of being unsafe were circled with an orange highlighter. The three points noted for night-time perceptions of being unsafe were circled with a blue highlighter. This was done to ease digitization into the GIS environment.

A Microsoft Access™ database was created for the first phase of data entry. Each survey was stamped with a rubber stamp number counter and its non-map information entered into a database form. Once this was completed, each of the maps' data was digitized into ArcGIS™. Two point datasets were created, one for the nighttime points and one for the daytime points. The unique identifiers used were the survey's number that was stamped onto it as it was entering the database, a “D” or “N” for time of day, and each point’s weight of 1, 2, or 3 for the day and an A, B, or C for the night.

Once the point data was digitized, a simple join was performed to bring the tabular data from the first page of the survey together with the surveyed perceptions of safety point data in the GIS. Once the data was joined, quality control measures were taken to evaluate the data, randomly pulling paper surveys and verifying the accuracy of its digitized record. Additional data was added at this point as well, such as living on east or west campus, based on the respondent’s response. Finally, points that were placed on buildings were removed because the nature of the study was to examine outdoor safety and the survey instrument specifically requested points that were not in buildings. However, points placed on the parking decks and on athletic stadiums were left in the study because these are generally considered open air facilities for the purpose of this study.

The survey data was analyzed with the CrimeStat (Levine 2010) software package as well as ArcGIS’ Spatial Analyst™ extension. CrimeStat was used to compute nearest neighbor statistics and nearest neighbor hierarchical clusters including second order clusters or, clusters of first order clusters (Eck et al. 2005). The nearest neighbor analysis generates several important outputs; the critical ones used for this study are the mean nearest neighbor distance, the nearest neighbor index, and the one/two tail p-values. The nearest neighbor index is a statistic that gives an indication to the level of clustering (Chainey and Ratcliffe 2005). It is a ratio of expected to observed nearest neighbor distances and can vary between 0.0 and 2.149 (Chainey and Ratcliffe 2005; Burt, Barber, and Rigby 2009).

The nearest neighbor index values have a range of 0 – 2.149. Results under 1.0 are considered clustered, values of 1.0 or close to 1.0 are considered random, and values towards

2.149 are found with relatively large nearest neighbor distances, meaning the points are dispersed farther from one another (Chainey and Ratcliffe 2005; Burt, Barber, and Rigby 2009). Combined with the nearest neighbor index is the one/two tailed p-values. A one or two tailed p-value less than 0.05 paired with a nearest neighbor index less than 1.0 means the chances that the phenomena analyzed is clustered to the extent that it is because of random variation is less than five percent, thus displaying a statistically significant finding (Chainey and Ratcliffe 2005).

ArcGIS' Spatial Analyst™ extension created Inverse Distance Weighted (IDW) interpolation models for the aggregate daytime and nighttime survey data. Additional IDW interpolation models and CrimeStat analysis were run on some of the disaggregated daytime and nighttime data (male, female, east campus, west campus, and off campus). Large point files (>500 points) were run with IDW parameters of a power of two, a minimum number of points as seventy-five, and a variable search radius. Small point files (< 500 points) were run with IDW parameters of a power of two, a minimum number of points as twenty-five, and a variable search radius (these settings were used only for east and west campus point files). These parameters were based on a series of trial IDW interpolations. The trials utilized a selection of the study's sub-groups and based on results that were meaningful for potential decision makers. Barrier polylines were not used because some points exist just outside the campus boundary but were included in the study.

Crime Data

Campus Crime Data

The one caveat of the data is that it only shows crime that is reported, and many crimes go unreported. This is highlighted when Carr (2007, 307) states in her *Campus Violence White Paper* that “Sloan et al. found that only 25% of campus crime is reported to *any* authority across all offenses.” The crime data came directly from the Appalachian online crime database (http://www.police.appstate.edu/crime-log). As discussed previously, yearly college campus crime statistics are mandated, by law, to be released to the general public in the fall of each academic year. Additionally, data for each police response event has to be publicly available for crimes committed. Appalachian utilizes a web based database that displays case number, date, time, location, nature of event, status, disposition, arrest information (name, sex, age, address, and employment), violations, and property seized. Information is withheld on identities of the complainant(s), victim(s), or witness(es). This database is updated every forty-eight to seventy-two hours.

Crime Data Selection

For the purpose of this study, crime data from the Appalachian campus crime log for August 20, 2008 to May 10, 2009 was used. The first day of class for Fall 2008 was August 26th. The crime data digitization started with August 20th because it is around the time of freshman move-in and thus the start of a school year. While this is not the formal start to the academic year, it is the beginning of students living on campus and new perceptions being created towards areas they perceive to be safe or not. The digitization period ended on May 10th because this is the last day of graduation and any on-campus residents must be moved out of their residences within twenty-four hours of the completion of graduation and/or their last exam.

Since the survey was administered during the first quarter of 2009, the crime data for the same academic year was gathered. This is because people's perceptions of safe and unsafe areas are going to be most altered by current events. Therefore, the current crime events are more than likely going to be a factor in where students' perceive areas to be unsafe.

Crime Data Digitization and Modeling

The Appalachian campus crime log was used to gather information on campus crime activity. Crime events were broken into four macro categories, vehicular based, inside buildings, outside buildings, and health/safety calls (not included or tabulated). As seen in table 1, the vehicular based crimes (e.g. driving under the influence) were tallied for a count of these events; inside crimes were tallied per building, and outside crimes were fully digitized as points on the map.

Table 1. 2008-2009 Academic Year Crime Event Counts

Location	Count
Outside of Buildings	198
Inside of Buildings	257
Vehicular Based	32
Total	**487**

The per building inside crime count was joined to data on each respective building and mapped using a choropleth method showing generalized gradients of quantity. The outside crime data was digitized as a point, using information given in the crime log.

Additional attribute data was added to each point, including geographic location, date, time of day, and what crime took place.

It is important to note that the location information in the crime log is very granular. For example, it may state that a car was broken into in Stadium Parking Lot. However, this parking lot holds hundreds of cars and there is no additional information given on the specific location of the break-in. Therefore, area specific knowledge and familiarity was used when digitizing all of these points. The area is correct, but the exact location is unknown. This does cause issues with precision; however, these are somewhat overcome with the rasterization process due to its generalizing nature.

After the crime points were digitized one other attribution was added to each of the points. Each point was given a weighted value of one, two, or three, just like the survey data. One represents a more severe crime, two represents less severe, and three represents somewhat severe. These weights were given to each type of event for ease of analysis and modeling with the other datasets.

The crime data was analyzed with the CrimeStat (Levine 2010) software package as well as ArcGIS' Spatial Analyst™ extension. CrimeStat was used to compute nearest neighbor statistics and nearest neighbor hierarchical clusters. The nearest neighbor analysis generates several important outputs; the critical ones that are used for this study are the mean nearest neighbor distance, the nearest neighbor index, and the one/two tail p-values.

The ArcGIS Spatial Analyst™ extension created IDW interpolation models for the aggregate daytime and nighttime crime data. The daytime and nighttime crime datasets were analyzed with IDW parameters of a power of four, a minimum number of points as twenty-two, and a variable search radius. No barrier polylines were used for the IDW interpolation models because while the crime events being studied mostly occurred on-campus, crime still happens beyond the campus' border and the exclusion of a barrier polyline takes this into consideration.

Lighting Data

Objective

The objective of gathering the lighting data was to add an additional modeling component to the final output because students have historically complained about a lack of lighting in some areas on Appalachian's campus. This evaluation was dual pronged. The first was to attempt to locate and map the majority of macro light sources in their two respective categories: electrical shop lampposts (green, human level, landscaping lampposts) and the security lights (large street/parking lot spun aluminum light poles).

The second component was to evaluate the amount of lux (equal to the amount of lumens in a square meter) being produced by the electrical shop light posts and compare this to known standards from the Illuminating Engineering Society of North America (2000). Additionally, each light source has a predicted coverage area based on engineering and construction parameters for placement of the two different types of units. This area was used in evaluating the amount of light coverage on Appalachian's campus and will be integrated into the final model.

Light Sampling Method

There are over a thousand light poles on Appalachian's campus, counting the security lights and the lampposts. For the lighting output study only the lampposts were examined. Appalachian's lampposts have three different globe assemblies (figure 1). The first and most prolific is the standard globe. The standard globe puts light out in all directions; these globes are best recognized by their glare. The second type of globe is the dark sky globe. This globe is starting to replace the standard globes because of its directional lighting capabilities. This globe does not put off the blinding glare of the standard globes because it reflects all of the light down, illuminating the same area but not putting out as much horizontal and upwardly projected light, thus preserving the night sky. The third type of globe, a light-emitting diode (LED) light source has only been installed around a newly renovated dorm. This type of globe is most recognizable by its harsher white/blue light.

Figure 1. Three Types of Lamppost Globes (L-R): Standard, Dark Sky, and LED.

There are over 600 electrical shop lampposts on Appalachian's campus and not everyone could be analyzed. Fifteen lampposts were randomly chosen to be analyzed. A one inch plastic plumbing pipe was cut so that once a cap was placed on it and the light sensor placed on the cap, it would measure to the average male/female eye height of 5' $1^{23}/_{32}$". This height was obtained from averaging the mean left and right, male and female average eye height (table 2) from the CAESAR: Summary Statistics for the Adult Population (Age 18-65) of the United States of America (Harrison and Robinette 2002).

Table 2. Average American Adult Eye Height

	Mean Left Eye Height	Mean Right Eye Height	Mean
Male	64.05”	64.04”	64.045”
Female	59.38”	59.37”	59.375”
Average	61.715”	61.705”	61.71” = ~5’ $1^{23}/_{32}$”

Since there are so many lampposts across a moderately large campus, a small sample size was decided on. Fifteen samples were taken on a clear night with little to no moonlight between 10:30pm and 12:30am. At each lamppost sampled, a twenty-five foot measuring tape was placed on the ground stretching out from the base of the lamp, in an unobstructed direction that had as little interference from other light sources as possible. A light measurement, in lux (equal to the amount of lumens in a square meter), was taken at 12.5 feet and again at twenty-five feet. These distances were chosen based on conversations with electric shop personnel indicating that the posts are typically placed fifty feet apart or in places where additional lighting needs are identified. Results from this sample were compared against the Illuminating Engineering Society of North America’s (IESNA) (2000) standards for recommended average maintained illuminance levels for pedestrian ways.

Light Analysis Tool

To properly measure the lampposts’ illuminance, a light meter was purchased. Based on comparative research and costs, an ExTech Instruments EasyView EA31 light meter was used (figure 2). This model is a lower range measuring device that measures up to 2,000Fc/20,000Lux (ExTech Industries EA31 Datasheet). This meter’s sensor was attached to the top of the PVC pipe (figure 3) that was cut to the male/female American adult average eye height of approximately 5’ 2” (table 2).

Figure 2. ExTech Instruments EasyView EA31 Light Meter.

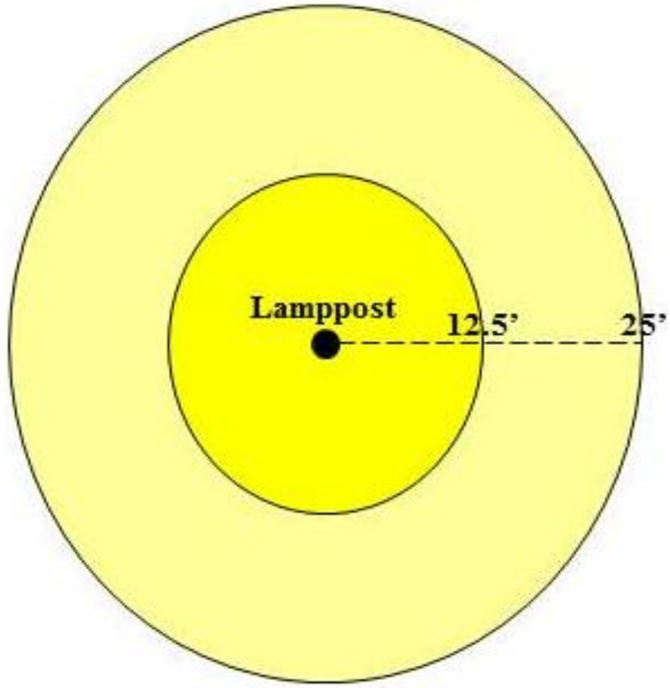


Figure 3. Diagram of Light Sampling Method and Testing Lux Values at 12.5 Feet from Lamppost Center.

Light Source Digitization and Modeling

As stated previously, there are two main types of exterior illumination sources on Appalachian's campus. The first type is electrical shop light posts (green, human level, landscaping lampposts) and the second is security lights (large street/parking lot spun aluminum light poles). The security light placement is directed by the university and is maintained by the university-owned, local utility, New River Light and Power. These lights' location information is maintained in computer-aided design (CAD) format at New River Light and Power. The location information for the security lights is fairly accurate and up-to-date. Very little additional digitization was needed to complete this GIS layer.

The green electric shop lampposts tend to be a function of landscape design or need discovered in the annual safety walk. There is no current geospatial location information or records on lamp locations. A much older shapefile does exist of lamppost locations and this was used as a starting point for digitization. To update the shapefile on lampposts, the 2009 six-inch color orthophoto was used. This orthophoto was considered satisfactory to use for the data set because it seems to have been taken in the late Winter/early Spring of 2009, and this time period falls within the active time period of the student survey. This higher-end aerial photo showed the majority of lampposts on Appalachian's campus. This allowed for deletion of old posts and the digitizing of new posts. Furthermore, some ground truthing was conducted on some of the newest areas of Appalachian's campus such as around the new Belk Library and Information Commons and the new Central Dining Facility.

To visualize the assumed illuminated areas, the centroids of the two macro light sources at Appalachian were used to create proximity buffers. The electric shop lampposts were given a twenty-five foot buffer and the New River Light and Power security lights were given a seventy-five foot buffer. These buffers were assigned at these respective distances because electric shop lampposts are placed approximately fifty feet apart and the security light poles are placed approximately 180 feet apart. The buffers created are round, full buffers with dissolved borders. The buffer shapefiles were merged and dissolved together as one to show a seamless spatial representation of expected illuminated areas on Appalachian’s campus. By layering these buffers over the areas of perceived feelings of being unsafe, the correlations between these areas become visible.

Chapter 4
Analysis and Results

Perceptions of Safety Survey Analysis

Descriptive Statistics of Perceptions of Safety Survey

There were a total of 758 surveys taken and of these, 640 (84.4 percent) correctly marked areas they perceived to be unsafe on the map, fifty-six (7.4 percent) properly took the survey but had no perceptions of being unsafe, and sixty-two (8.18 percent) improperly took the survey and had to be culled out (table 3). The survey results were analyzed not only for the points on the map deemed unsafe but also for descriptive statistics. These statistics help to create a clearer picture of the survey respondents and how they view campus safety. The following table (table 3) presents the survey respondents into divided aggregate groups.

Table 3. Perception Survey Descriptive Statistics

	Surveys Administered	Respondents That Marked Any Unsafe Areas		Did Not Mark Any Unsafe Areas		Culled	
	Total	Total	%	Total	%	Total	%
Freshman	173	164	94.8	9	5.2		
Sophomore	176	168	95.5	8	4.5		
Junior	164	151	92.1	13	7.9		
Senior	178	152	85.4	26	14.6		
Graduate	5	5	100.0	0	0.0		
Male	335	288	86.0	47	14.0		
Female	361	352	97.5	9	2.5		
On-Campus	292	278	95.2	14	4.8		
Off-Campus	404	362	89.6	42	10.4		
East Campus	115	112	97.4	3	2.6		
West Campus	177	166	93.8	11	6.2		
Off Campus	404	362	89.6	42	10.4		
No Car	145	136	93.8	9	6.2		
Car	551	504	91.5	47	8.5		
Total	758	640	84.4	56	7.4	62	8.18

Additional data was gathered on how much the respondent traveled on campus during the day (TOCD) and night (TOCN). The respondent was asked to rank their travel on a Likert scale of one to ten, ten being the most. The following histograms (figures 4 and 5) depict all respondents and the male/female trends for amount of travel on campus during the day and night.

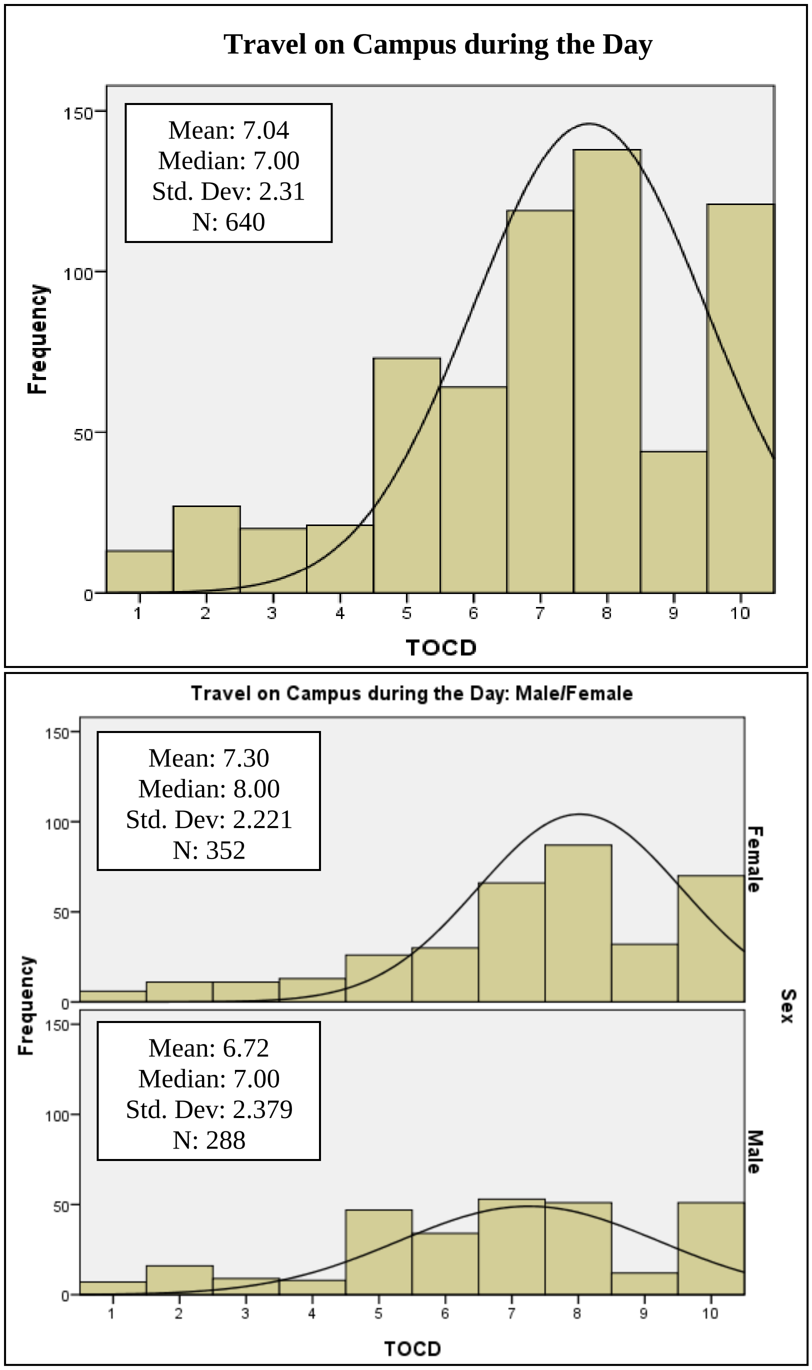


Figure 4. Travel on Campus during the Day: All Respondents and Male/Female.

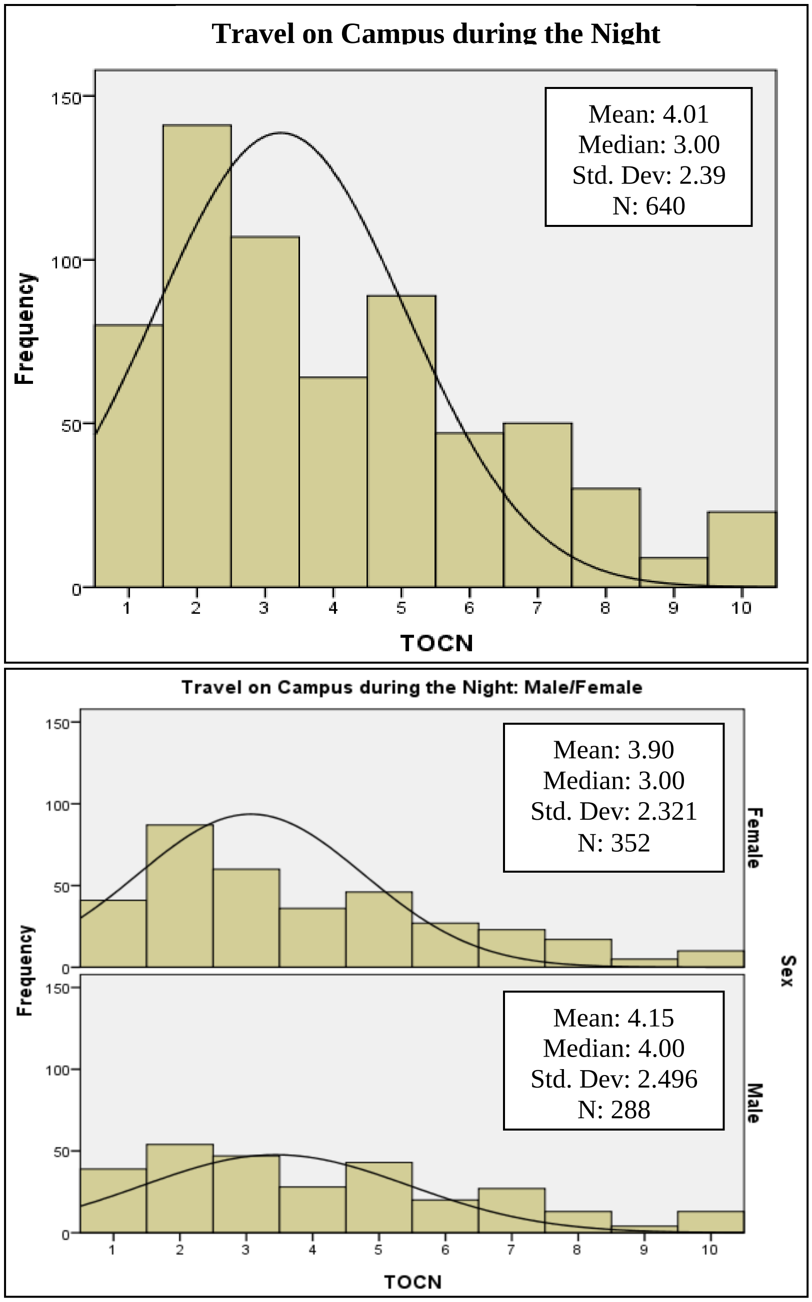


Figure 5. Travel on Campus during the Night: All Respondents and Male/Female.

Additional questions were asked to gather data on how cautious students were when traveling on campus during the day (COCD) and night (COCN). The respondent was asked to rank their cautiousness on a scale of one to ten, ten being the most. The following histograms (figures 6 and 7) depict all respondents and the male/female trends for level of cautiousness on campus during the day and night.

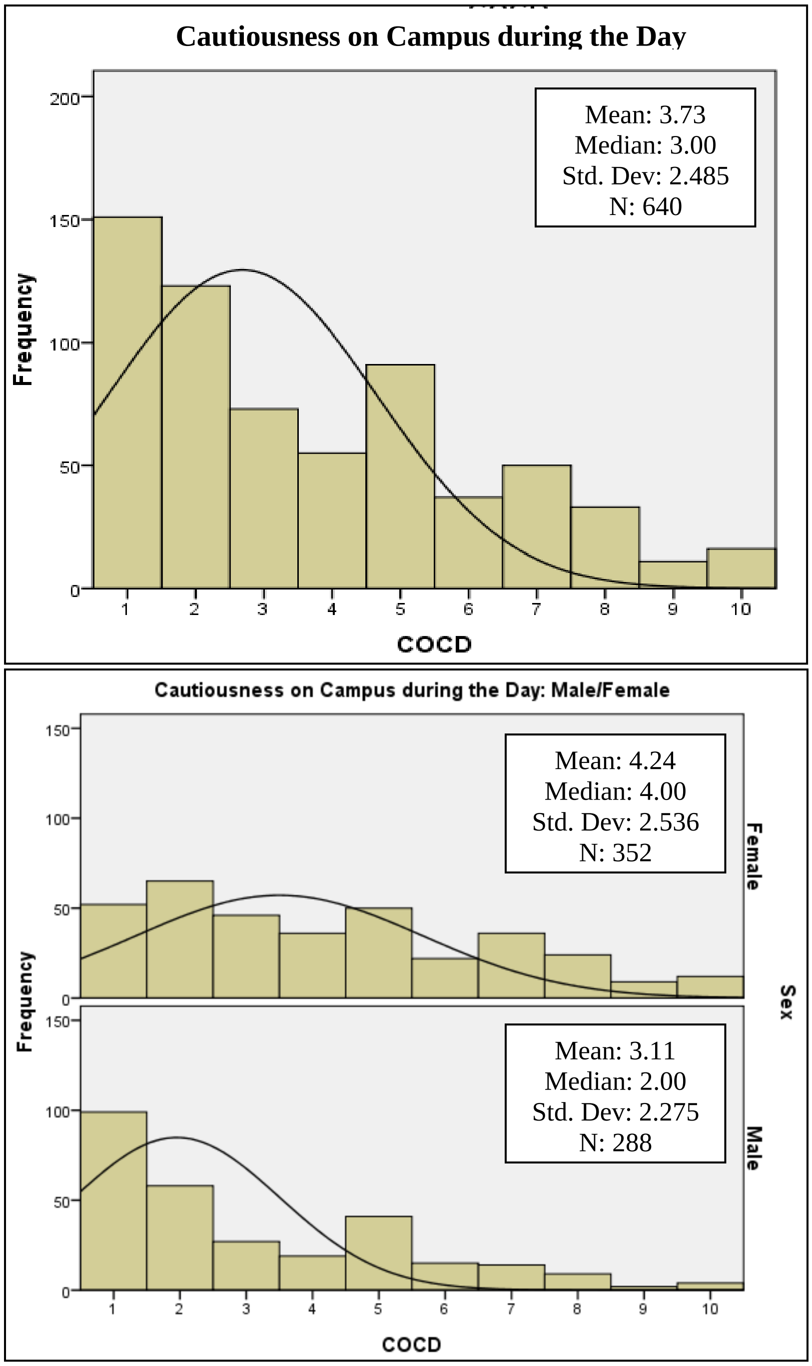


Figure 6. Cautiousness on Campus during the Day: All Respondents and Male/Female.

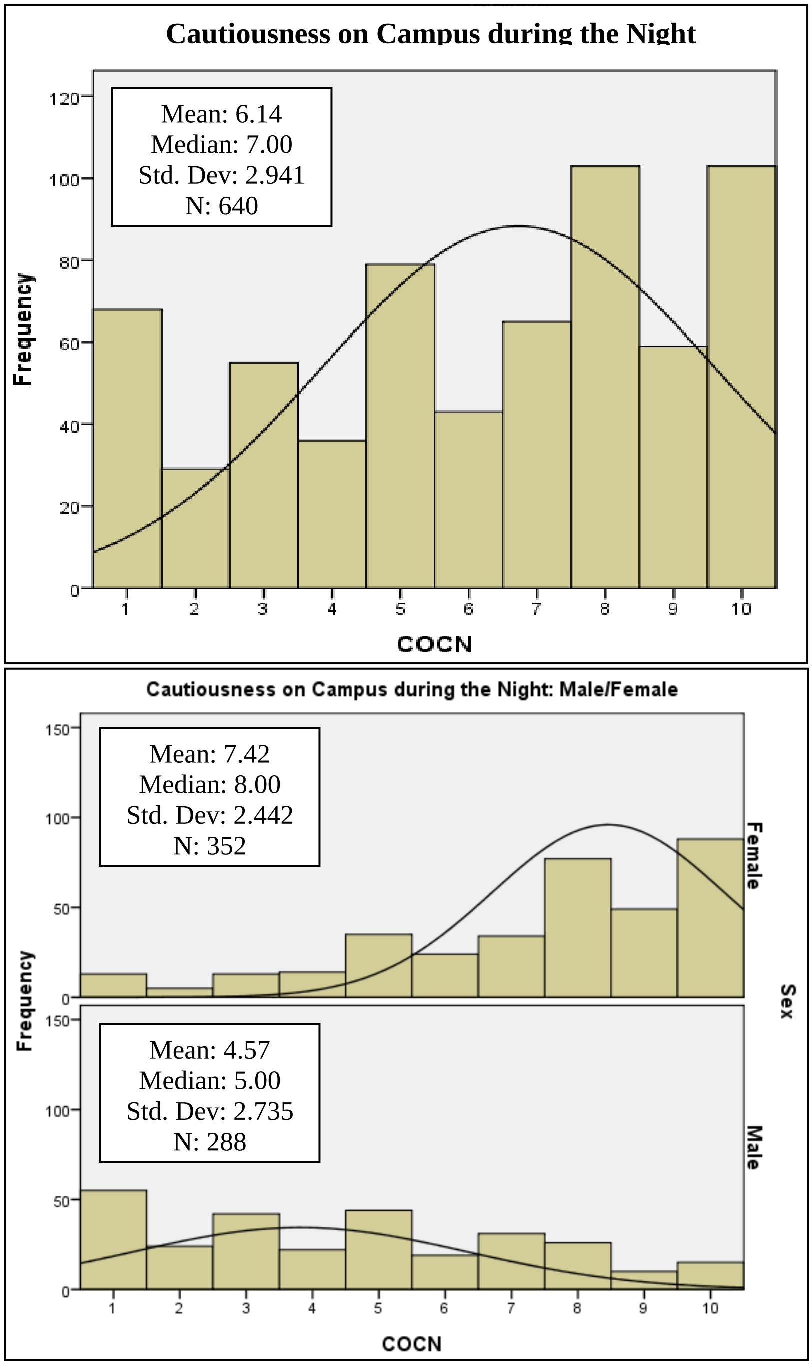


Figure 7. Cautiousness on Campus during the Night: All Respondents and Male/Female.

The number of points placed on the survey map by the respondents were compared to the whole. This analysis rendered a greater picture of where the majority of points were derived from compared to the whole. Additionally, it helps to create a clearer picture of the study sub groups (daytime, nighttime, male, female, east campus, west campus, and off campus) before analyses are conducted on each of the sub groups.

Table 4. Points Collected from Respondent Groups

	Respondents That Marked Any Unsafe Areas	Number of Points	Percent
Daytime	565	1,568	50.9
Nighttime	538	1,513	49.1
Freshman	164	813	26.4
Sophomore	168	808	26.2
Junior	151	717	23.3
Senior	152	722	23.4
Graduate	5	21	0.7
Male	288	1,365	44.3
Female	352	1,716	55.7
On-Campus	278	1,375	44.6
Off-Campus	362	1,706	55.4
East Campus	112	549	17.8
West Campus	166	826	26.8
Off Campus	362	1,706	55.4
No Car	136	628	20.4
Car	504	2,453	79.6
Total	640	3,081	100

Perceptions of Unsafe Areas: Daytime: All Points, Male, and Female

The first group of analysis examined the perception survey data for all of the daytime unsafe points, and the male/female subgroups. A nearest neighbor analysis, IDW interpolation, and a nearest neighbor hierarchical cluster analysis was used to examine clustering and distribution.

Table 5. Daytime Survey Points: Nearest Neighbor Analysis: All Points, Males, and Females

	Sample Size	Mean NN Distance	Standard Error	NN Index	Test Statistic (z)	p - Value (one tail)	p - Value (two tail)
All Points	1,568	30.06 ft.	0.76 ft.	0.5246	-36.0169	0.0001	0.0001
Male	726	44.46 ft.	1.63 ft.	0.5280	-24.3325	0.0001	0.0001
Female	842	42.01 ft.	1.41 ft.	0.5373	-25.6854	0.0001	0.0001

The nearest neighbor analysis of the daytime survey points yielded significant results (table 5). All results had one and two tail p-values of 0.0001 with nearest neighbor indexes under 1.0, thus displaying survey points in clustered patterns that are significant. The total daytime surveyed unsafe areas point group was the most clustered and has the shortest nearest neighbor distance out of the three groups examined in this sub-study.

The IDW interpolation method was used to create a hot spot map of the study area based on the clusters of points and each point's weight denoting how unsafe the respondent felt in that location. Figure 8 shows the location of all of the daytime unsafe points, while figures 9, 10, and 11 depict the IDW interpolation results from all of the daytime unsafe points gathered in the survey, the daytime unsafe male respondents' points, and the daytime unsafe female respondents' points.

Finally, the nearest neighbor hierarchical cluster analysis results are displayed in table 6 and figure 12. Figure 12 shows second order clusters for each of the three groups examined in this sub-study. There are some similarities displayed between the three groups of points.

Table 6. Daytime Survey Points: Nearest Neighbor Hierarchical Cluster Analysis: All Points, Males, and Females

	Sample Size	Likelihood of Grouping Pair of Points By Chance	z - Value for Confidence Interval	Min # of Points to Generate Up To Three 2nd Order Clusters	Standard Deviation	Clusters Found
All Points	1,568	50%	0.00	10	1.0	31
Male	726	50%	0.00	6	1.0	29
Female	842	50%	0.00	10	1.0	18

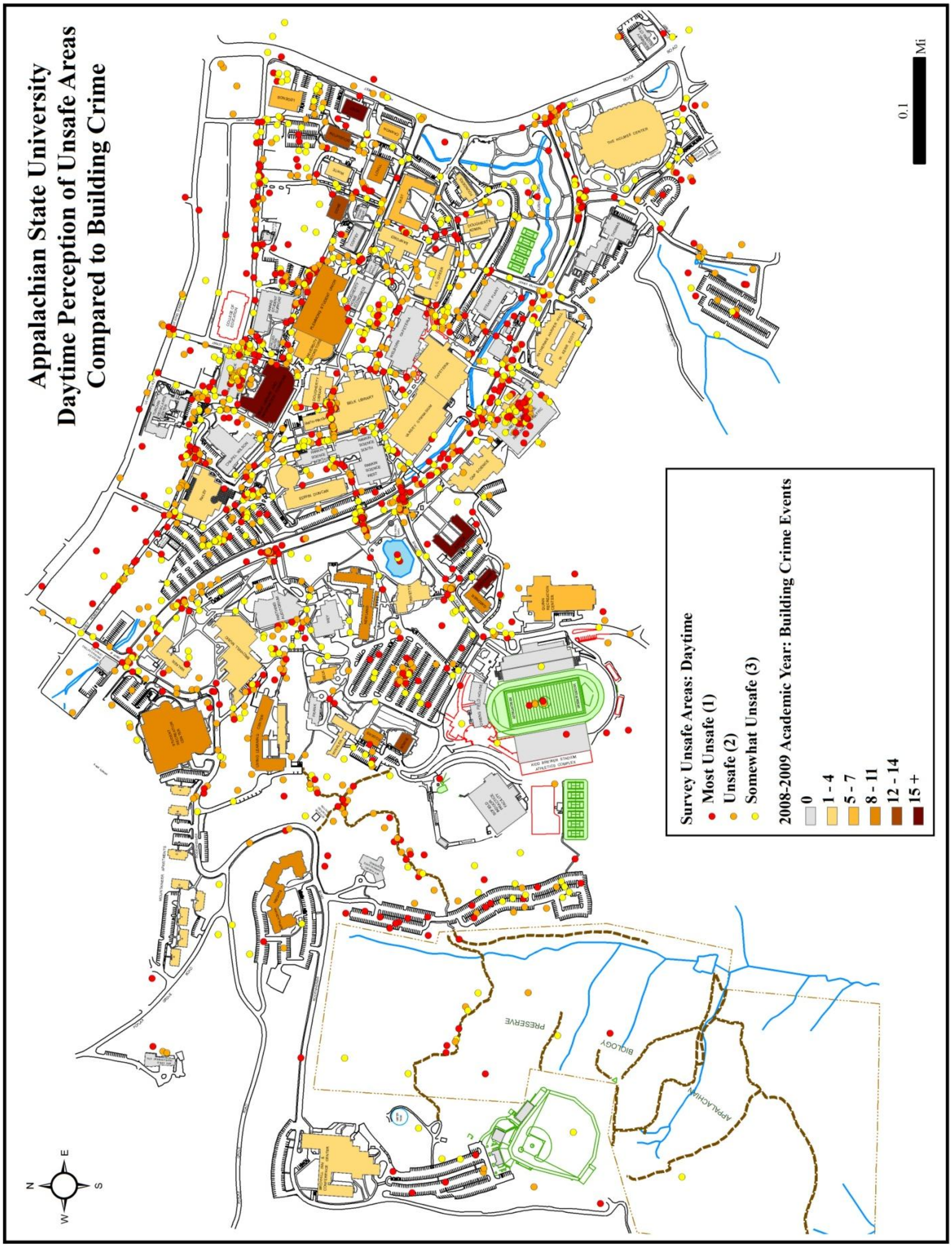


Figure 8. Surveyed Perception of Unsafe Areas in the Daytime, Compared to Building Crime Events.

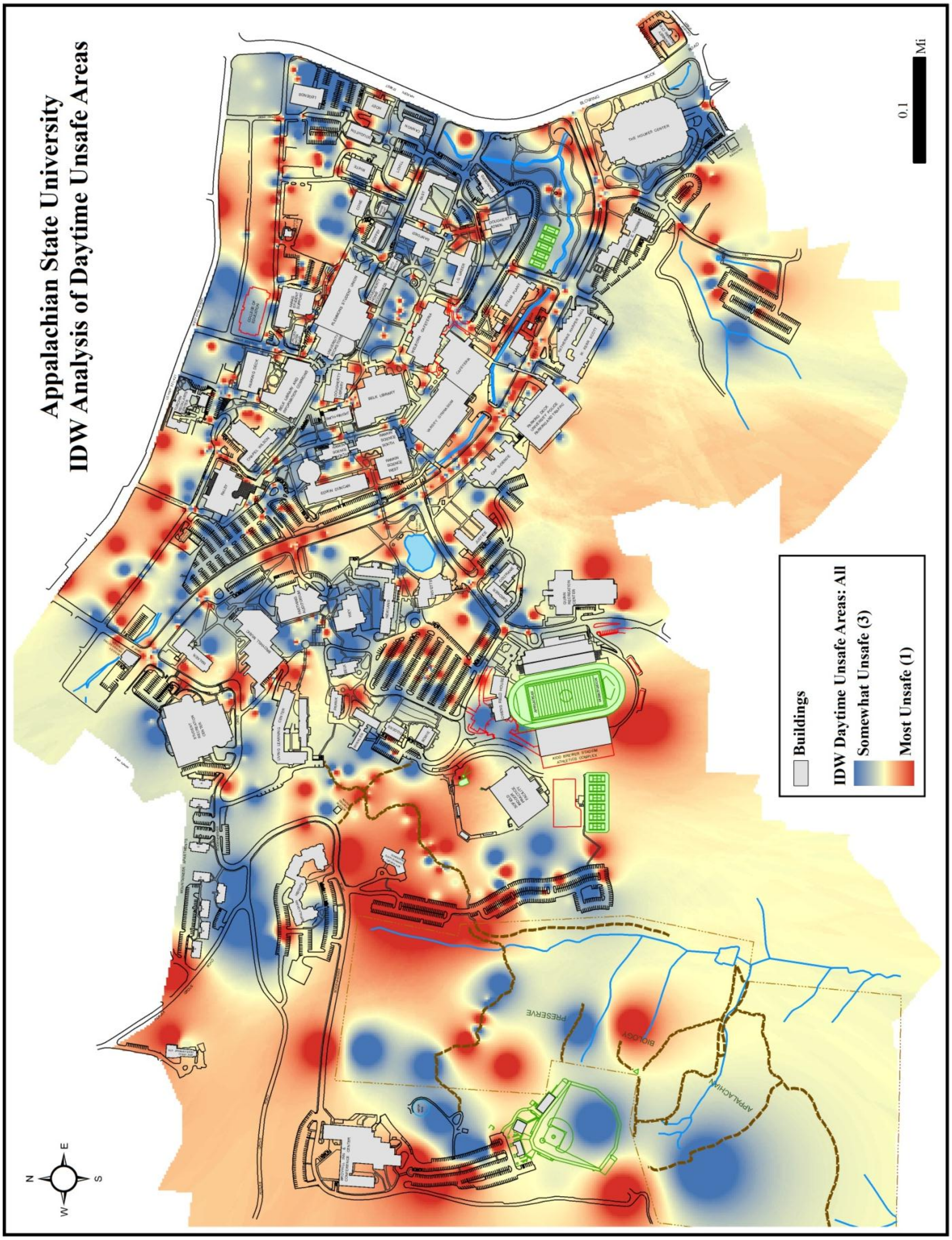


Figure 9. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (All Points).

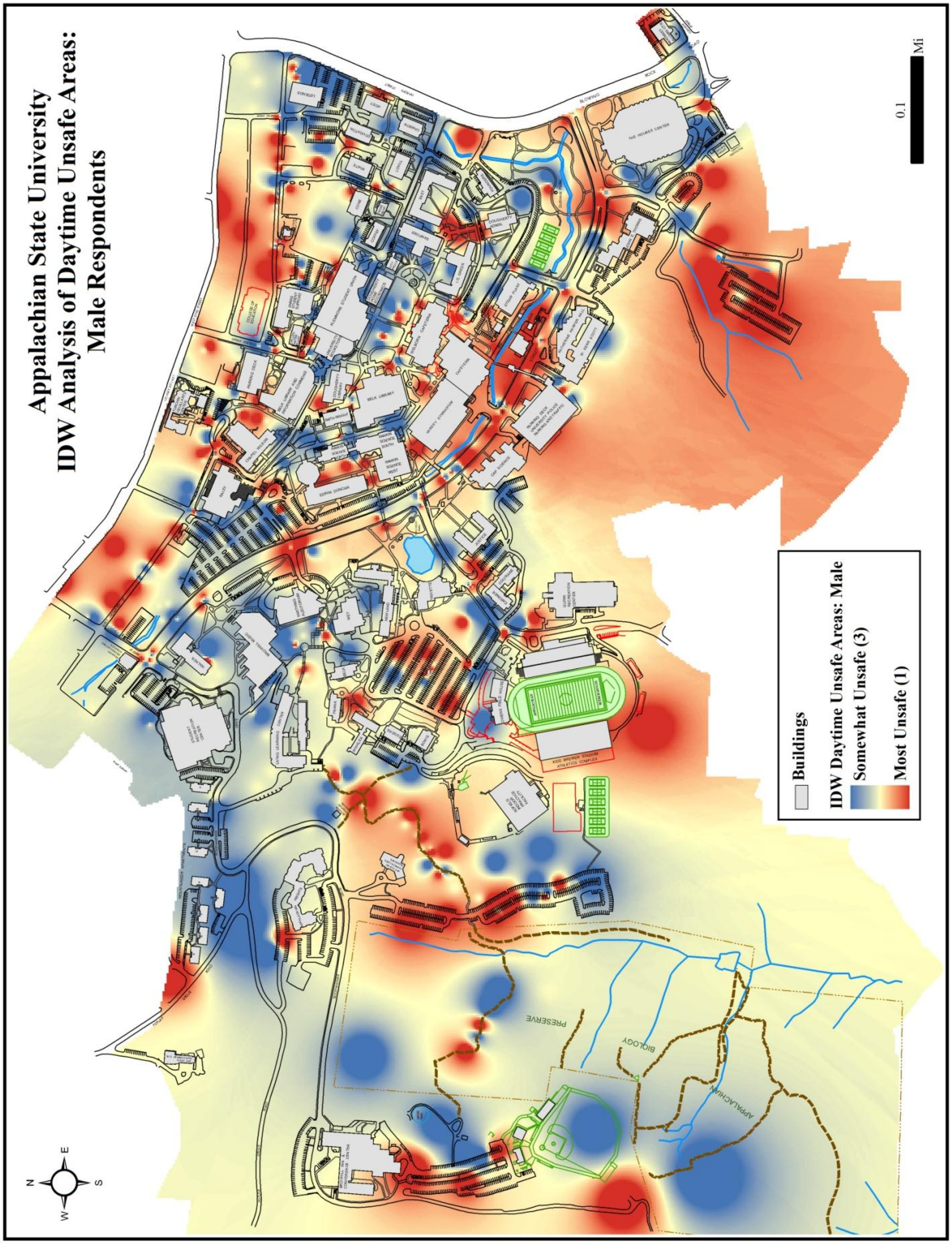


Figure 10. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (Male Points).

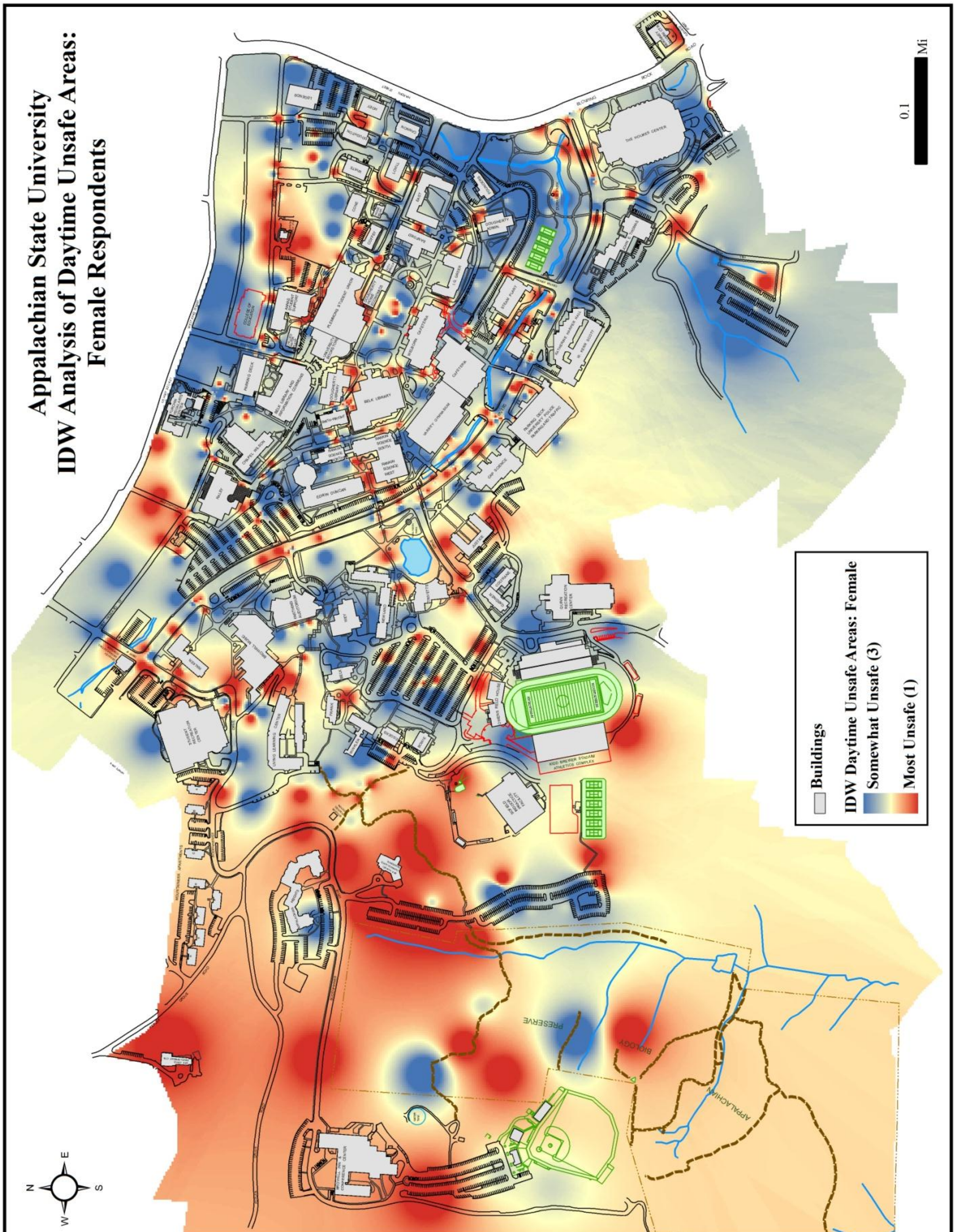


Figure 11. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (Female Points).

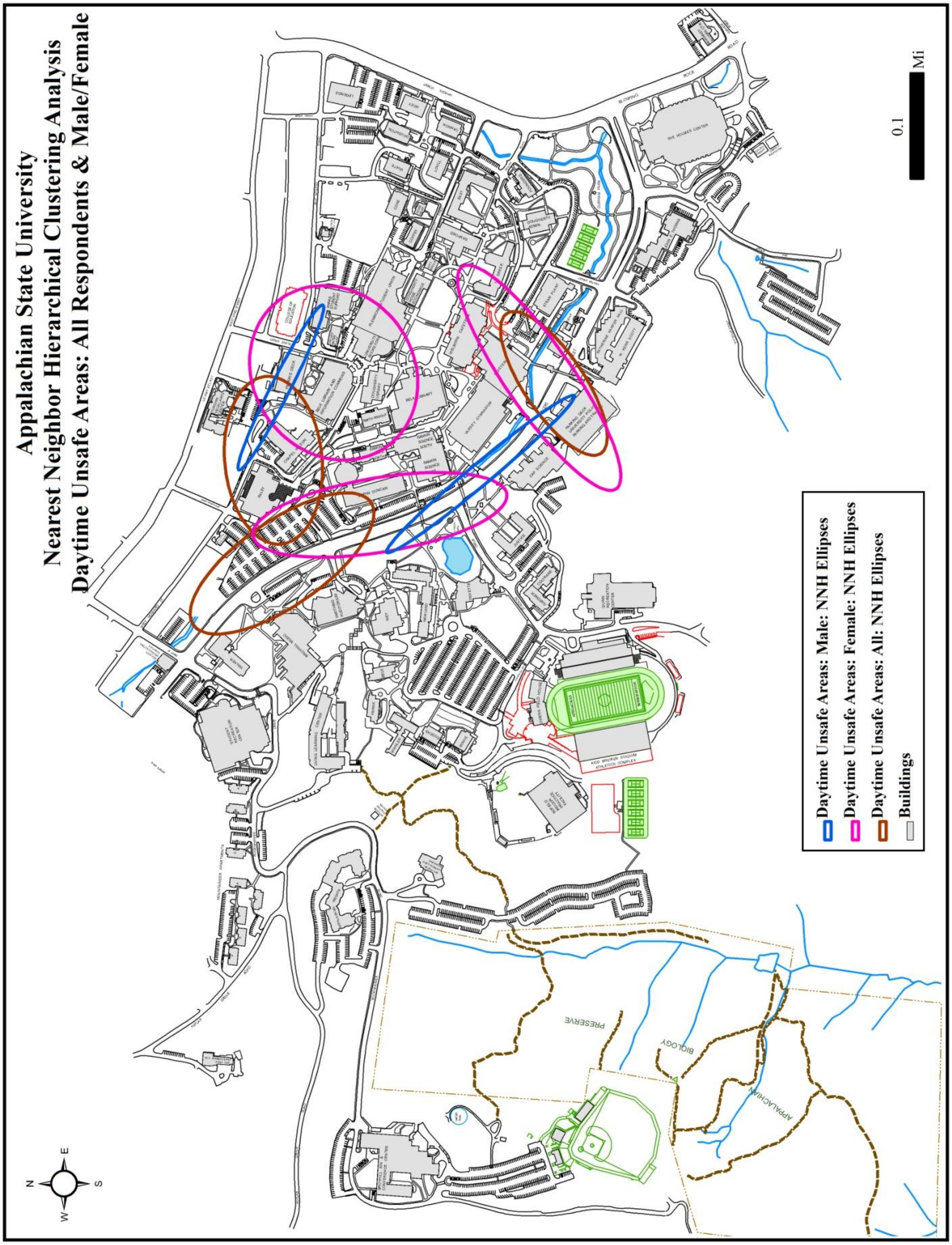


Figure 12. Nearest Neighbor Hierarchical 2nd Order Cluster Ellipses: Daytime (All, Male, & Female).

Perceptions of Unsafe Areas: Daytime: East Campus, West Campus, Off Campus

The second group of analysis examined the perception survey data for the daytime unsafe points based on where the respondent lives. This sub-study examined respondents living on east campus, west campus, and off campus. A nearest neighbor analysis, IDW, and a nearest neighbor hierarchical cluster analysis was used to examine clustering and distribution.

Table 7. Daytime Survey Points: Nearest Neighbor Analysis: Living Locations: East Campus, West Campus, Off Campus

	Sample Size	Mean NN Distance	Standard Error	NN Index	Test Statistic (z)	p - Value (one tail)	p - Value (two tail)
East Campus	270	76.40 ft.	4.39 ft.	0.5533	-14.0407	0.0001	0.0001
West Campus	396	57.39 ft.	2.99 ft.	0.5034	-18.9058	0.0001	0.0001
Off Campus	902	40.45 ft.	1.31 ft.	0.5354	-26.6946	0.0001	0.0001

The nearest neighbor analysis of these daytime survey points all yielded significant results (table 7). All results had one and two tail p-values of 0.0001 with nearest neighbor indexes under 1.0, thus displaying survey points in clustered patterns that are statistically significant. The daytime unsafe locations given by respondents living on west campus was the most clustered out of the three groups examined in this sub-study.

The IDW interpolation method was used to create a hot spot map of the study area based on the clusters of points and each point's weight denoting how unsafe the respondent felt in that location. Figures 13, 14, and 15 depict the IDW interpolation results from all of the daytime unsafe areas east campus respondents, the daytime unsafe areas west campus respondents, and the daytime unsafe areas off campus respondents.

Finally, the nearest neighbor hierarchical cluster analysis results are displayed in table 8 and figure 16. Figure 16 shows second order clusters for each of the three groups examined in this sub-study. There are some similarities displayed between the three groups of points. It is important to note that the daytime unsafe areas west campus respondents points' only generated two second order ellipses.

Table 8. Daytime Survey Points: Nearest Neighbor Hierarchical Analysis: Living Locations: East Campus, West Campus, Off Campus

	Sample Size	Likelihood of Grouping Pair of Points By Chance	z - Value for Confidence Interval	Min # of Points to Generate Up To Three 2nd Order Clusters	Standard Deviation	Clusters Found
East Campus	270	50%	0.00	4	1.0	19
West Campus	396	50%	0.00	4	1.0	27
Off Campus	902	50%	0.00	8	1.0	24

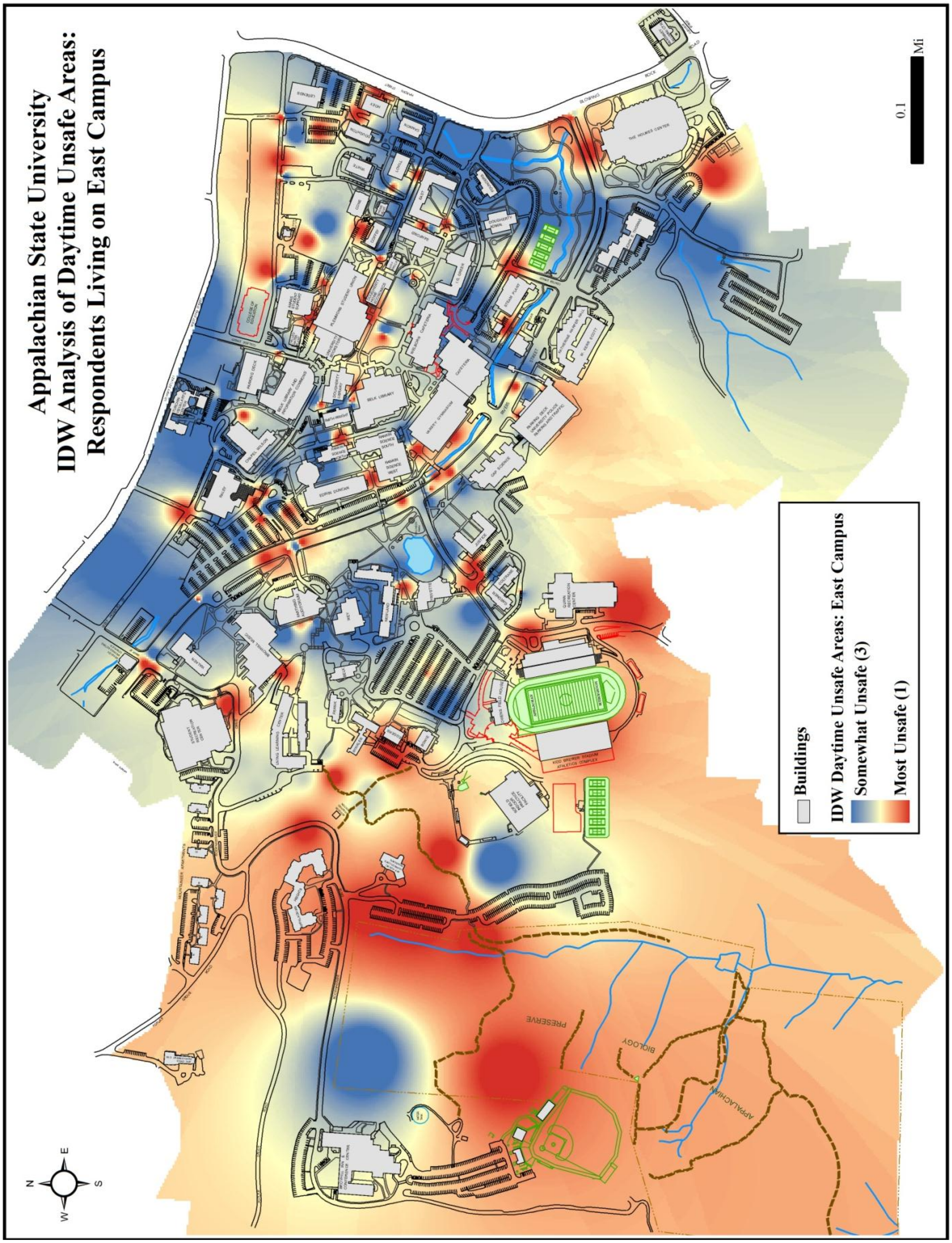


Figure 13. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (East Campus Points).

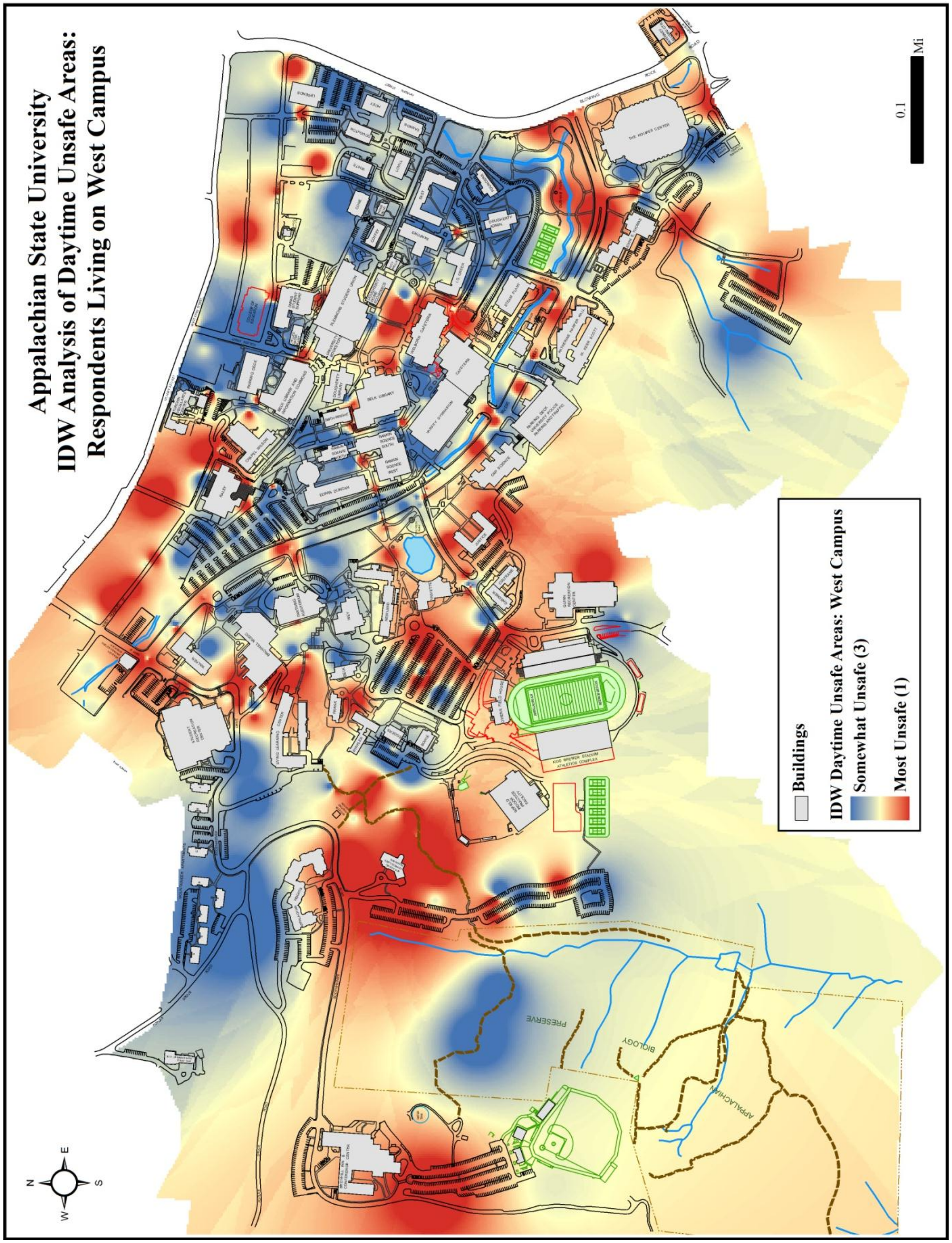


Figure 14. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (West Campus Points).

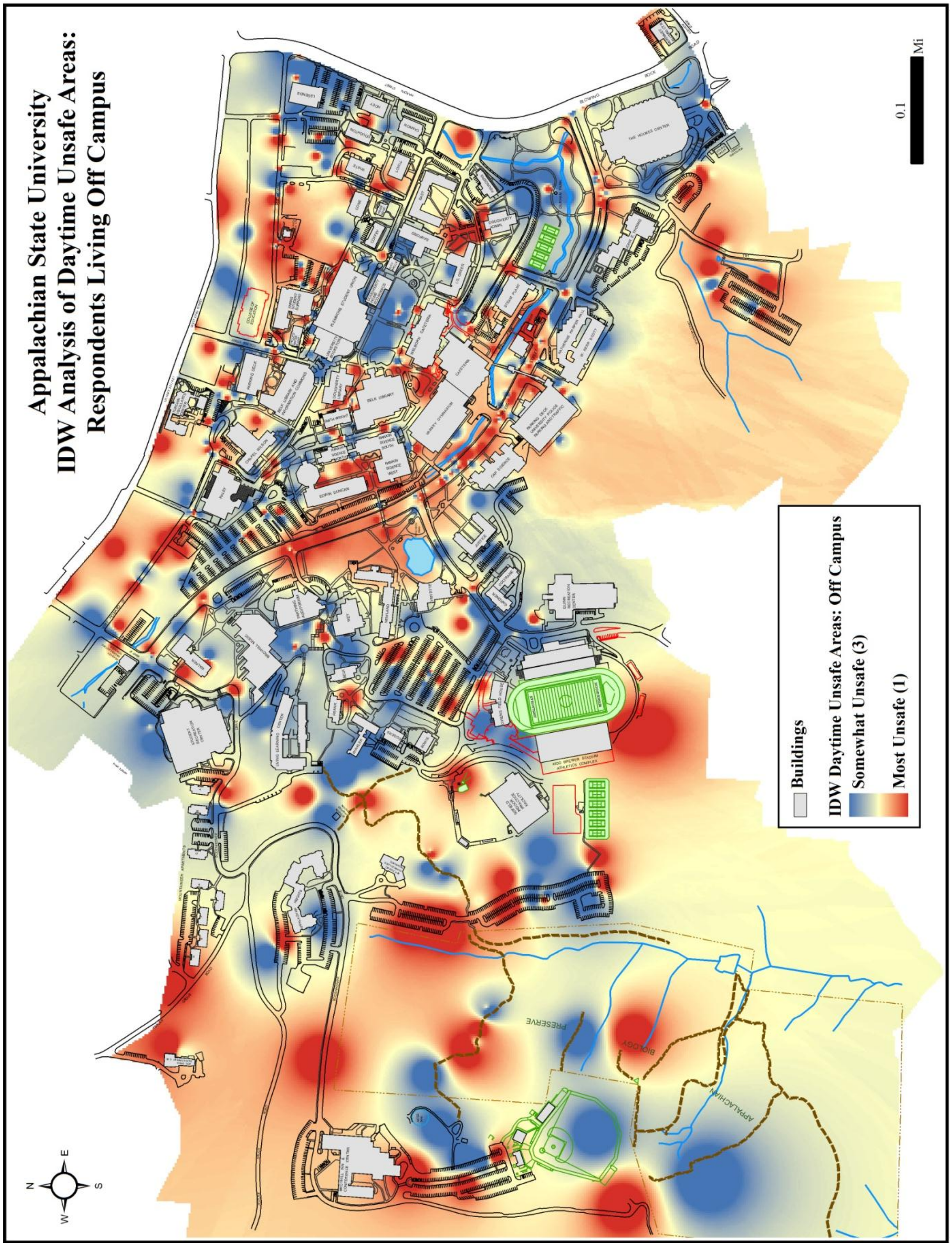


Figure 15. Inverse Distance Weighted Interpolation of Daytime Unsafe Areas (Off Campus Points).

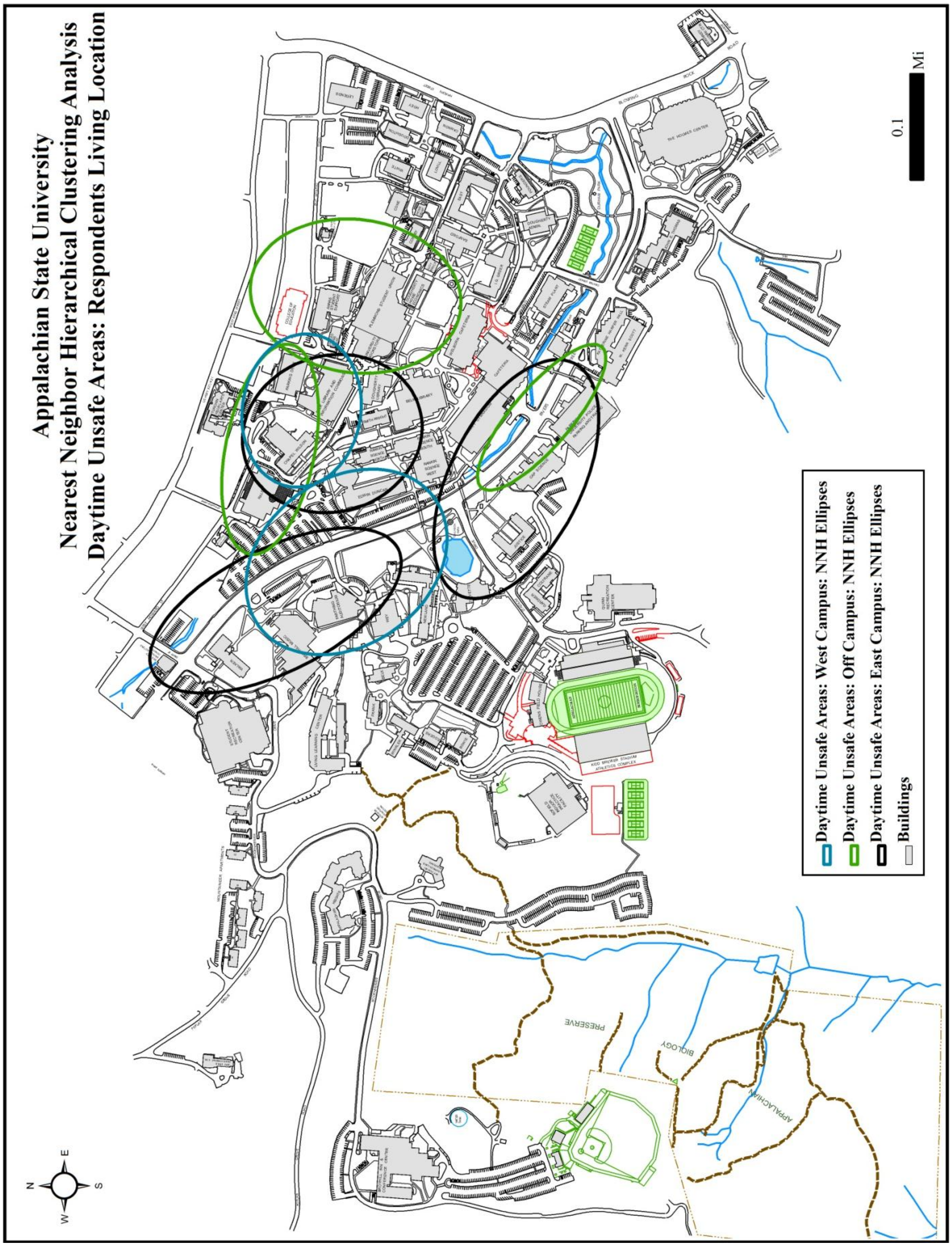


Figure 16. Nearest Neighbor Hierarchical 2nd Order Cluster Ellipses: Daytime (East, West, & Off Campus).

Perceptions of Unsafe Areas: Nighttime: All Points, Male, and Female

The first group of the nighttime analysis examined the perception survey data for all of the nighttime unsafe points, and the male/female subgroups. A nearest neighbor analysis, IDW interpolation, and a nearest neighbor hierarchical cluster analysis was used to examine clustering and distribution.

Table 9. Nighttime Survey Points: Nearest Neighbor Analysis: All Points, Males, and Females

	Sample Size	Mean NN Distance	Standard Error	NN Index	Test Statistic (z)	p - Value (one tail)	p - Value (two tail)
All Points	1,513	31.17 ft.	0.78 ft.	0.5343	-34.6512	0.0001	0.0001
Male	639	52.43 ft.	1.86 ft.	0.5842	-20.1077	0.0001	0.0001
Female	874	38.37 ft.	1.36 ft.	0.4999	-28.2824	0.0001	0.0001

The nearest neighbor analysis of the nighttime survey points yielded significant results (table 9). All results had one and two tail p-values of 0.0001 with nearest neighbor indexes under 1.0, thus displaying survey points in clustered patterns that are statistically significant. The female nighttime surveyed unsafe areas point group was the most clustered and has the shortest nearest neighbor distance out of the three groups examined in this sub-study.

The IDW interpolation method was used to create a hot spot map of the study area based on the clusters of points and each point's weight denoting how unsafe the respondent felt in that location. Figure 17 shows the location of all of the nighttime unsafe points, while figures 18, 19, and 20 depict the IDW interpolation results from all of the nighttime unsafe points gathered in the survey, the nighttime unsafe male respondent's points, and the nighttime unsafe female respondent's points.

Finally, the nearest neighbor hierarchical cluster analysis results are displayed in table 10 and figure 21. Figure 21 shows second order clusters for each of the three groups examined in this sub-study. There are some similarities displayed between the three groups of points.

Table 10. Nighttime Survey Points: Nearest Neighbor Hierarchical Cluster Analysis: All Points, Males, and Females

	Sample Size	Likelihood of Grouping Pair of Points By Chance	z - Value for Confidence Interval	Min # of Points to Generate Up To Three 2nd Order Clusters	Standard Deviation	Clusters Found
All Points	1,513	50%	0.00	9	1.0	29
Male	639	50%	0.00	6	1.0	27
Female	874	50%	0.00	7	1.0	26

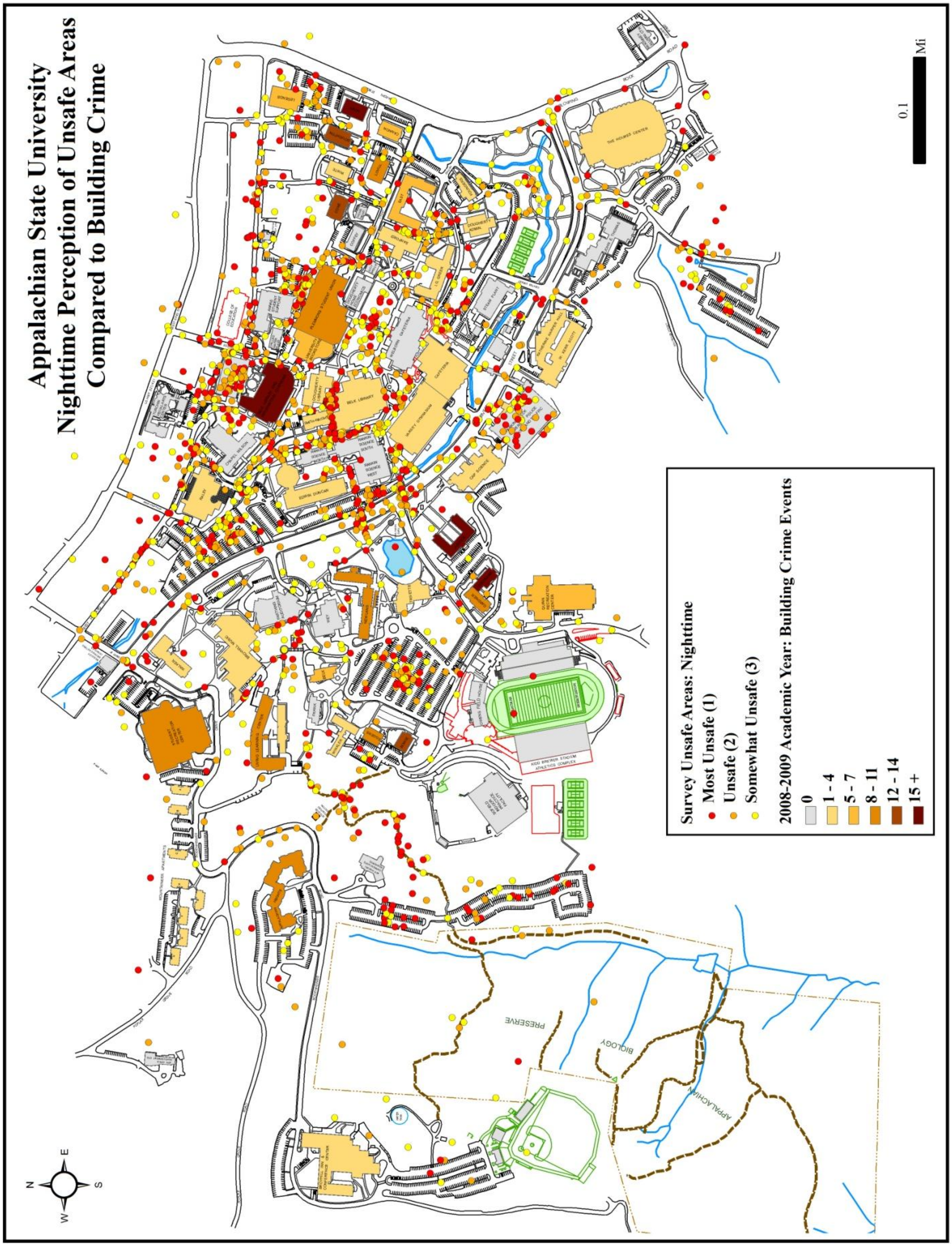


Figure 17. Surveyed Perception of Unsafe Areas at Nighttime, Compared to Building Crime Events.

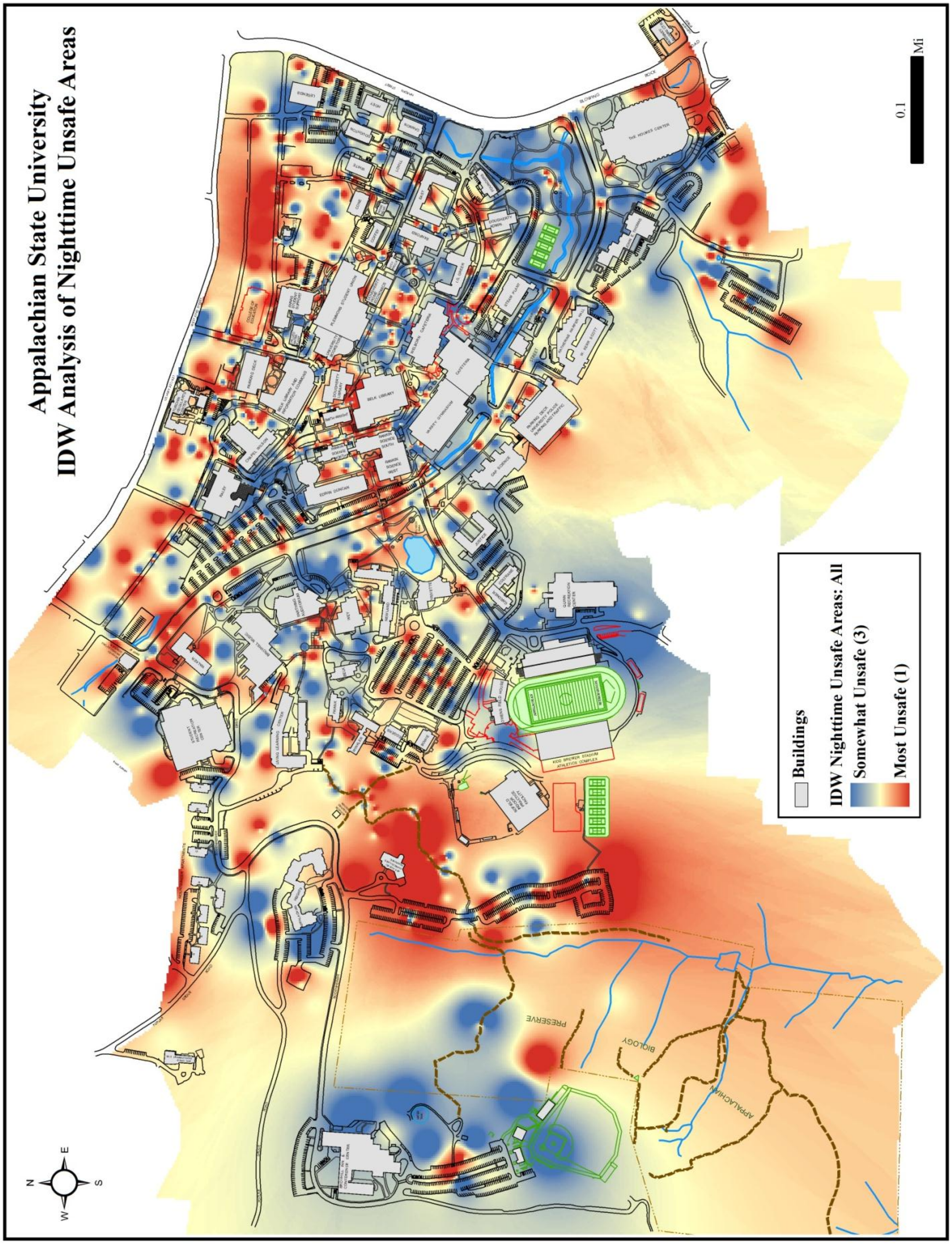


Figure 18. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (All Points).

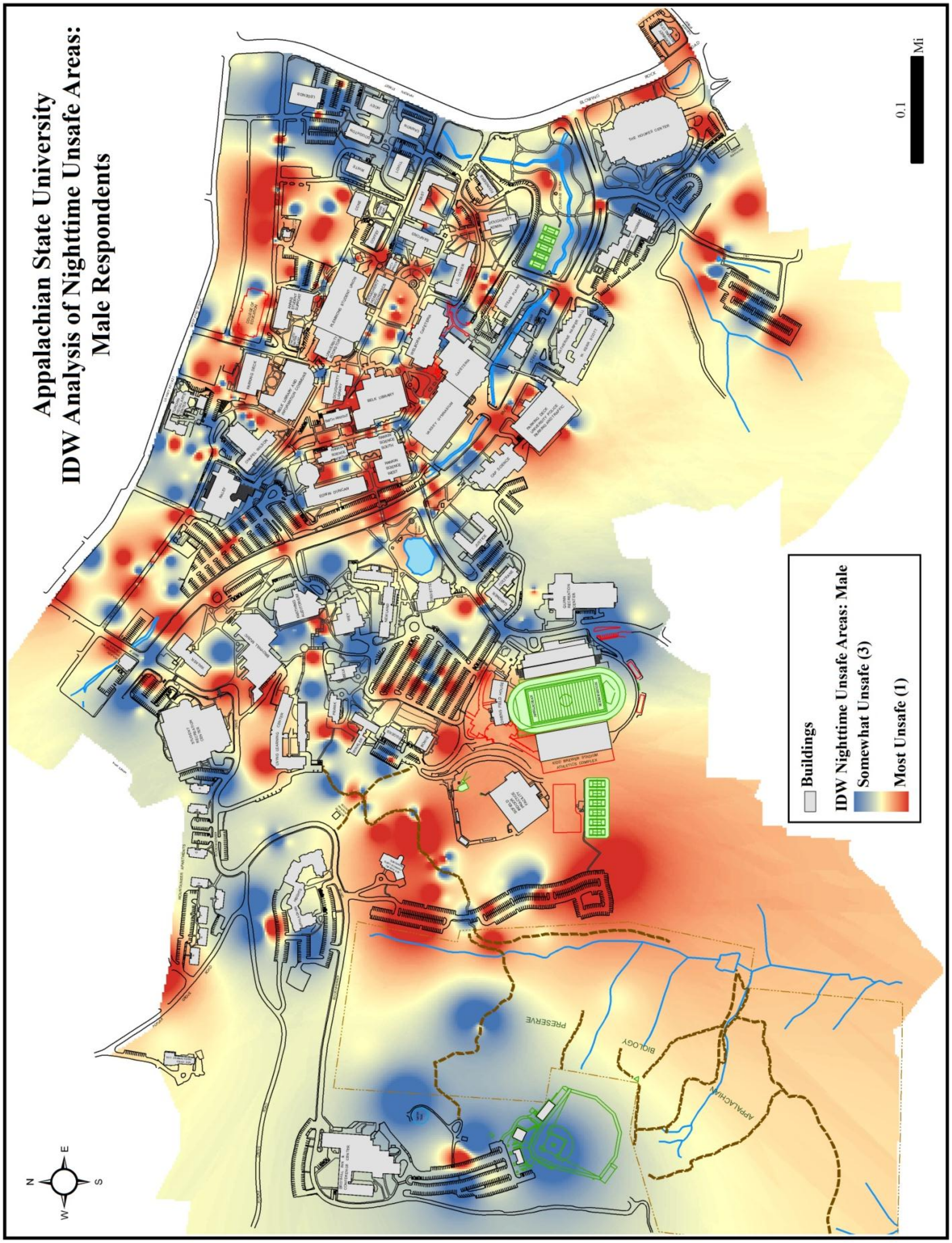


Figure 19. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (Male Points).

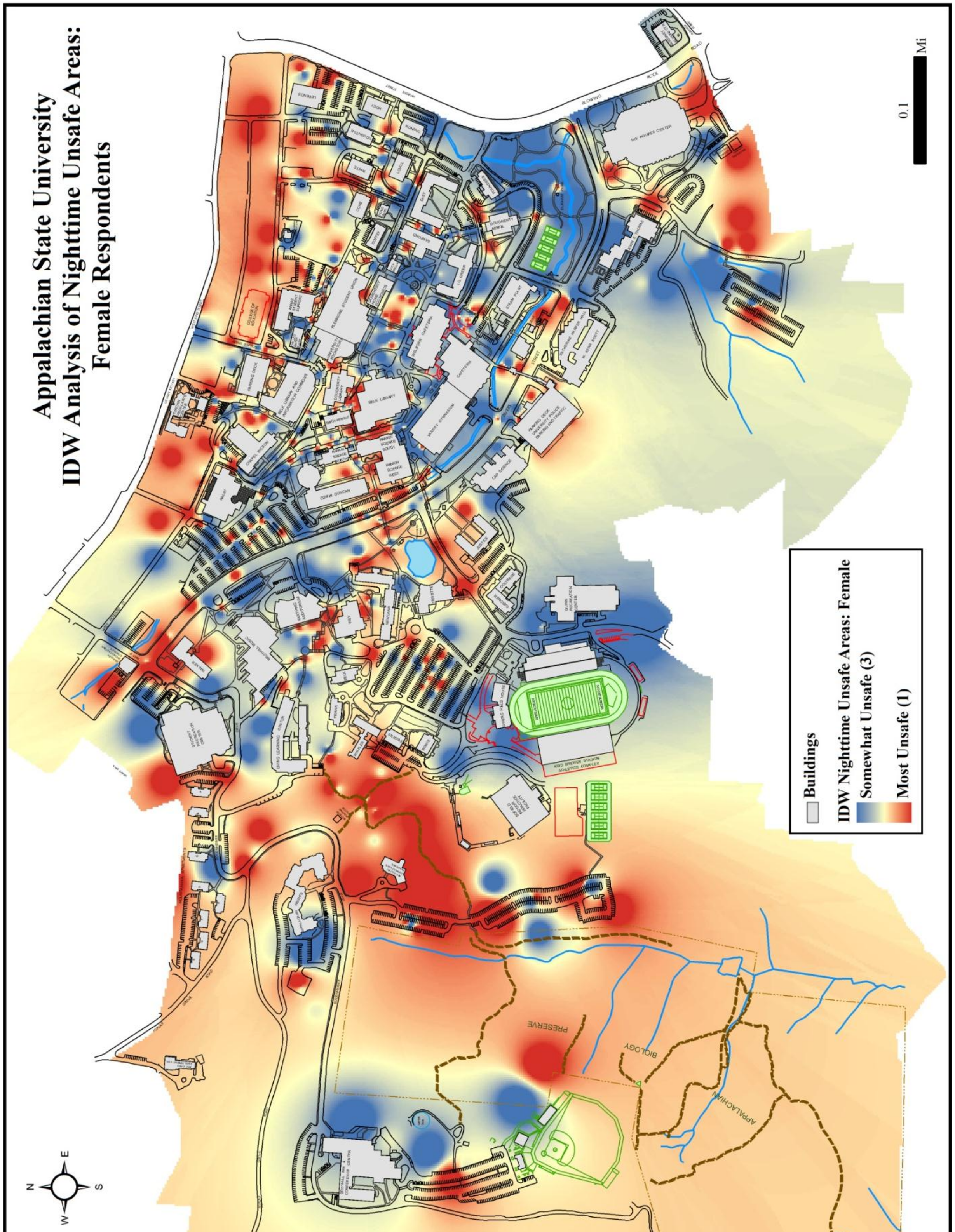


Figure 20. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (Female Points).

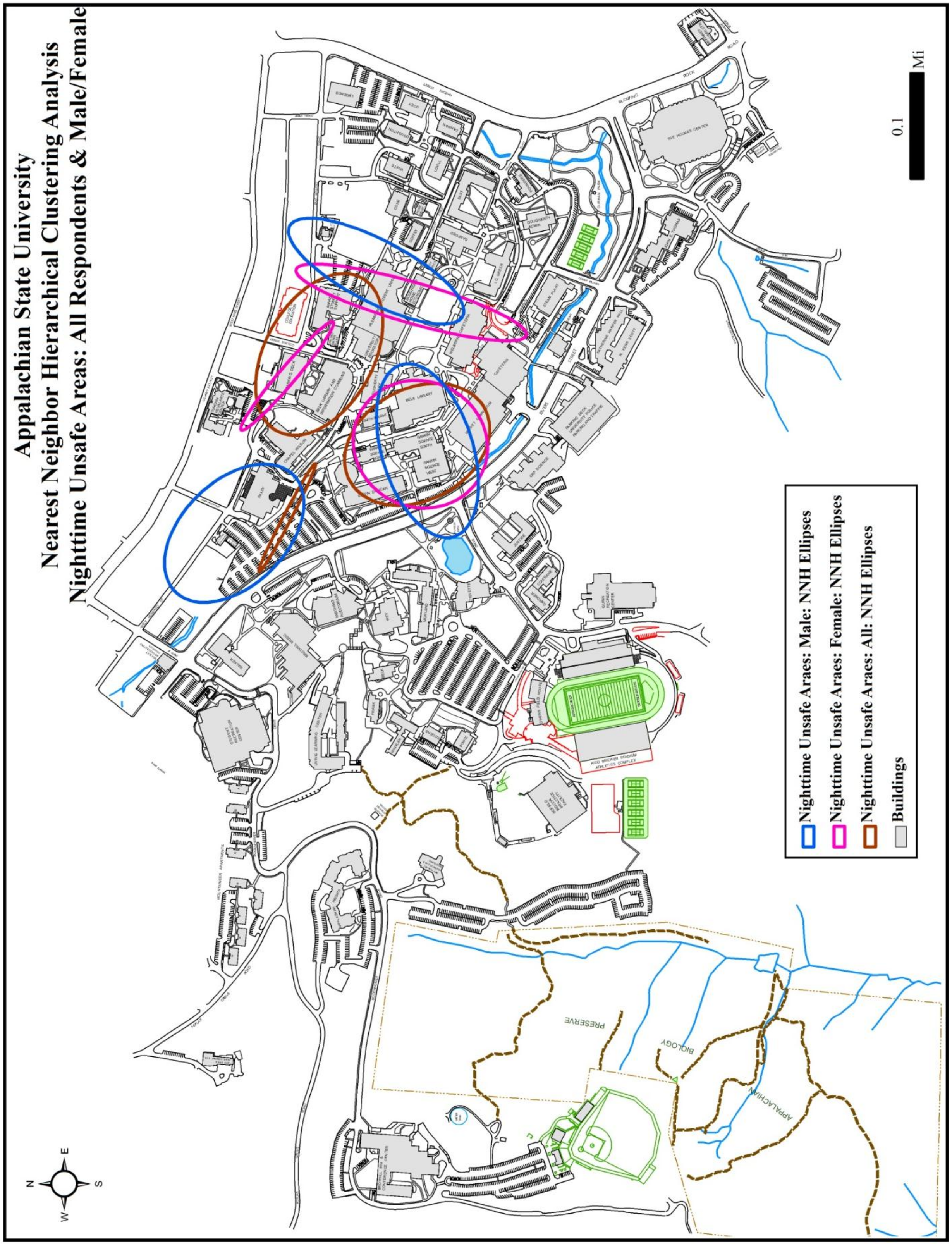


Figure 21. Nearest Neighbor Hierarchical 2nd Order Cluster Ellipses: Nighttime (All, Male, & Female).

Perceptions of Unsafe Areas: Nighttime: Off Campus, East Campus, West Campus

The second group of nighttime analysis examined the perception survey data for the unsafe points based on where the respondent lives. This sub-study examined respondents living on east campus, west campus, and off campus. A nearest neighbor analysis, IDW, and a nearest neighbor hierarchical cluster analysis was used to examine clustering and distribution.

Table 11. Nighttime Survey Points: Nearest Neighbor Analysis: Living Locations: East Campus, West Campus, Off Campus

	Sample Size	Mean NN Distance	Standard Error	NN Index	Test Statistic (z)	p - Value (one tail)	p - Value (two tail)
East Campus	279	69.87 ft.	4.25 ft.	0.5144	-15.5170	0.0001	0.0001
West Campus	430	60.96 ft.	2.76 ft.	0.5571	-17.5690	0.0001	0.0001
Off Campus	804	43.36 ft.	1.48 ft.	0.5419	-24.8490	0.0001	0.0001

The nearest neighbor analysis of these nighttime survey points yielded significant results (table 11). All results had one and two tail p-values of 0.0001 with nearest neighbor indexes under 1.0, thus displaying survey points in clustered patterns that are statistically significant. The nighttime unsafe locations given by respondents living on east campus was the most clustered out of the three groups examined in this sub-study.

The IDW interpolation method was used to create a hot spot map of the study area based on the clusters of points and each point's weight denoting how unsafe the respondent felt in that location. Figures 22, 23, and 24 depict the IDW interpolation results from all of the nighttime unsafe areas east campus respondents, the nighttime unsafe areas west campus respondents, and the nighttime unsafe areas off campus respondents.

Finally, the nearest neighbor hierarchical cluster analysis results are displayed in table 12 and figure 25. Figure 25 shows second order clusters for each of the three groups examined in this sub-study. There are some similarities displayed between the three groups of points. It is important to note that the nighttime unsafe areas east campus and west campus respondents' points only generated two second order ellipses each.

Table 12. Nighttime Survey Points: Nearest Neighbor Hierarchical Cluster Analysis: Living Locations: East Campus, West Campus, Off Campus

	Sample Size	Likelihood of Grouping Pair of Points By Chance	z - Value for Confidence Interval	Min # of Points to Generate Up To Three 2nd Order Clusters	Standard Deviation	Clusters Found
East Campus	279	50%	0.00	4	1.0	23
West Campus	430	50%	0.00	4	1.0	29
Off Campus	804	50%	0.00	7	1.0	27

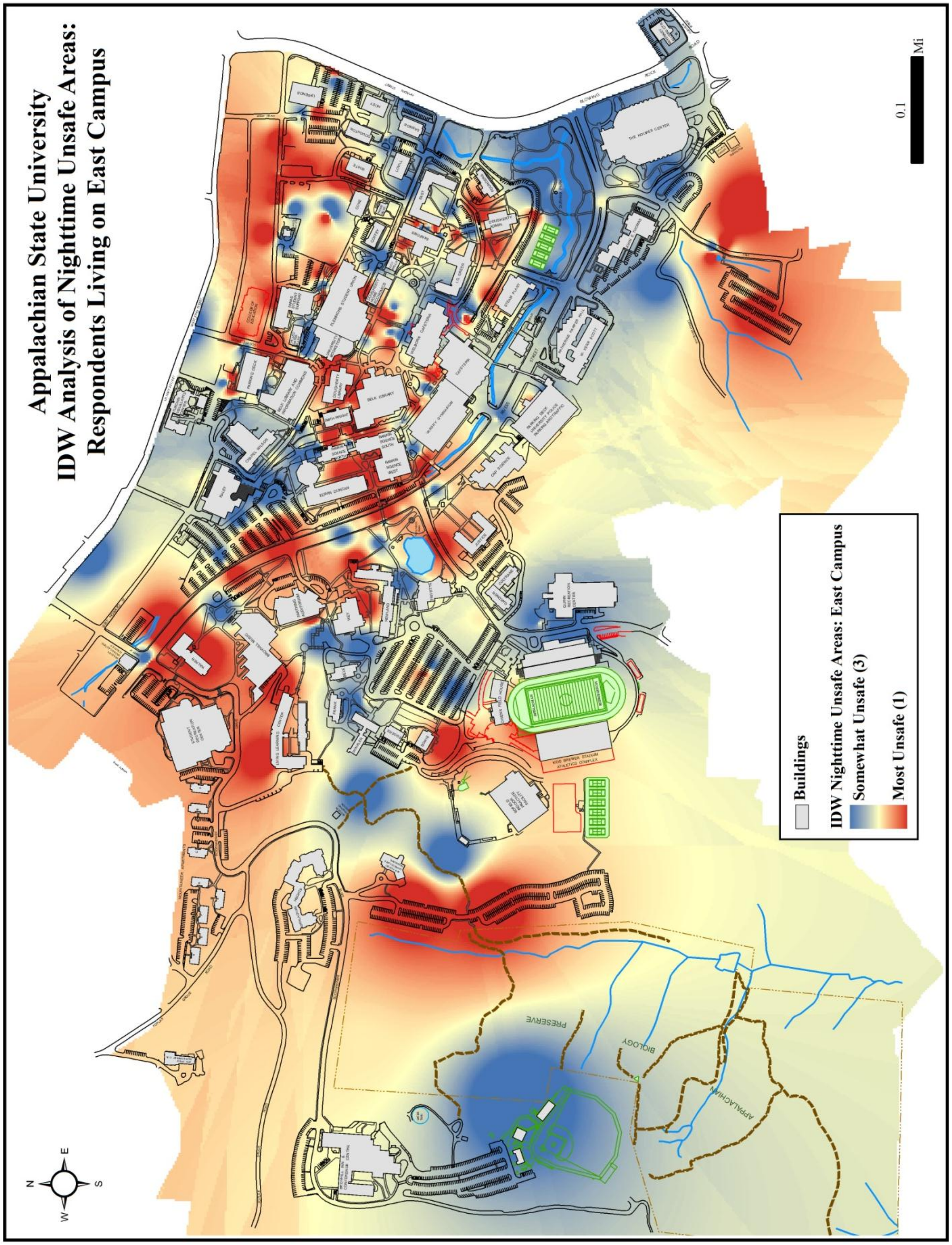


Figure 22. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (East Campus Points).

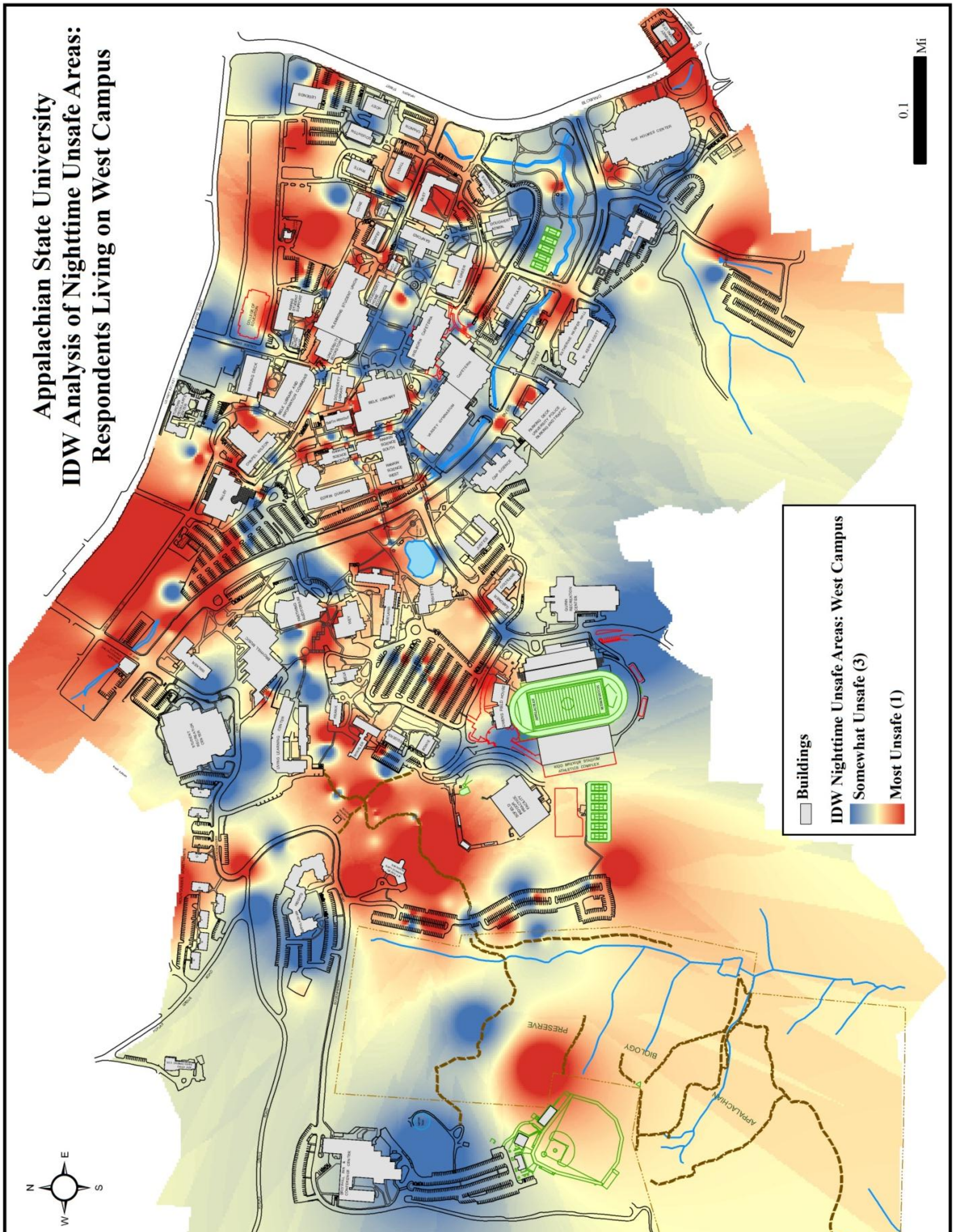


Figure 23. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (West Campus Points).

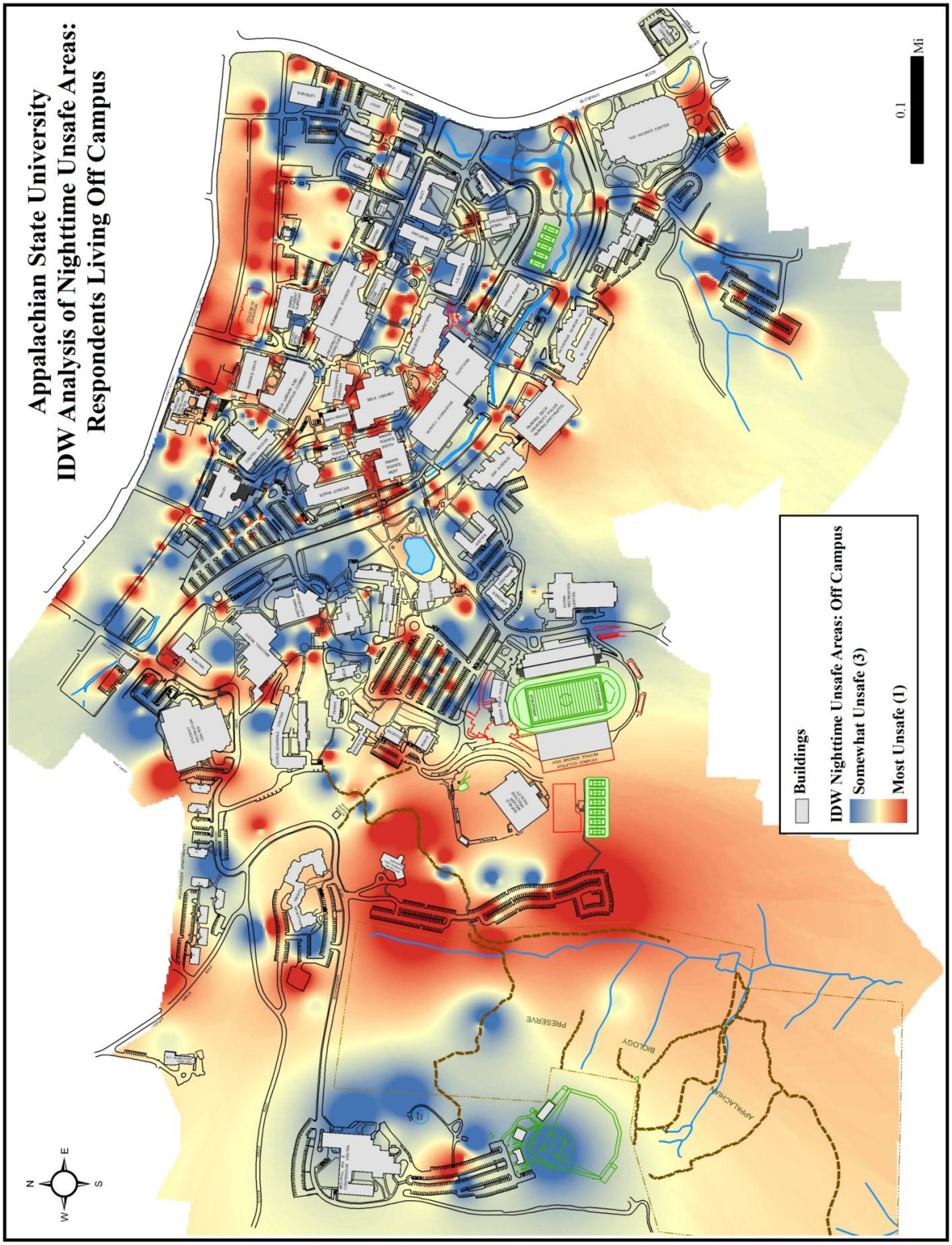


Figure 24. Inverse Distance Weighted Interpolation of Nighttime Unsafe Areas (Off Campus Points).

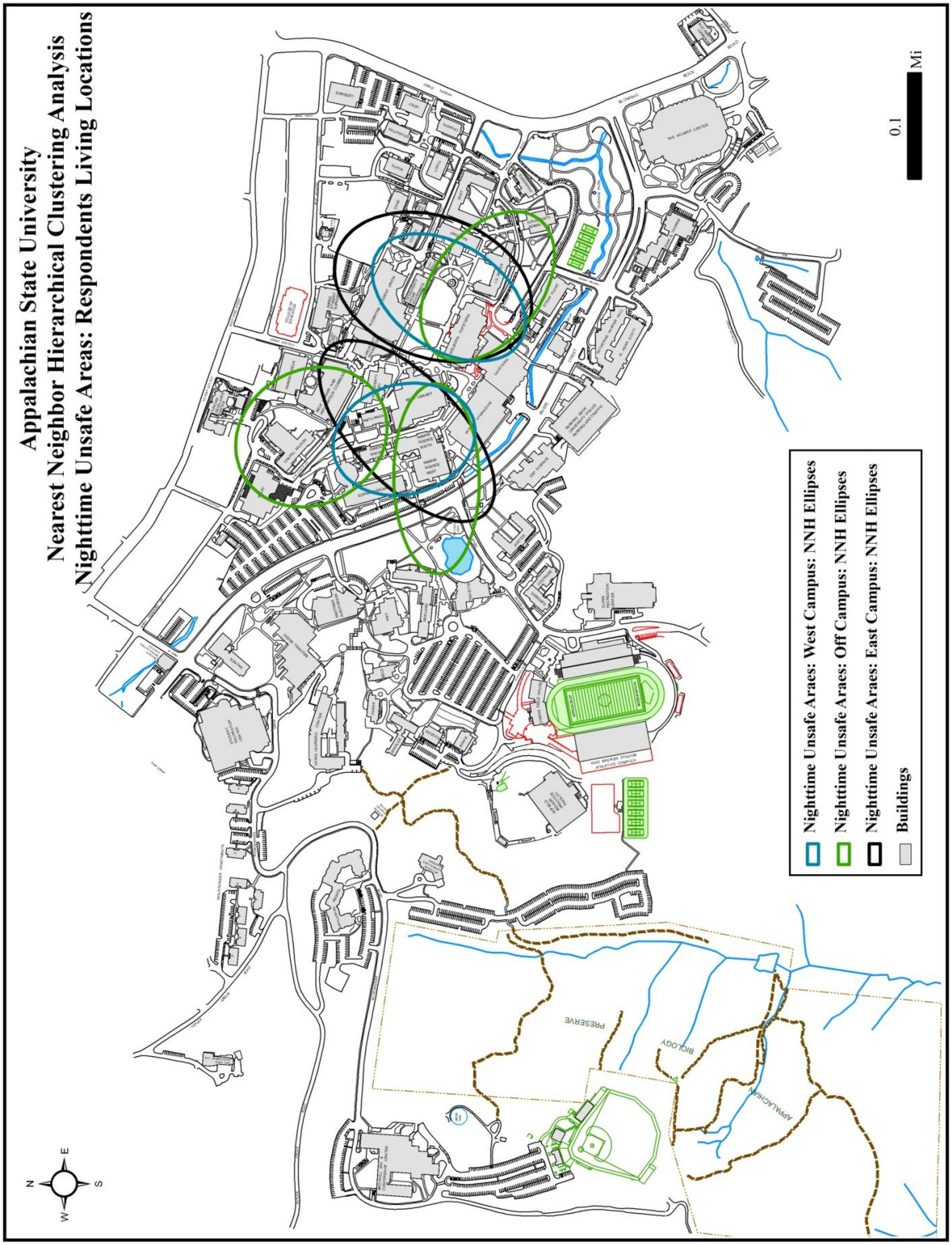


Figure 25. Nearest Neighbor Hierarchical 2nd Order Cluster Ellipses: Nighttime (East, West, & Off Campus).

Crime Data Analysis

Daytime and Nighttime Crime

The digitized crime event points were broken into daytime and nighttime subgroups to match the analysis of the perceptions of safety survey study. Similarly, the crime datasets were examined with a nearest neighbor analysis, IDW interpolation, and a nearest neighbor hierarchical cluster analysis was used to examine clustering and distribution.

Table 13. Crime Events: Nearest Neighbor Analysis: Daytime and Nighttime

	Sample Size	Mean NN Distance	Standard Error	NN Index	Test Statistic (z)	p - Value (one tail)	p - Value (two tail)
Daytime Crime	122	131.17 ft.	9.72 ft.	0.6386	-7.6373	0.0001	0.0001
Nighttime Crime	76	157.22 ft.	15.60 ft.	0.6041	-6.6027	0.0001	0.0001

The nearest neighbor analysis of these crime event points yielded significant results (table 13). All results had one and two tail p-values of 0.0001 with nearest neighbor indexes under 1.0, thus displaying survey points in clustered patterns that are statistically significant. Even though the daytime crime event dataset contained more points, the nighttime crime events were the most clustered out of the daytime and nighttime points examined in this study.

The IDW interpolation method was used to create a hot spot map of the study area based on the clusters of points and each point's weight denoting how severe the crime was. Figures 26 and 27 show the location of all of the daytime and nighttime crime events that happened on Appalachian's campus during the 2008-2009 academic year. Figures 28 and 29 depict the IDW interpolation results from the analysis of the daytime and nighttime crime events.

Finally, the nearest neighbor hierarchical cluster analysis results are displayed in table 14 and figure 30. It is important to note that while the nearest neighbor analysis shows statistically significant clustering, the clustering was not great enough to generate any second order clustering for either of these to datasets. The map in figure 30 shows only first order clusters; there are some similarities displayed between the two groups of points.

Table 14. Crime Events: Nearest Neighbor Hierarchical Cluster Analysis: Daytime and Nighttime

	Sample Size	Likelihood of Grouping Pair of Points By Chance	z - Value for Confidence Interval	Min # of Points to Generate Up To Three 2nd Order Clusters	Standard Deviation	Clusters Found
Daytime Crime	122	50%	0.00	1	1.0	28
Nighttime Crime	76	50%	0.00	1	1.0	19

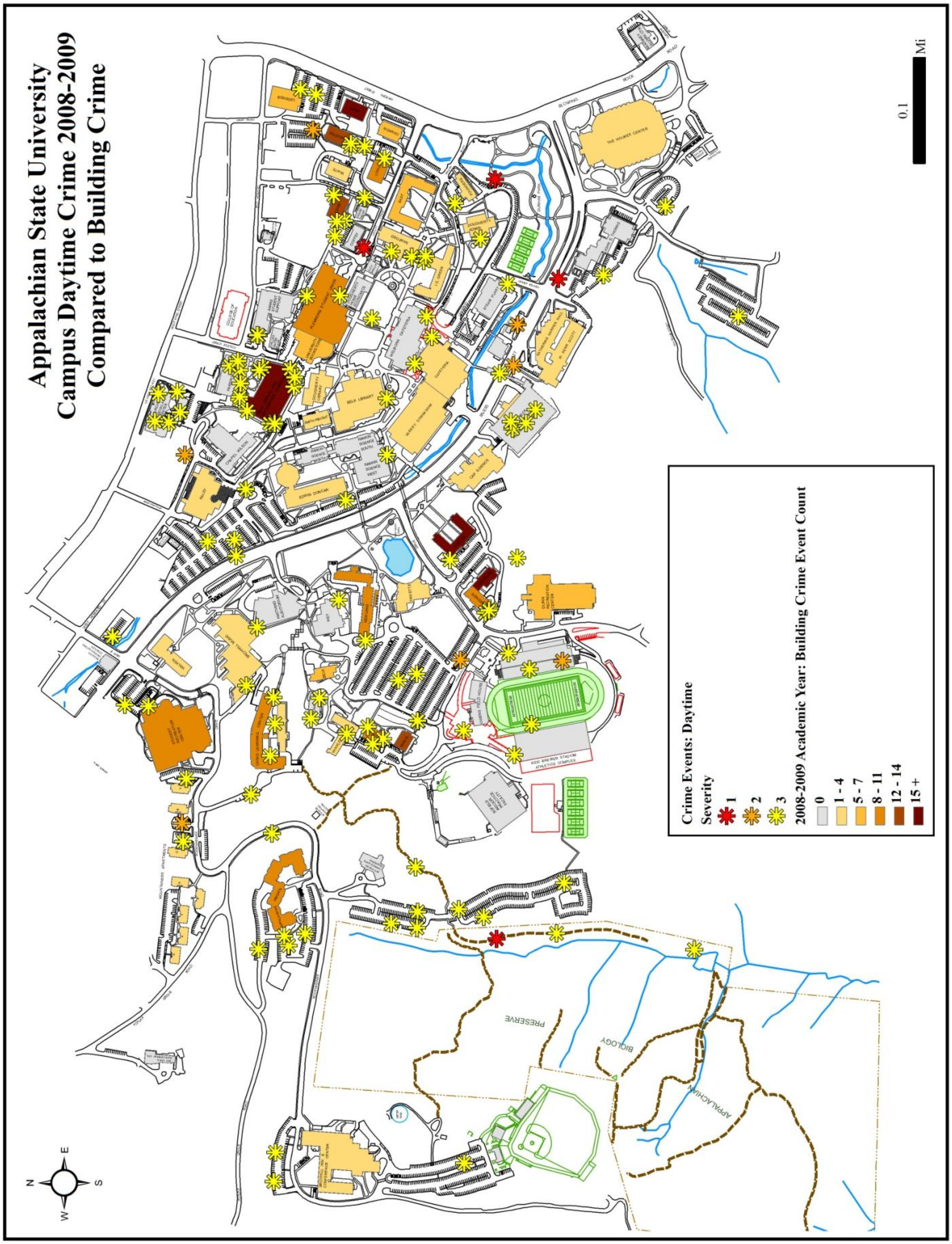


Figure 26. 2008-2009 Daytime Crime Event Points, Compared to Building Crime Events.

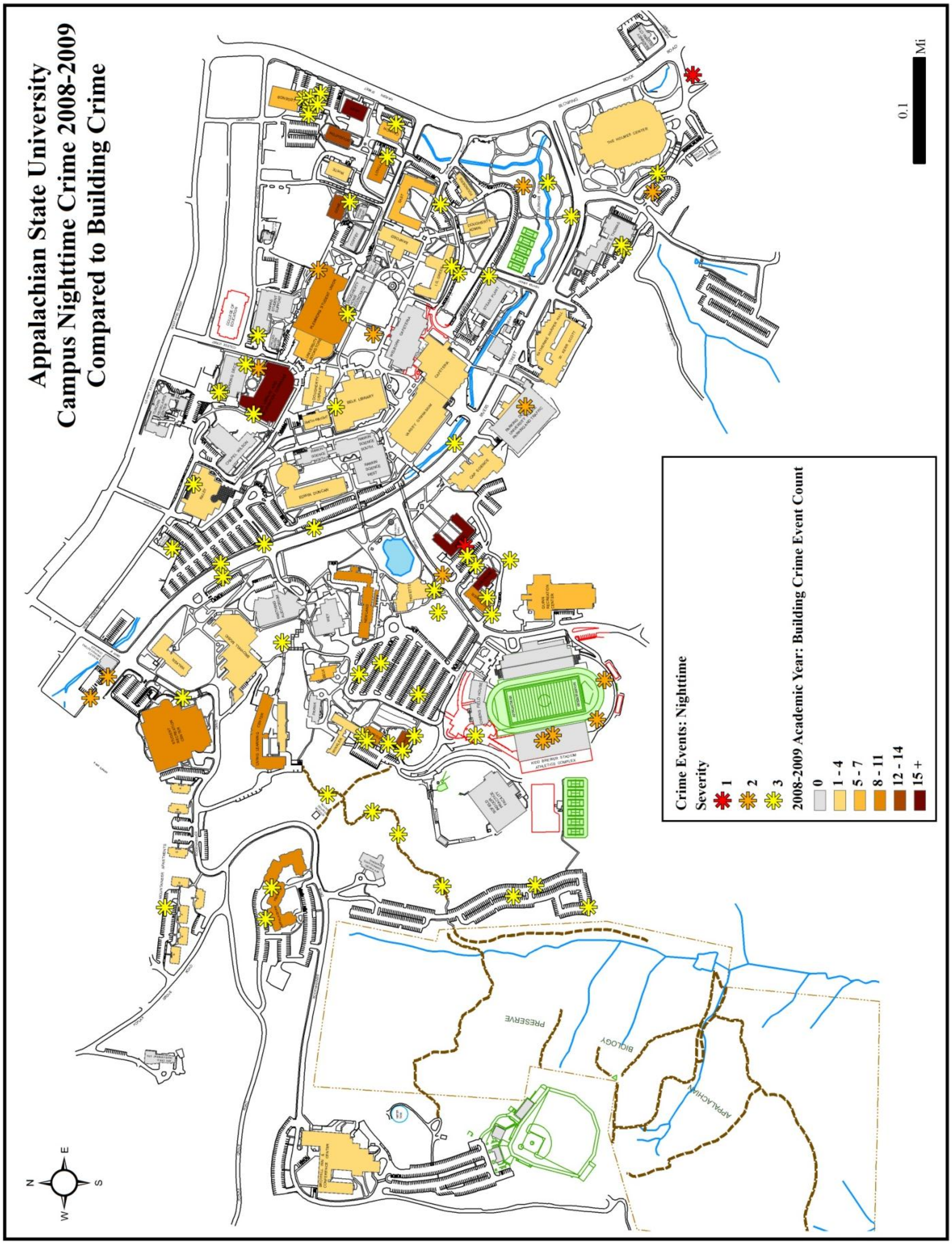


Figure 27. 2008-2009 Nighttime Crime Event Points, Compared to Building Crime Events.

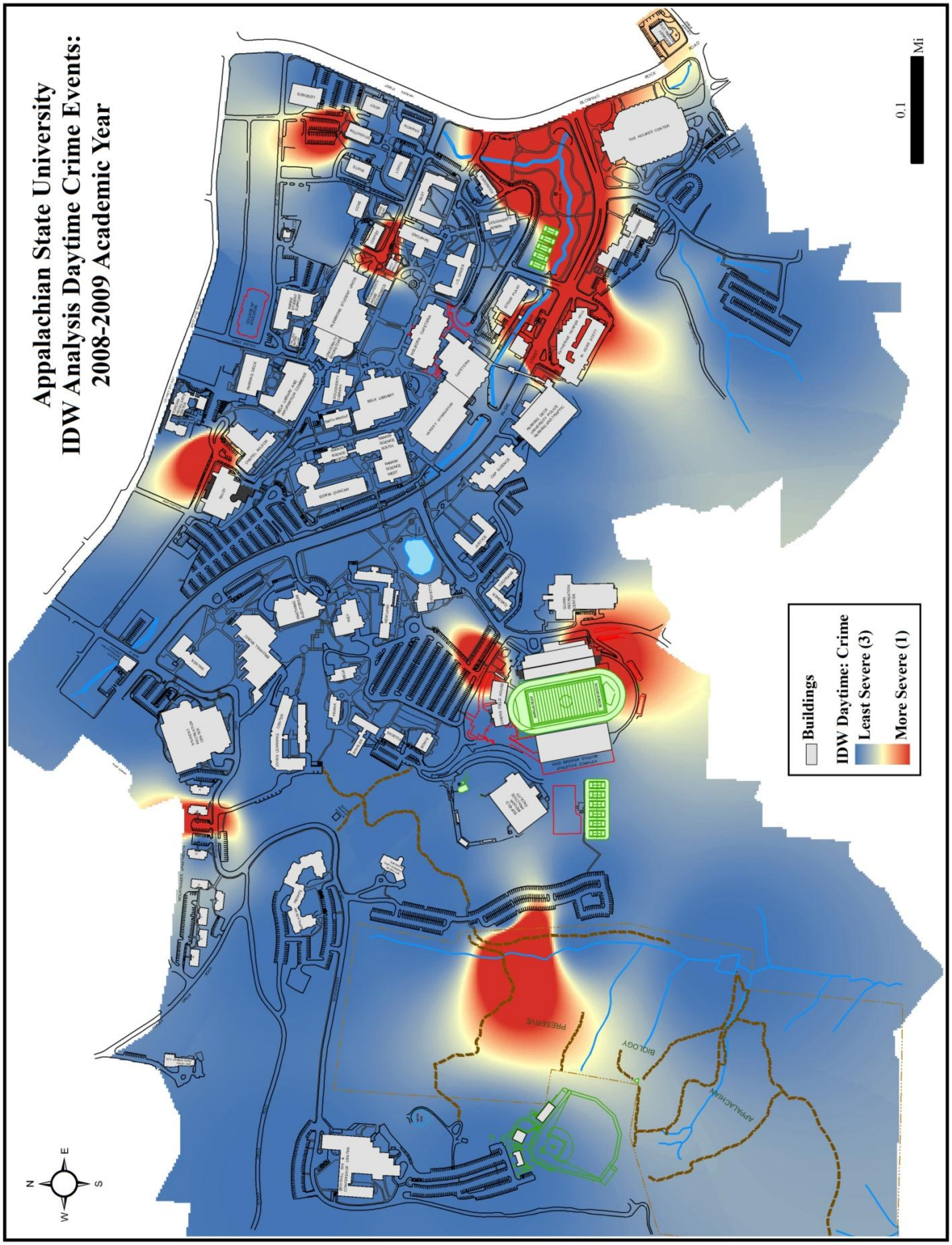


Figure 28. Nearest Neighbor Analysis 2008-2009 Daytime Crime Events.

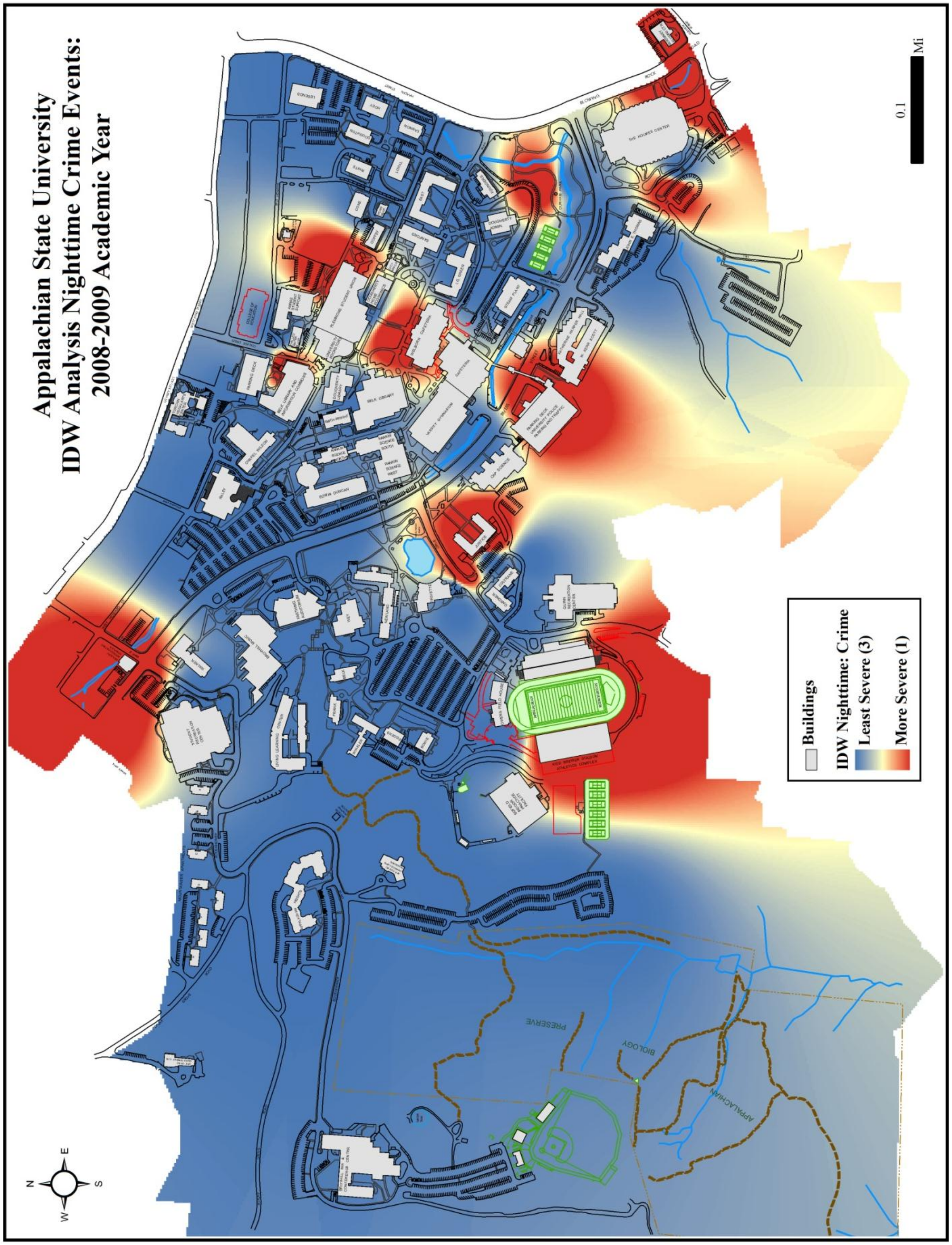


Figure 29. Nearest Neighbor Analysis 2008-2009 Nighttime Crime Events.

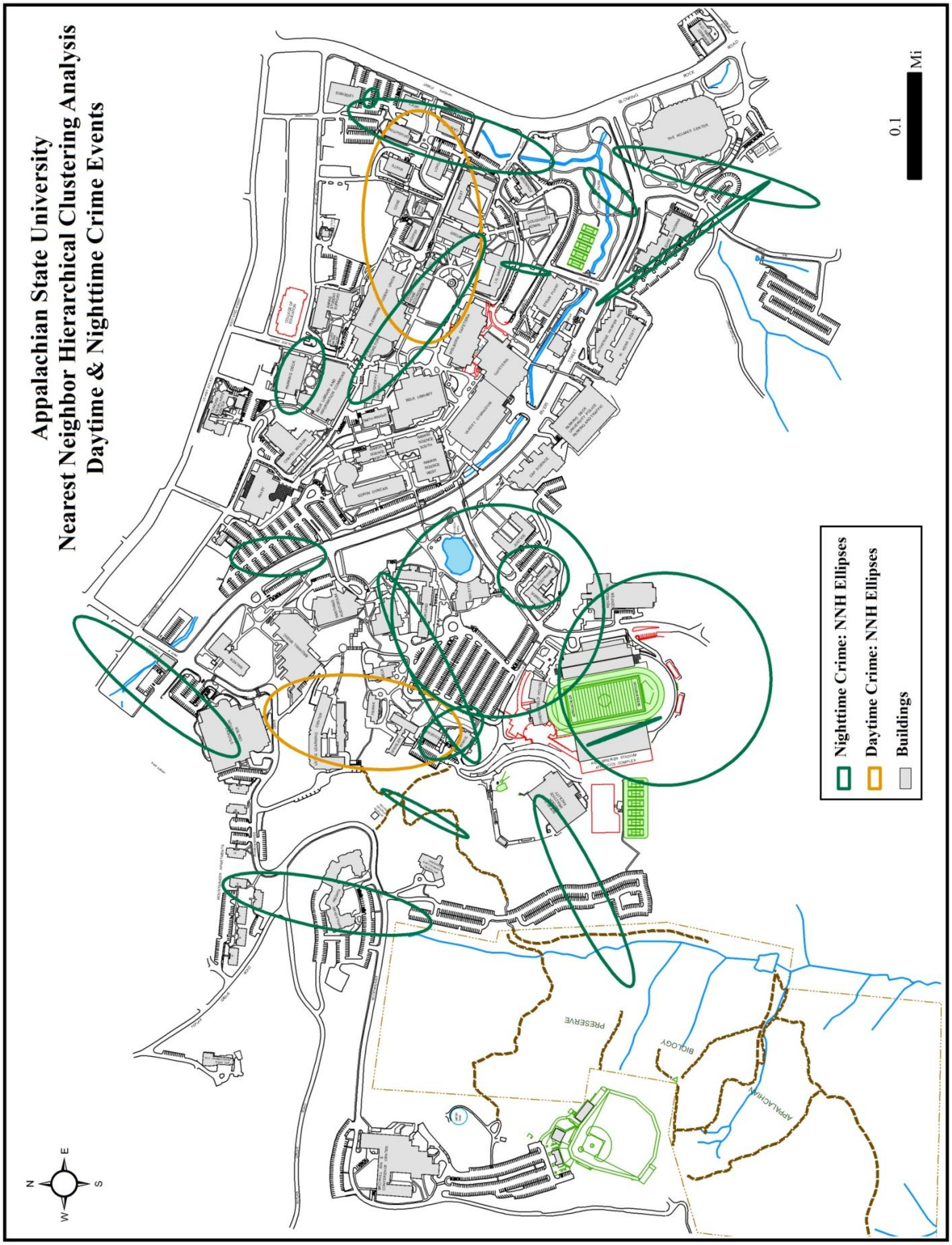


Figure 30. NN Hierarchical 1st Order Ellipses, 2008-2009 Daytime & Nighttime Crime Events.

Lighting Data Analysis

Light post/pole point data gathered from electrical shop light (green, human level, landscaping lampposts) and the New River Light and Power security lights (large street/parking lot spun aluminum light poles) were extracted and placed into a GIS. Additional post/pole points were added to the data set from examining the 2009 six-inch color orthophoto.

As discussed previously, the centroids of these post/poles (figure 31) were used to create proximity buffers based on the two types of light sources' expected placement. Electric shop lampposts are placed approximately fifty feet apart and New River Light and Power security lights are placed 180 feet apart. Therefore, their buffers were set at twenty-five feet and ninety feet, respectively. This analysis showed an estimated coverage area of the light sources on Appalachian's campus (figure 32).

Further analysis was conducted on the actual light sources and the quantity of light projected. Only the human level light sources, the green electrical shop lampposts, were used for this analysis. Of the over 600 lampposts on Appalachian's campus, fifteen were randomly chosen for further examination (table 15).

Table 15. Appalachian Lamppost Illuminance Samples

Lamppost Sample	Type	12.5 Feet (lux)	25 Feet (lux)
1	DS	18.20	4.90
2	S	25.50	12.80
3	S	17.65	5.50
4	DS	35.80	3.80
5	S	23.50	5.50
6	S	31.50	5.80
7	S	18.50	4.75
8	S	18.20	4.80
9	S	21.50	5.80
10	LED	38.50	5.50
11	S	32.50	6.00
12	S	11.90	2.50
13	S	34.20	5.80
14	S	17.30	5.60
15	DS	42.00	5.20
Mean		25.78	5.62

When these sample data are compared against the IESNA (2000) recommended standards for average maintained luminance levels for pedestrian ways (table 16), some areas where lighting does not meet the standards is found. It is important to note that the vertical measurements listed in Table 16 were taken at six feet and the vertical measurements taken in this study were taken at average eye height, just less than five feet two inches (table 2).

Since the majority of Appalachian's campus is near roadways, the best values to use from the IESNA table would be the commercial and intermediate areas. At 12.5 feet from the lamppost, there are no values that fall under the minimum average (eleven lux), and eight lampposts producing more lux than the minimum average for commercial areas (twenty-two lux).

Table 16. Recommended Average Maintained Illuminance Level for Pedestrian Ways (Lux)*

Walkway & Bikeway Classification	Minimum Average Horizontal Levels	Average Vertical Levels For Special Pedestrian Security**
Sidewalks (Roadside) & Type A Bikeways:		
Commercial Areas	10	22
Intermediate Areas	6	11
Residential Areas	2	5
Walkways Distant From Roadways & Type B Bikeways:		
Walkways, Bikeways, & Stairways	5	5
Pedestrian Tunnels	43	54

*Illuminating Engineering Society of North America 2000, 22-11
** For pedestrian identification at a distance. Values at 1.8 meters (6 feet) above walkway.

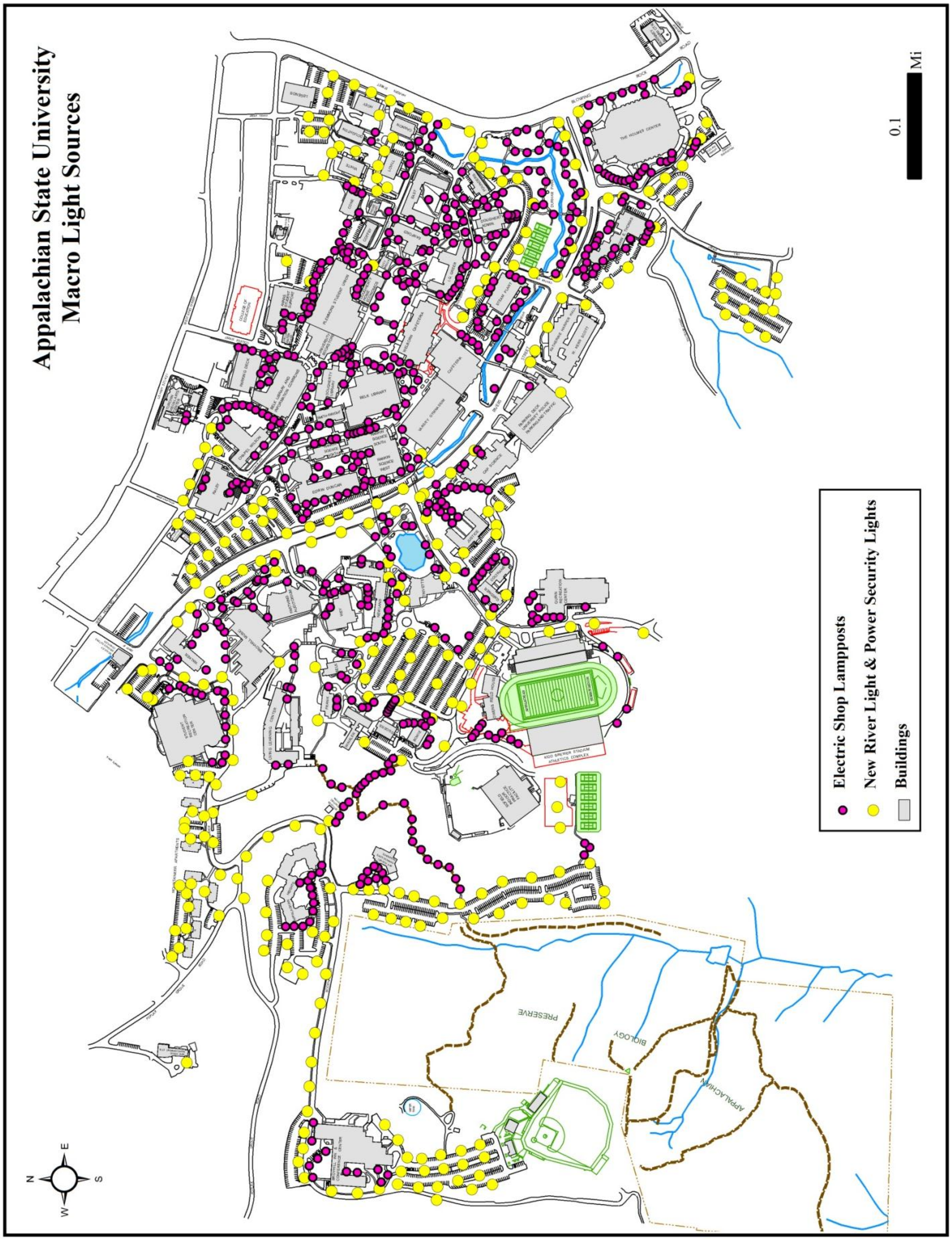


Figure 31. Macro Light Source Centroids.

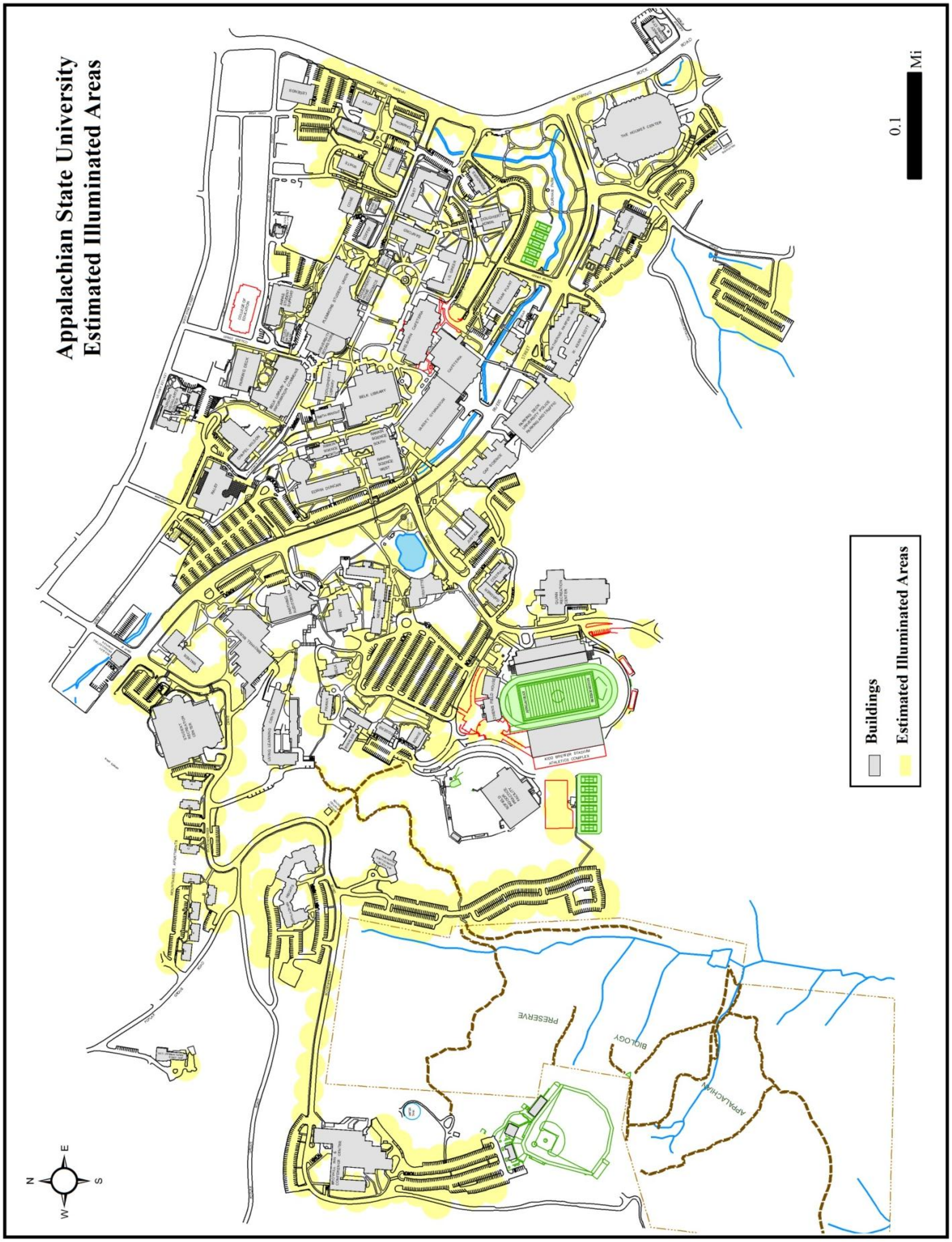


Figure 32. Estimated Illuminated Areas.

This chapter has presented results on surveyed perceptions of safety, crime, and lighting at Appalachian. Significant results were discovered among the clusters of points for the surveyed perceptions data as well as the crime data. Additionally, illuminance levels were found to be satisfactory, however, there were some areas that were found to be lacking in coverage according to the estimated illuminated areas analysis. The relationships amongst these analyses will be further discussed in chapter five.

Chapter 5
Discussion

Perceptions of Safety Survey Analysis

Perceptions of Unsafe Areas: Daytime

The study yielded some interesting findings about students' daytime perceptions of unsafe areas. From this study's infancy, the objective of the survey was to identify areas where students felt unsafe but it was always assumed that the study would point towards areas where students perceived they could be victimized. However, the daytime study yielded different results and focus. The daytime study therefore transformed into an examination of unsafe areas due to pedestrian transportation issues.

Figure 4 showed that the students surveyed at Appalachian travel on campus far more during the day compared to traveling at nighttime (figure 5). Much of this has to do with the traditional class hours (8am – 5pm) that Appalachian keeps. Survey respondents' level of cautiousness on campus during the daytime (figure 6) was also reduced compared to nighttime (figure 7). Figure 6 shows that the male respondents are much less cautious on campus during the day while the female respondents keep a more constant level of moderate cautiousness on campus during the daytime. When examining the nearest neighbor indexes, the males' daytime perception of unsafe areas, it is slightly more clustered than the females (table 5) as is that of the respondents that live on the western side of Appalachian's campus.

The IDW interpolation of the respondents' daytime points of unsafe areas yielded an interesting map. In figure 9 the hot spots are predominantly along transportation corridors such as Rivers Street or along peripheral areas in and around South Parking Lot (south of the Broyhill Inn) and Greenwood Parking Lot (adjacent to the Chancellor's residence) which both lie in the western edge of Appalachian's main campus. The other prominent hot spot areas were to the northern edge of the campus along East Howard Street and along portions of King Street.

When examining males' perceptions in the daytime (figure 10) many of the western edge areas were less prominent while the northern areas as well as Hill Street Parking Lot, Rivers Street, and the Greenwood Parking Lot trail were most prominent. Females' perceptions (figure 11) highlighted the western and northwestern third of Appalachian's main campus. However, females' perceptions of safety in the central, northern, and eastern parts of the campus were much more clustered than the males' perception. This difference may be due in part to limitations inherent to explicit reports as methods of eliciting truthful assumptions from males (Montello and Sutton 2006). However, gender differences in fear have been reported in other studies.

The IDW interpolation method takes into consideration the weight of each point as well as its proximity to other points around it. However, the nearest neighbor hierarchical clustering analysis does not take into consideration the weights given to each point, as it looks only at the clusters. For this study, as mentioned earlier, it was decided to look at the second order clusters. These are clusters of first order clusters, therefore representing areas that multiple respondents felt unsafe. Figure 12 shows that much of the daytime points were clustered around the major transportation networks: Rivers Street in the middle of Appalachian's campus and the northern side of many of the major buildings in the central part of the campus that abut Howard Street or where Howard Street previously connected.

Since perception has been shown to be affected by anchor points, one layer of the study examined the respondents' perception of unsafe areas during the daytime based on if they live off campus, or on east or west campus. The IDW interpolation of respondents that live on Appalachian's east campus (figure 13) showed hot spots on the western third of the campus and along East Howard Street. This could be because the western edge of the campus holds some academic buildings as well as Appalachian's new Student Recreation Center and it is the furthest, main campus, student facility that would be utilized on a regular basis from the eastern side of the campus. There were few predominant hot spots around the dorms on the eastern side of the campus. The study of the west campus respondents (figure 14) yielded results similar to the campus wide daytime perceptions analysis, highlighting the peripheral areas, major roads, and parking lots. The off campus analysis (figure 15) yielded a rather pockmarked result most likely due to the smaller sample size and less clustering. This subgroup predominantly emphasized parking lots, Rivers Street, and Howard Street as areas where they felt the most unsafe during the daytime.

The nearest neighbor hierarchical clustering analysis (figure 16) yielded similar results as the previous subgroups'. The predominant second order cluster locations were along Rivers Street; however this subgroup's focus on Rivers Street stretched further along the corridor than the others. Additionally and similarly, there was significant clustering to the northern edge of campus along the Howard Street corridor. This is most likely due to the amount of vehicular and pedestrian traffic both of these streets see daily.

Perceptions of Unsafe Areas: Nighttime

The study yielded some interesting but not surprising findings about students' nighttime perceptions of unsafe areas. From the study's infancy, the objective of the survey was to identify areas where students felt unsafe and where students perceived they could be victimized. The nighttime study yielded results that followed this objective.

In figure 5, it is seen that the students surveyed at Appalachian travel on campus less during the night compared to traveling during the daytime (figure 4). Much of this has to do with the traditional class hours (8am – 5pm) that Appalachian keeps; very few night classes are offered. Survey respondents' level of cautiousness on campus during the nighttime (figure 7) are far greater than compared to daytime (figure 6). Figure 7 shows that the male respondents are much less cautious on campus during the nighttime hours while the female respondents are far more cautious on campus during the nighttime. When examining the nearest neighbor indexes, the females' nighttime perception of unsafe areas is much more clustered than the males (table 9), as is the response from those who live on the eastern side of Appalachian's campus.

The IDW interpolation of the respondents' nighttime points of unsafe areas yielded a telling hot spot graphic. In figure 18 the hot spots are no longer predominantly along transportation corridors such as Rivers Street or even along peripheral areas like South Parking Lot (south of the Broyhill Inn). The hot spots are predominantly along the Greenwood Parking Lot trails, East Howard Street, Hamby Alley, and in the core of campus. The hot spots located in the core of campus are between Rankin Science West and Edwin Duncan Hall, the triangle behind the Old Library Classroom Building (now Anne Belk Hall), Smith-Wright Hall, and D.D. Dougherty Hall, and behind the Student Union.

When examining males' perceptions in the nighttime (figure 19) many of the prominent hot spot areas previously listed were again highlighted but there were additional hot spots covering the Greenwood Parking Lot (adjacent to the Chancellor's residence) and in triangle that is created by the southeastern edge of the Old Library Classroom Building (now Anne Belk Hall), Varsity Gymnasium, and the new Central Dining Hall. The females' perceptions (figure 20) removed much of the emphasis on the core of campus and placed it heavily on the peripheral areas of King Street, Hamby Alley, East Howard Street, and the Greenwood Parking Lot trails. There was some additional emphasis placed on Stadium Drive to the southwest as well as around the Old Library Classroom Building (now Anne Belk Hall).

The IDW interpolation method takes into consideration the weight of each point as well as its proximity to other points around it. However, the nearest neighbor hierarchical clustering analysis does not take into consideration the weights given to each point, as it looks only at the clusters. For this study, as mentioned earlier, it was decided to look at the second order clusters. These are clusters of first order clusters, therefore representing areas in which multiple respondents felt unsafe. Figure 21 shows that much of the nighttime points were clustered around the buildings in the core of campus.

Since perception has been shown to be affected by anchor points, one layer of the study examined the respondents' perception of unsafe areas during the nighttime based on whether they live off campus, or on east or west campus. The IDW interpolation of respondents that live on Appalachian's east campus (figure 13) showed hot spots on Greenwood Parking Lot (adjacent to the Chancellor's residence), around the Student Recreation Center, Hill Street Parking Lot, the same central core areas of the campus as discussed previously, around the north side of the B.B. Dougherty Administration Building, and along East Howard Street and Hamby Alley. The western edge of the campus holds some academic buildings as well as Appalachian's new Student Recreation Center and it is the furthest, main campus, student facility that would be utilized on a regular basis from the eastern side of the campus. There were several hot spots around the dorms and other predominant structures on the eastern side of the campus which correlates to the concept that perceptions are made in part from anchor points.

The study of the west campus respondents (figure 23) yielded interesting results. These respondents' perceptions highlighted the peripheral areas, but not west of the Greenwood Parking Lot (adjacent to the Chancellor's residence). The predominant hot spot areas were the road crossing tunnels under and perpendicular to Rivers Street, the northern boundary of campus, around East and Lovill Residence Halls, and the southeastern edge of the Holmes Convocation Center around US Highway 321. This scattered perception is most likely a result of the volume of travel a student living on west campus has in order to get to major university services such as the library or student union. The off campus analysis (figure 24), again yielded a rather pockmarked result most likely due to the smaller sample size and less clustering. This subgroup predominantly emphasized parking lots, Rivers Street, and Howard Street as areas where they felt the most unsafe during the nighttime, as well as some central campus areas such as between Rankin Science West and Edwin Duncan Hall.

The nearest neighbor hierarchical clustering analysis (figure 25) yielded similar results as the previous subgroups'. The predominant second order cluster locations were again located mostly in the core of the campus. However this subgroup's ellipses included the road crossing tunnels under and perpendicular to Rivers Street, features commonly perceived as unsafe on Appalachian's campus. Additionally, there was significant clustering within the campus mall and around the back of the Old Library Classroom Building (now Anne Belk Hall).

Crime Data Analysis Discussion

Daytime Crime Events

The daytime crime analysis showed areas that were clustered via the IDW interpolation. However, as seen in table 13 the nighttime crime points were fewer in number but slightly more clustered. When comparing the daytime crime event points to the volume of crime per building in figure 26, there are some similarities between number of external crime events and buildings with higher crime counts. The Belk Library and Information Commons, Cone, Eggers, and Doughton Residence Halls were all buildings that had higher internal crime counts with multiple daytime crime events taking place around them.

The IDW interpolation of daytime crime events yielded several significant hot spots. From west to east they were: west of the Greenwood Parking Lot (adjacent to the Chancellor's residence) going up the trail towards the Broyhill Inn, around the backside of the football stadium, in front of the football stadium towards Duck Pond Field, around the old Mountaineer Apartments (torn down summer 2010) near the Student Recreation Center, to the west of Chapel Wilson Hall and behind Raley Hall, to the east of Plemmons Student Union and in front of Coffey Residence Hall (torn down summer 2010), the Doughton Residence Hall parking lot, and from Dauph Blan Street south along US Highway 321 to the Holmes Convocation Center and northwest through Durham Park and up Rivers Street to the Rivers Street Parking Deck.

The nearest neighbor hierarchical clustering analysis (figure 30) yielded two second order clusters. The first was on the northwestern corner of Stadium Parking Lot stretching up across the Living Learning Center and touching the southeastern wall of the Student

Recreation Center. The second predominantly covered the east campus residence halls as well as part of the campus's mall.

Nighttime Crime

The nighttime crime analysis showed areas that were clustered via the IDW interpolation and the nearest neighbor hierarchical clustering analysis. As seen in table 13, the nighttime crime points were fewer in number but slightly more clustered than the daytime points. When comparing the nighttime crime event points to the volume of crime per building in figure 27, there are some similarities between number of external crime events and buildings with higher crime counts. The Gardner, Coltrane, and Justice Residence Halls were all buildings that had higher internal crime counts with multiple nighttime crime events taking place around them.

The IDW interpolation of nighttime crime events yielded several significant hot spots. From west to east they were: northwest of the Student Recreation Center heading away from campus, around the western and score board sides of the football stadium, around the front of Justice Residence Hall including Stadium Drive and the CAP Building parking lot, around the front of the Rivers Street Parking Deck, around the southern edge of the campus mall, the back of the Belk Library and Information Commons and Plemmons Student Union, the northeastern section of Durham Park, and around the southern side of the Holmes Convocation Center.

The nearest neighbor hierarchical clustering analysis (figure 30) yielded results that was different than any of the others because the analysis was not able to identify any second order clusters, only first order. Therefore, the nearest neighbor hierarchical clustering analysis is rather vague and random for the nighttime crime event points.

Lighting Data Analysis Discussion

The lighting portion of the study showed that the majority of the lights sampled were within IESNA's (2000) standards for external illumination (lux) and that Appalachian's campus is mostly well lit. Examining figure 32 there are still some areas under lit. Based on the information provided on the location of the lampposts and their traditional spacing there are parts of Appalachian's mall, around the front of Rankin Science West, around the front entrance to Farthing Auditorium, on the Rivers Street side of Varsity Gymnasium, and around the ATM machines on Rivers Street that could use some additional lighting. It is important to reiterate that this study only took into consideration the macro light sources (green electric shop lampposts and the New River Light and Power security lighting), and there are other light sources on Appalachian's campus in the form of wall units and lamps that are under awnings and overhanging parts of buildings that allow pedestrians to walk under, like the southern side of Belk Library and Information Commons.

There are little to no correlations to crime events taking place outside of lit areas; all but a few nighttime crime events happened in lit areas. This may draw a parallel to Mellard's (1997) theory that light may even make the criminal's job easier by providing a "work" environment with favorable visibility. The one caveat is the walking trails that lead up to the parking lots above campus. Several of these trails are illuminated; however, they may not be the most well lit areas and crime events have happened around those trails.

Areas of Interests

Three Daytime Critical Areas and Suggestions

There was an additional analysis done on the nearest neighbor hierarchical cluster ellipses of perceptions of unsafe areas that allowed correlations to be made across the datasets. The daytime unsafe areas nearest neighbor hierarchical cluster ellipses were merged using the intersect command. If four or more ellipses overlapped, the intersect command pulled out that overlapping area, thus showing areas that were similarly clustered across the subgroups. The daytime results can be seen in figure 33.

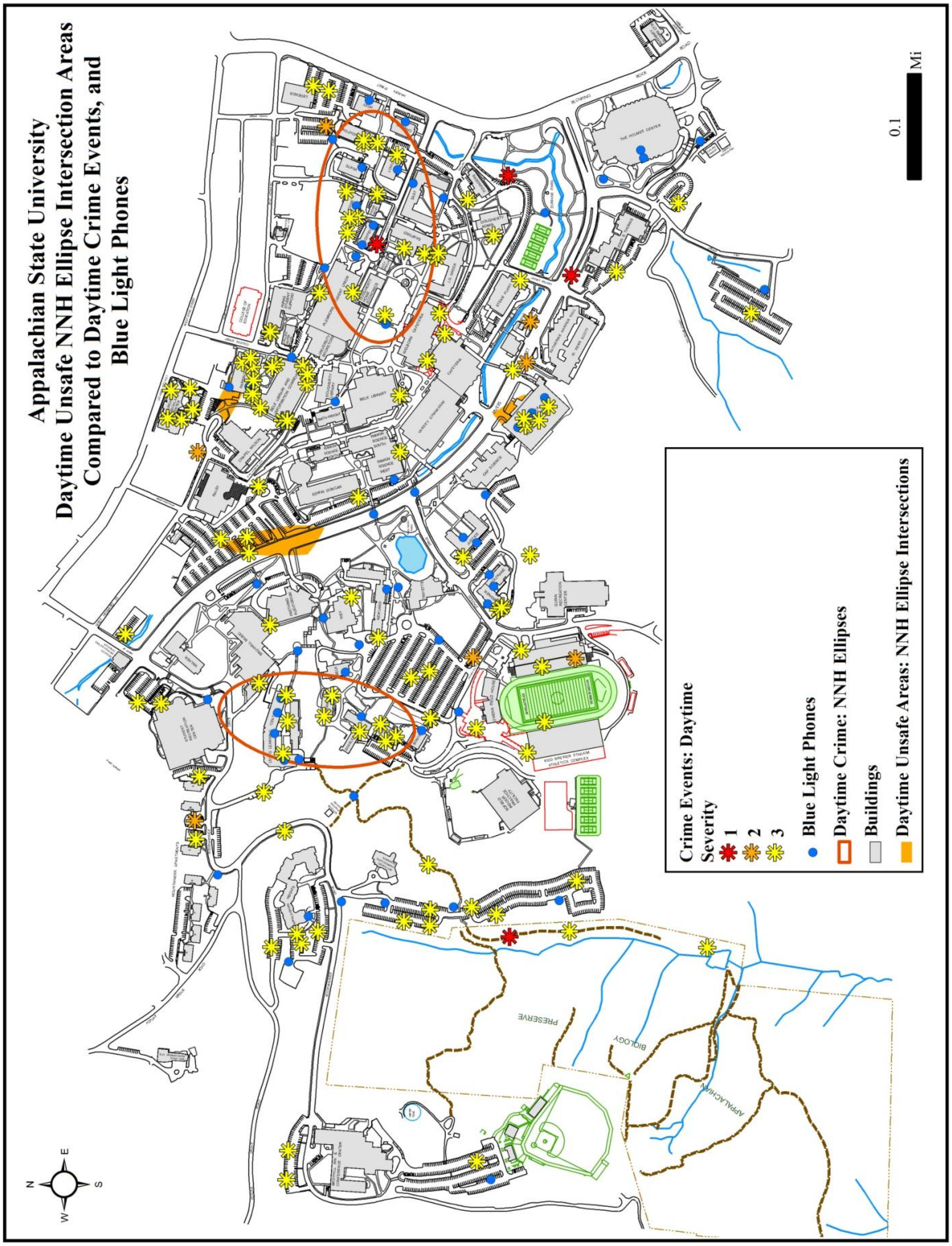


Figure 33. Daytime Unsafe Areas NNH Ellipse Intersections, Crime Events, and Blue Light Phones.

Figure 33 shows three areas where multiple ellipses intersected. The first is to the northwestern part of Rivers Street. It stretches from the middle of Raley Parking Lot diagonally across Rivers Street to the open space west of Farthing Auditorium's entrance. Only a few crimes took place near this intersection and they all happened in the Raley Parking Lot. This area is densely trafficked with buses, automobiles, bikes, and pedestrians (figure 34 and 35). Near the middle of this zone is a major bus entrance and turnaround used for several of the town's AppalCart bus routes. It is also a major area for people to cross from Appalachian's east campus to its west campus.

Figure 34. First Daytime Area of Interest, Raley Lot, Looking Southeast.

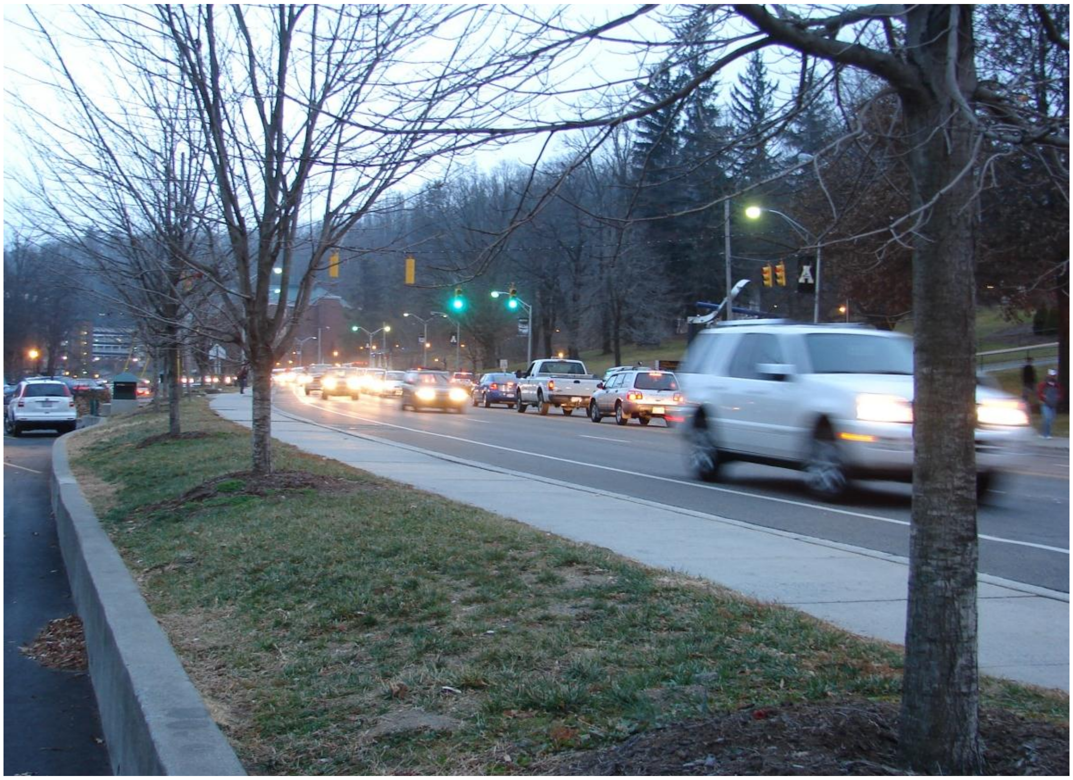


Figure 35. First Daytime Area of Interest, Raley Lot, Looking Southeast Down Rivers Street.

Improvements for this zone would include widening sidewalks and bike lanes along Rivers Street as well as increasing police patrols for speeding and reckless driving. Additionally, audible crosswalk signals may be beneficial around the Raley Circle entrance. Since so many modes of transportation use this entrance, increasing the pedestrian's awareness of incoming traffic and/or a change in traffic signals may boost students' perception of safety in this area. Also, using natural access controls, like a three foot hedgerow to more clearly define the boundary between the parking lot and sidewalk could help keep the parking lot safer from people randomly cutting through (APA 2006).

The second ellipse intersection is on the backside of the library parking deck stretching northwestern towards the turnaround in front of Chapel Wilson Hall (figure 36). This area is somewhat remote in regards to visibility and it now has a good bit of automobile traffic going in and out of the parking deck. The two main methods of improving this area would be to encourage pedestrians to stay on the sidewalks and enforce the traffic laws for vehicles coming into and out of the parking deck. This can be achieved by better restricting pedestrians to sidewalks through hedgerows, an increase in police presence, and the inclusion of traffic calming devices.

Figure 36. Second Daytime Area of Interest, Rear of Library Parking Deck, Looking Northwest.

The final daytime ellipse intersection is similar to the previous one. The third ellipse intersection is in front of the Rivers Street Parking Deck, stretching at an angle towards Rivers Street and the entrance of the parking deck (figure 37). This is a very heavily used parking structure on Appalachian's campus. Students are allowed to purchase parking spots in this deck, it is used by visitors for any number of university functions, and faculty/staff are allowed to purchase spots in it as well. On bad weather days it is known to fill-up quite fast. The sightline for vehicles coming into the deck is excellent and the sightline for vehicles exiting is good as well. The problem arises from pedestrian and bike traffic merging with vehicles trying to quickly get into the parking deck to make it to class or an appointment.

Figure 37. Third Daytime Area of Interest, Rivers Street Parking Deck, Looking Northwest.

Since the sightlines are good at this location and the sidewalks are wider to handle larger pedestrian flows, the best way to improve students' perception of safety in this area is to increase police presence and enforcement of traffic laws in and around the Rivers Street Parking Deck. It also should be indicated that all three areas have some type of parking lot association and as Tseng, Duane, and Hadipriono (2004, 21) pointed out, "unattended motor vehicles serve as magnets attracting criminals with the intent of theft of both the vehicle itself and its contents."

When examining these three areas in figure 33 it is important to note that there is no daytime crime event nearest neighbor hierarchical clustering analysis second order ellipses nearby. There are some clusters of crime events, especially around the Belk Library and Information Commons and the adjacent parking deck. However, for the bulk of daytime perceived unsafe areas, there is little correlation with crime events.

Four Nighttime Critical Areas and Suggestions

There was an additional analysis done on the nearest neighbor hierarchical cluster ellipses of perceptions of unsafe areas that allowed correlations to be made across the datasets. The nighttime unsafe areas nearest neighbor hierarchical cluster ellipses were merged using the intersect command. If four or more ellipses overlapped, the intersect command pulled out that overlapping area, thus showing areas similarly clustered across the subgroups. The nighttime results can be seen in figure 38. No second order ellipses were included for nighttime crime as the clusters were too random.

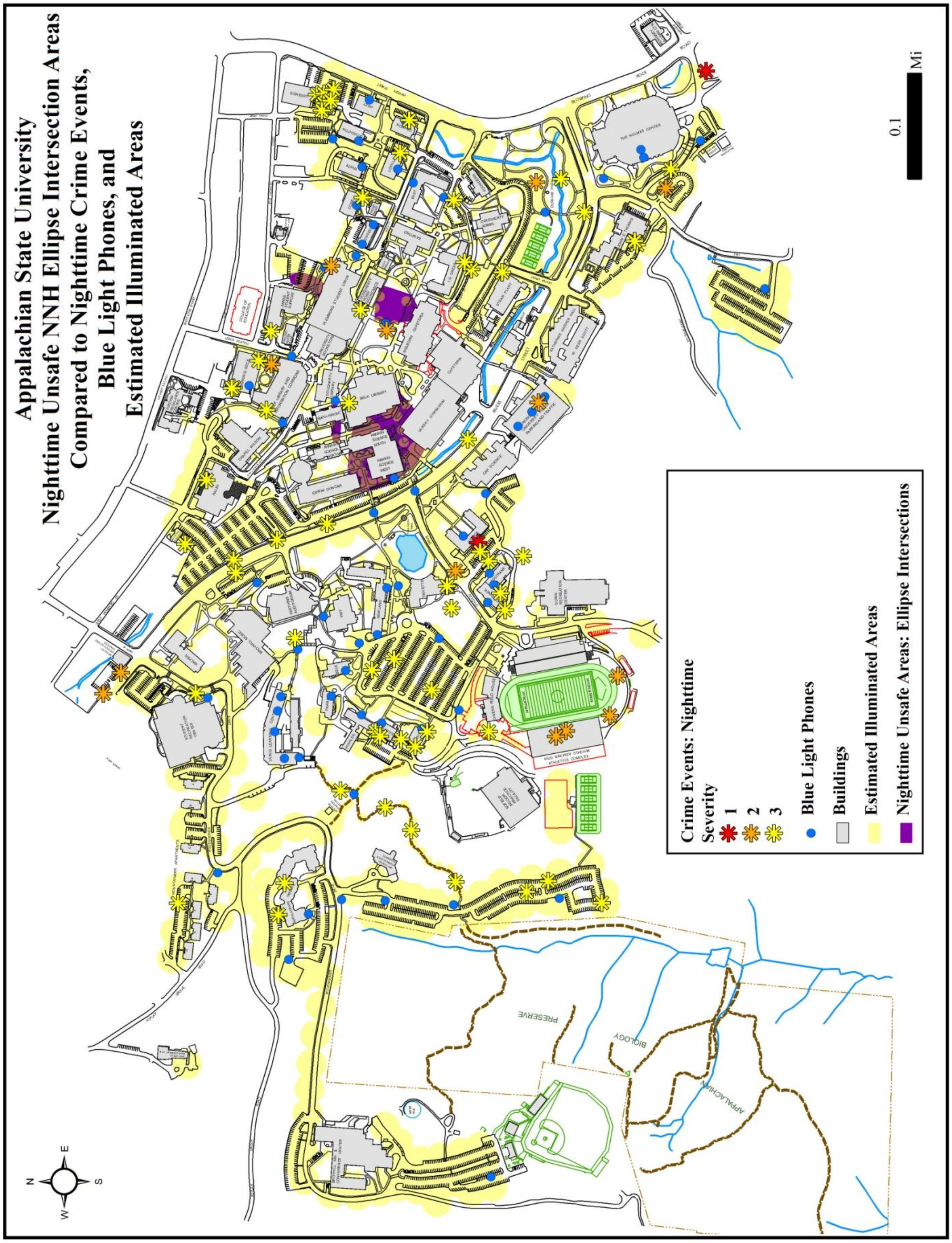


Figure 38. Nighttime Unsafe Areas NNH Ellipse Intersections, Crime Events, and Blue Light Phones.

Figure 38 shows four areas where multiple ellipses intersected. The first and largest area surrounds Rankin Science West and South and abuts the western outer wall of the Old Library Classroom Building (now Anne Belk Hall) as well as the northwestern wall of Varsity Gymnasium. The second area is just north of the first. It is a smaller area that stretches west to east through Smith-Wright Hall with the majority of it on the western side of the building and touching Rankin Science North. The first area (figure 39) is highly trafficked by students at night as they cross campus to go to the library, cafeteria, or meetings in the student union. The second area (figure 40) just to the north of the first area is part of students' walking patterns if they have to use Raley Parking Lot at night to get to functions or facilities on campus.

Figure 39. First Nighttime Area of Interest, Open Area At Front Entrance of Rankin Science South.

Figure 40. Second Nighttime Area of Interest, Front Entrance of Smith-Wright Hall, Looking West Towards Rankin Science North.

Parts of this area is not the best lit and offers lots of elevation changes and corners, thus giving people blind spots in their fields of vision. There is not a lot of eye level vegetation in this area, which enables students to see in all directions. The only areas that have sightline-blocking-vegetation are the southern facing side door in the stairwell coming out of Rankin Science South. Evidence suggests two problems in these areas are a lack of lighting and lack of blue light emergency telephones. If a person in the front of Rankin Science South was in distress he or she would have to travel over 375 feet to the nearest blue light emergency phone on the backside of the building. To compound this issue, there is not a blue light emergency phone anywhere on the entire stretch of sidewalk that runs from the side doors of the Central Dining Hall to the front doors of Rankin Science South to the front doors of Raley Hall. Nor is there a blue light phone in the quad area formed by the Rankin Science structures and Edwin Duncan Hall.

Furthermore, this area is a little darker than others and it has lots of shadows caused by lights reflecting off of other structures, corners, or trees. Therefore, increasing the bulb wattage may help to better illuminate this high traffic area. As seen in table 15 and compared to table 16, the majority of lampposts on Appalachian's campus meet both IESNA (2000) and APA (2006) design standards at the twelve and a half foot distance from the source; however, at the twenty-five foot mark the lamppost are about fifty percent too weak.

The next area (figure 41) is to the northeast of the others and is located behind Plemmons Student Union and projects out towards the parking lot beside the student support building. This area is frequently recognized as being unsafe within the student community. This area, while aesthetically pleasing, is very "tucked away." It is not frequently used at night, and there is lighting, but there are lots of shadows and corners. Furthermore, there is an ATM located within this area too, thus adding to the targeting potential for a criminal. Increasing lighting in this area would be beneficial. It would also be an excellent place to put closed circuit cameras to record anything that may happen in this area and provide students with an added sense of security.

Figure 41. Third Nighttime Area of Interest, Rear of The Student Union, Looking North.

The final area is directly south of the previous area. It is located in the middle of the open area on the campus's mall nearest to the teaching statue (figure 42). It stretches almost in a rectangle from the front door area of the no longer existing Welborn Cafeteria, across the mall to the front of the L.S. Dougherty Building. This area is very poorly lit and is somewhat secluded when one examines the typical nighttime pedestrian traffic patterns across Appalachian's campus. Most students when in the library or the student union either walk from the east campus dorms along the sidewalks beside Locust Street or in front of the student union. If they are coming from the west campus residential area, chances are they will travel through the tunnels and along the walkways between Rankin Science South and Varsity Gymnasium and along the front edge of the Old Library Classroom Building (now Anne Belk Hall). Finally, if they are coming from off campus, most likely they will be parking in the parking deck adjacent to the Belk Library and Information Commons and not come close to the mall area.

Figure 42. Fourth Nighttime Area of Interest, Eastern End of Stanford Mall, Looking North Towards L.S. Dougherty.

While better lighting along the northern edge of this area would be a beneficial addition, it may also be beneficial to follow the concept described by Zahm (2004). She suggests changing the purpose of some areas at nighttime by creating preferred pathways to guide nighttime campus pedestrian traffic. Zahm (2004) continues on to explain that these pathways are not all the pathways on campus but are pathways that have brighter lighting along them and connect the student to critical features such as dining, libraries, parking, and residence halls. This could be an excellent way to repurpose Appalachian's mall at night and keep students on the two, wide, pedestrian friendly walkways.

Chapter 6
Conclusion

The analysis of the students' perception of unsafe areas during the daytime yielded three similar areas between the sub-groups but no correlation between where crime occurred in the daytime. The nighttime perceptions yielded four areas of interest that had additional correlations to poor lighting. However, again, there were no correlations to where nighttime crime occurred. These results offered an interesting insight into how the students at Appalachian perceive areas to be unsafe but it could also be used to inform design at other college campuses or municipal areas in a rural setting with a moderate population.

On the broader scale, this study has helped to better understand how young adults perceive areas to be unsafe or safe. It also shows different geographical behaviors for males and females as well as individuals with other perspectives, such as living off campus and traveling to campus only for class. This interesting view point comes from a college campus that has a number of students that have to travel varying distances to get to campus and can again share similarities with other mid-major rural campuses.

Additionally, there are correlations between areas perceived as unsafe and poor lighting. However, there were no correlations, in this study, between crime events and perceived unsafe areas. While this could be a factor of the lack of spatially accurate data, it seems that within college populations there is not as much of a correlation as in other populations.

On college campuses administrators and campus leaders are becoming more aware of crimes and potential problems because of federal legislation like the Clery Act and because of media attention that has come from watershed events that have taken place over the past few years at Virginia Tech University and Northern Illinois University. People are starting to see places of higher learning no longer as isolated ivory towers but as critical components and sometimes cornerstones of a community. This has created a sense of openness that on one hand is extremely beneficial but on the other could lead to crime events spilling over from the community onto the campus or vice versa, as well as providing a copious and almost never ending supply of potential victims.

By using Appalachian as a study area and gathering data on people's perceptions of unsafe areas, actual crime events, and macro exterior illumination, a better defined concept of students' perceptions of unsafe areas compared to crime and, at nighttime, exterior lighting, was created. While the results were not as expected (correlations between crime events and people's perceptions of unsafe areas), they did show areas of vulnerability. It has also aided in proving that sometimes people's perceptions of areas as being unsafe do not directly parallel crime events but other "gut" feelings like poor lighting, sensation of being secluded, or poor sightlines.

In many of the areas perceived as unsafe or where there was a greater clustering of crime, simple changes could be made to improve safety and perceptions by following the CPTED methodology. Creating layered security by designating areas as public, semi-public, or private depending on the area or building's use could create areas of more or less defensible space (Tseng et al. 2004). Add access control methods (Tseng, Duane, and Hadipriono 2004) such as hedgerows, trees, signage, or low fencing to areas would also prove beneficial based on the results gathered from the analysis. Finally, using light not only as a way to illuminate an area for security, but also to create shadows within areas to limit access and to allow law enforcement to more easily apprehend a criminal is another cornerstone of CPTED that could benefit Appalachian's campus.

In addition to CPTED and improving the built environment, changing the way campuses and municipalities plan against and treat crime is a must. It requires broad interdisciplinary and interprofessional planning because prevention is built on understanding the breadth of issues involved and the riskiest populations (Roark 1987). At the collegiate planning level, there would need to be knowledge of college student development, the campus, the collegiate experience, and the more common forms of collegiate crimes and abuse (Roark 1987). These are good crime prevention and safety prerequisites for a college setting. However, if this study model was being deployed in a municipal setting for a project, such as a downtown redevelopment, the knowledge group would need to be more from the perspective of urban development, restaurateurs, transportation planning, and knowledge of predominant crime types in the area.

Employing this study in the college environment is also best coupled with policies and practices that will receive public support from the university community and the surrounding municipal community (Griffith et al. 2004). As campuses move away from the ivory tower concept of seclusion, campuses should be designed as pedestrian hubs; using a constant barrage of activities to dispel students' safety concerns, fostering feelings of community, and provide better surveillance of public areas (Colman 1996). Colman (1996) also suggests utilizing senior students to help create and maintain socially acceptable codes of conduct and behavior.

This study lends its self to a tremendous amount of potential for further study and enhancement. Gathered along with the perception survey data were statements about why the student felt unsafe in the areas that they marked and what they would do to change those areas. This data could be evaluated for additional suggestions on how to improve many of these areas and why enough students consider them unsafe to the level of a cluster developing on a map.

The crime data is a critical component of this study because it provides a comparison to the perception data. Digitizing all of the crime data would be beneficial because it would allow for a greater temporal examination of campus crime. Utilizing the CrimeStat package along with GIS software, a yearly centroid could be created for different types of crime; this would allow the police department to visualize if a type of crime moves around in a pattern and predict where it may be moving to in future years. When combined with the data on crimes that have taken place inside of buildings and residence halls, it could possibly help to clarify any yearly connections between indoor crimes and crimes that are taking place outside of buildings.

The single biggest change that could happen to improve the crime data is to get more spatially accurate location for the crime event. For example, providing more accurate location data for, “Larceny from motor vehicle, Raley Parking Lot,” would remove the need for the person entering the crime point to make a random choice as to where to place the event. Since crime could have taken place anywhere within the Raley Parking Lot, having a poorly located point decreases the overall accuracy of the model and makes it difficult to learn more about the spatio-temporal relationships between indoor and outdoor crimes.

Further work with the lighting data also has potential benefits. Since Appalachian does not know the location of all of the green lampposts, having them all digitized would not only benefit this study but also the campus' physical plant, design and construction department, and the police. To get a clearer picture of lighting on Appalachian's campus, or in any other area that may employ this type of study, all of the lighting sources must be accounted for. This study examined only the macro light sources, however; it did not account for lights mounted on walls, awnings, or areas adjacent to buildings. This may help to clarify the lighting issue as well as show areas that actually are better lit than the high level macro light source map shows.

Finally, future work on a comprehensive perception of safety, crime, and lighting model would provide additional insight. This model would incorporate raster analysis of three major layers as well as any other additional information such as emergency blue light phone locations into one output. It would allow for administrators, planners, and designers to alter weightings for each layer, thus giving more significance to some layers than others and creating varying outputs based on the user generated settings. This type of model would allow for queries that could indicate areas of low lighting, higher crime, and poor perceptions, thus showing that a change was needed in a specific location.

People's perceptions of areas change regularly based on a number of different factors, but three of the most prominent reasons are: the events that happen around a person, a person's surroundings, and the transportation patterns they take on a daily basis. Crime is a function of what happens around a person and because of constant media influence people are more aware than ever of events that happen within their spheres of influence and concern. This research has demonstrated the relationships between perceptions of safety and the relationship to crimes and sources of lighting. It can be concluded that although Appalachian is a safe campus for students, environmental design and campus planning can have a great effect on students' perceptions of living on a safe campus.

Appendix A

Appalachian State University Police Department
Jeanne Clery Disclosure of Campus Security and Crimes Statistics Act
2005 - 2009

Offense Type	On-Campus					Residential Facilities (#1)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Murder & Nonnegligent Manslaughter	0	0	0	0	0	0	0	0	0	0
Negligent Manslaughter	0	0	0	0	0	0	0	0	0	0
Forcible Sex Offenses	7	2	2	4	5	6	0	1	1	4
Nonforcible Sex Offenses	0	0	0	0	0	0	0	0	0	0
Robbery	0	0	1	1	0	0	0	0	0	0
Aggravated Assault	0	2	1	0	0	0	1	0	0	0
Burglary	12	24	24	18	22	9	19	20	15	11
Arson	2	9	3	0	0	2	9	0	0	0
Motor Vehicle Theft	2	8	1	0	2					
Larceny	138	138	142	107	136	54	43	30	38	35

Number of Arrests for Selected Offenses

Offense Type	On-Campus					Residential Facilities (#1)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Liquor Law Violations	80	160	281	136	149	22	33	57	68	82
Drug Violations	35	42	86	90	151	5	22	58	66	81
Weapons Violations	1	3	1	1	2	1	1	1	0	0

Number of Judicial Referrals for Selected Offenses

Offense Type / Judicial Referrals	On-Campus					Residential Facilities (#1)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Liquor Law Violations	607	515	297	223	201	560	450	296	204	153
Drug Violations	157	144	32	32	48	152	97	20	20	30
Weapons Violations	14	19	9	2	9	14	7	9	1	9

Appalachian State University Police Department
Jeanne Clery Disclosure of Campus Security and Crimes Statistics Act
2005 - 2009

Offense	Non-Campus Buildings & Property (#2)					Public Property (#3)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Murder & Nonnegligent Manslaughter	0	0	0	0	0	0	0	0	0	0
Negligent Manslaughter	0	0	0	0	0	0	0	0	0	0
Forcible Sex Offenses	0	0	0	0	0	0	1	0	1	1
Nonforcible Sex Offenses	0	0	0	0	0	0	0	0	0	0
Robbery	0	1	0	0	0	0	0	0	0	0
Aggravated Assault	0	0	0	0	0	0	3	1	1	0
Burglary	1	0	0	0	1					
Arson	0	0	0	0	0	0	0	0	0	0
Motor Vehicle Theft	0	0	0	0	0	0	2	1	0	1
Larceny	0	0	2	7	2					16

Number of Arrests for Selected Offenses

Offense Type	Non-Campus Buildings & Property (#2)					Public Property (#3)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Liquor Law Violations	0	12	0	2	1	16	12	2	1	6
Drug Violations	0	0	0	0	0	1	3	16	4	6
Weapons Violations	0	0	0	0	0	0	0	0	0	0

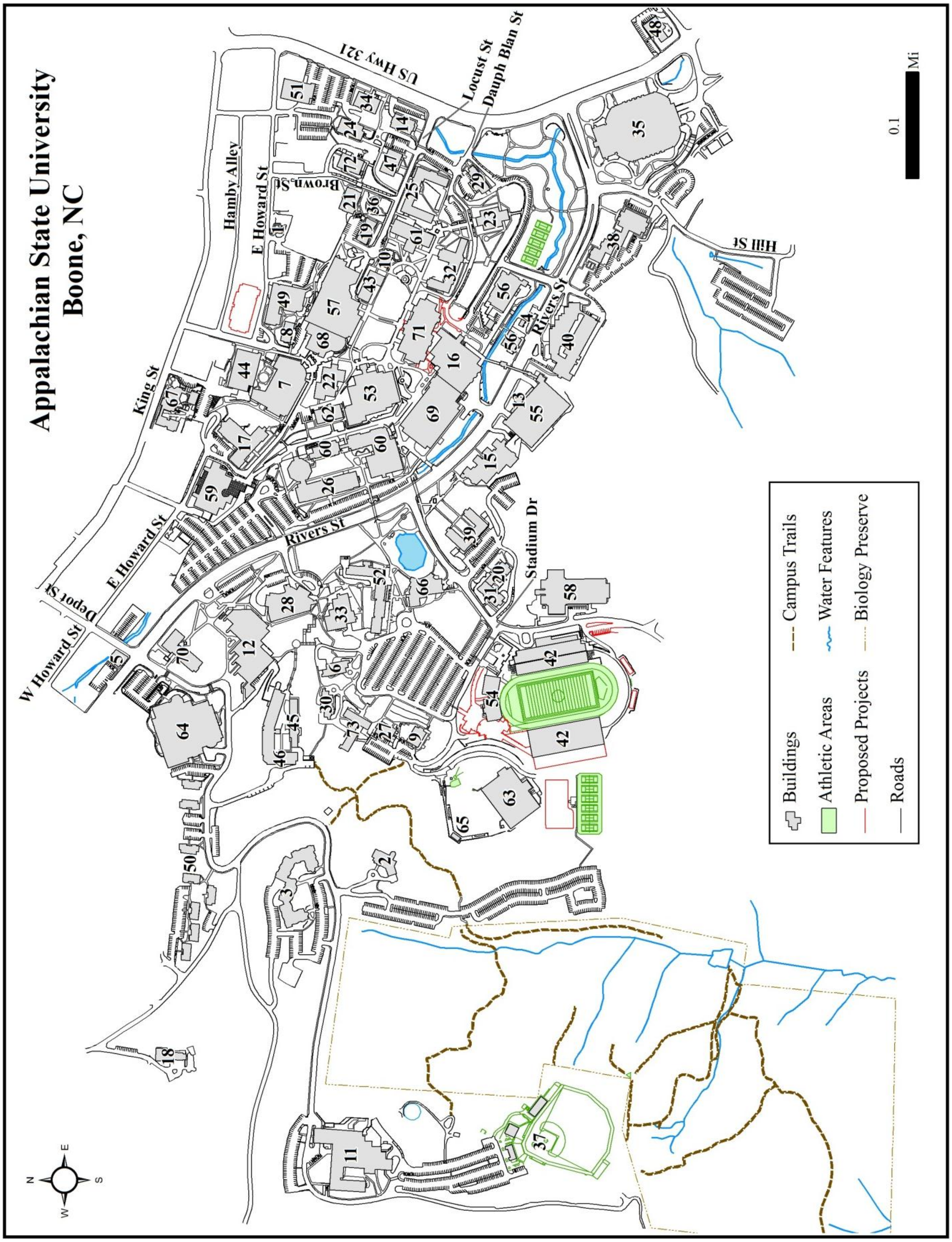
Number of Judicial Referrals for Selected Offenses

Offense Type / Judicial Referrals	Non-Campus Buildings & Property (#2)					Public Property (#3)				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
Liquor Law Violations	0	0	0	1	0	0	2	0	0	0
Drug Violations	0	0	0	0	0	0	0	0	0	0
Weapons Violations	0	0	0	0	0	0	0	0	0	0

Notes:

1. Crimes that occur in a residential facility are also included in crimes on campus and non-campus as appropriate
2. Non-campus buildings and property are defined as: university property outside the boundaries of main campus and property owned or controlled by student organizations recognized by the university
3. Public property includes only crimes reported to the Town of Boone for locations adjacent to main campus
4. No hate crimes reported in 2005, 2006, 2007, 2008, and 2009
5. Liquor law arrests for 2005, 2006, 2007, 2008, and 2009 include arrests made on campus by North Carolina law enforcement agents
    a. 2005 ALE made 46 arrests
    b. 2006 ALE made 95 arrests
    c. 2007 ALE made 124 arrests
    d. 2008 ALE made 47 arrests
    e. 2009 ALE made 0 arrests

Appendix B



Appalachian State University
Boone, NC
US Hwy 321
Locust St
Dauph Blan St
Hamby Alley
E Howard St
Brown St
King St
Rivers St
Hill St
Depot St
W Howard St
Stadium Dr
Buildings
Athletic Areas
Proposed Projects
Roads
Campus Trails
Water Features
Biology Preserve
0.1
Mi
N
E
S
W

Building Name	Floors	Acronym	Type	Number
Howard St. Psychology Research House	3	PRH	A	1
Chancellor's Residence	2	ACH	S	2
Appalachian Heights Apartments	4	AHR	R	3
ATM	1	ATM	S	4
Beasley Broadcasting Complex	3	BBC	A	5
Belk Hall	5	BKR	R	6
Belk Library & Information Commons	5	BLIC	A	7
Bookstore Regional Chiller	1	BRC	S	8
Bowie Hall	9	BWR	R	9
Lucy Brock Child Development Center	1	LBCC	S	10
Broyhill Inn & Conference Center	2	BI	S	11
Broyhill Music Center	4	BM	A	12
Campus Police	3	PD	S	13
Cannon Hall	8	CNR	R	14
CAP Science Building	4	CAP	A	15
Central Dining Hall	0	CDH	S	16
Chapel Wilson Hall	3	CW	A	17
Child Care Center	3	CCC	S	18
Coffey Hall	4	CFR	R	19
Coltrane Hall	9	CLR	R	20
Cone Hall	8	COR	R	21
D.D. Dougherty Library	2	DL	S	22
B.B. Dougherty Administration Building	3	DA	S	23
Doughton Hall	7	DTR	R	24
East Hall	3	ESR	R	25
Edwin Duncan Hall	3	ED	A	26
Eggers Hall	9	EGR	R	27
Farthing Auditorium	2	FA	A	28
Founders Hall	3	FH	S	29
Frank Hall	6	FKR	R	30
Gardner Hall	9	GRR	R	31
Greer Hall	2	GH	A	32
Herbert Wey Hall	3	HW	A	33
Hoey Hall	7	HYR	R	34
Holmes Convocation Center	2	HCC	RAS	35
Home Management House (College of FAA)	2	HMH	A	36
Jim & Bettie Smith Stadium	0	JBSS	RAS	37
John E. Thomas Hall	3	JET	S	38
Justice Hall	4	JTR	R	39
Kerr Scott Hall	2	KS	A	40

Building Name	Floors	Acronym	Type	Number
Kidd Brewer Stadium	3	KB	RAS	42
L.S. Dougherty Hall	2	DH	A	43
Library Parking Deck	4	LPD	S	44
Living Learning Center (Academic)	4	LLA	A	45
Living Learning Center (Residence)	4	LLR	R	46
Lovill Hall	6	LVR	R	47
McKinney Alumni Center	1	MAC	S	48
Miles Annas Student Support Facility	2	MAB	S	49
Mountaineer Apartments A-H	3	MAR	R	50
Legends	1	LEG	RAS	51
Newland Hall	4	NLR	R	52
Old Library Classroom Building (Anne Belk Hall)	3	OLC	A	53
Owens Field House	2	OFH	RAS	54
Rivers Street Parking Deck	6	PDS	S	55
Physical Plant Buildings	1	PPB	S	56
Plemmons Student Union	5	PSU	S	57
Quinn Recreation Center	1	QC	RAS	58
Raley Hall	4	RH	A	59
Rankin Science	4	RS	A	60
Sanford Hall	5	SH	A	61
Smith Wright Hall	3	SW	A	62
Sofield Family Indoor Practice Facility	4	SFPF	RAS	63
Student Recreation Center	2	SRC	RAS	64
Sywassink/Lloyd Family Stadium	0	SLFS	RAS	65
Trivette Hall Cafeteria	2	THC	S	66
Turchin Center for Visual Arts	3	TCV	A	67
University Bookstore	5	UB	S	68
Varsity Gymnasium	3	VG	RAS	69
Walker Hall	3	WA	A	70
Welborn Hall Cafeteria	2	WHC	S	71
White Hall	7	WTR	R	72
Winkler Hall	10	WKR	R	73

Appendix C

Appalachian State University
Campus Safety Survey

The following brief survey will help us identify where students feel unsafe on Appalachian State University's campus. This survey is voluntary; you are by no means required to participate. If you choose to not participate there is no penalty, academic or any other. If you decide to participate and you wish to learn more about the results of the study feel free to contact either James Waynick at (828)262-3000 (jw54345@appstate.edu) or Dr. Christopher Badurek at (828)262-7054 (badurekca@appstate.edu). Approved by the Institutional Review Board of Appalachian State University on January 21, 2009. Approval expires on January 21, 2010.

1) What year are you at Appalachian State University? *Please Circle*
Freshman Sophomore Junior Senior Graduate Student

2) Sex: Male ______ Female ______

3) Where do you live? On Campus ______ Off Campus ______

- If you live on campus, which dorm do you live in? ______________________________

4) Do you have a car in Boone? Yes ______ No ______
- If you have a car in Boone, where, specifically, do you park on campus? ____________

5) Please rank your on campus evening social life. (1 none – 10 extremely active) ___________

6) Please rank how cautious you are on campus. (1 not cautious – 10 extremely cautious) _____

7) On the opposite page place and "x" on <u>three</u> different areas on the map of Appalachian State University's campus were you feel the most unsafe at any time, day or night, when you are outside of a building during your daily activities. Please rank the three locations 1-3 as to which one you feel the most unsafe (1) to the place where you feel somewhat unsafe (3). Please use each number only once.

8) Please write 2-3 sentences as to why you feel unsafe in the areas that you marked as unsafe.
____
____
____
____
____

9) Please write 2-3 sentences as to what you would do to change the area that you marked on the map to make them safer.
____
____
____
____
____

Appendix D

2009-2009 Academic Year Crime Events (Outside Buildings)	**Severity** **1= severe** **2= somewhat severe** **3= least severe**
Alcohol Violation	3
All Other Liquor Law Violation	3
Communicating Threats	2
Consuming Alcohol On Side Walk	3
Damage To Property	3
Disorderly Conduct	2
Drunk/Disruptive & Use/Consuming Tax Paid Liquor	3
Drunk/Disruptive	3
Drunk/Disruptive & Simple Physical Assault	2
Drunk/Disrupt & Trespassing	3
Drug Violation - Equipment/Paraphernalia, Possession/Conceal Marijuana, Underage Possession Alcohol	3
Drug Violation-Equipment/Paraphernalia/Possession of Schedule 6 & 2 Substance & Felony Possession of Firearm	1
Drug Violation-Equipment/Conceal, Assault of Female and Sexual Battery	1
Drug Violation-Equipment/Conceal	3
Drug Violation-Equipment/Paraphernalia, Possession/Conceal Heroin	1
Drug Violation-Equipment/Paraphernalia, Possession/Conceal	3
Drug Violation-Equipment/Paraphernalia, Possession/Conceal Marijuana	3
Drug Violation-Possession/Conceal Tax Paid Liquor & Marijuana	3
Drug Violation-Possession Marijuana	3
Drug Violation-Possession of Schedule 6 Substance	3
Fraud-Credit Card/ATM	2
Harassment	2
J-Walk/Disorderly Conduct/Delay Officer	2
Larceny	3
Larceny (from vehicle)	3
Motor Vehicle Theft (Golf Cart)	2
Possession/Conceal-Tax Paid Liquor & Marijuana	3
Possession/Conceal Weapon Simple Physical Assault	1
Possession/Conceal Weapons	1
Possession Fake License/Underage Alcohol	3
Possession Marijuana	3
Public Intoxication	3
Resisting Arrest	2
Resisting Arrest Disorderly Conduct	2
Resisting Arrest & Drunk/Disruptive	2

2009-2009 Academic Year Crime Events (Outside Buildings)	**Severity** **1= severe** **2= somewhat severe** **3= least severe**
Simple Physical Assault	2
Trespassing	3
Underage Drinking, Resisting Arrest, & Drunk/Disruptive	2
Underage Consumption Alcohol	3
Underage Possession Alcohol	3
Using/Consuming Tax Paid Liquor	3
Vandalism	3
Vandalism & Larceny	3

Appendix E

Building Name	Acronym	Crime Count
413 E Howard Street Psychology Research House	PRH	0
Chancellor’s Residence	ACH	0
Appalachian Heights Apartments	AHR	9
Belk Residence Hall	BKR	5
Belk Library & Information Commons	BLIC	15
Bookstore Regional Chiller	BRC	0
Bowie Residence Hall	BWR	13
Lucy Brock Child Development Center	LBCC	0
Broyhill Inn & Conference Center	BI	2
Broyhill Music	BM	2
Cannon Residence Hall	CNR	6
CAP Science Building	CAP	1
Chapel Wilson Hall	CW	0
Child Care Center	CCC	0
Coffey Residence Hall	CFR	0
Cone Residence Hall	COR	13
D.D. Dougherty Hall	DL	1
B.B. Dougherty Administration Building	DA	1
Doughton Residence Hall	DTR	14
East Residence Hall	ESR	7
Edwin Duncan Hall	ED	2
Eggers Residence Hall	EGR	11
Farthing Auditorium	FA	0
Founders Hall	FH	1
Frank Residence Hall	FKR	0
Coltrane Residence Hall	CLR	17
Gardner Residence Hall	GRR	10
I.G. Greer Hall	GH	2
Wey Hall	HW	0
Hoey Residence Hall	HYR	17
Holmes Convocation Center	HCC	1
Home Mgt House (College of FAA)	HMH	0
John E. Tomas Building	JET	0
Justice Residence Hall	JTR	16
Katherine Harper Hall	KS	3
Kidd Brewer Stadium	KB	0
L.S. Dougherty Hall	DH	0
Living Learning Center (Academic)	LLA	1

Building Name	Acronym	Crime Count
Living Learning Center (Residence)	LLR	8
Lovill Residence Hall	LVR	9
McKinney Alumni Center	MAC	0
Miles Annas Student Support Facility	MAB	0
Mountaineer Apartments (A-H)	MAR	3
Legends	LEG	6
Newland Residence Hall	NLR	9
Old Library Classroom Building (Anne Belk Hall)	OLC	1
Owens Field House	OFH	0
Rivers Street Parking Deck	PDS	0
University Police	PD	3
Physical Plant Building	PPB	0
Plemmons Student Union	PSU	9
University Bookstore	UB	6
Quinn Recreation Center	QC	5
Raley Residence Hall	RH	1
Rankin Science	RS	0
Sanford Hall	SH	2
Smith Wright Hall	SW	1
Student Recreation Center	SRC	10
Trivette Hall Cafeteria	THC	3
Turchin Center for Visual Arts	TCV	0
Varsity Gymnasium	VG	2
Walker Hall	WA	1
Welborn Hall Cafeteria	WHC	0
White Residence Hall	WTR	3
Winkler Residence Hall	WKR	4
Central Dining Hall	CDH	1
Total		257

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VITA

James Shaw Waynick was born in Greensboro, North Carolina, on March 3, 1983. He attended grade school in Greensboro and graduated from Western Guilford High School in June 2002. The following autumn, he entered Appalachian State University. While at Appalachian he studied Geographic Information Science and Community/Regional Planning. In December 2006, he was awarded the Bachelor of Science degree.

In September of 2006 he accepted a research assistantship in GIS at Appalachian and while working in the assistantship in the autumn of 2007, he began his studies towards a Master of Arts in Geography degree. Simultaneously, he began working on a Masters in Project Management through Western Carolina University that was completed in August of 2009. In the autumn of 2009 he also began ambitiously studying towards a Master of Public Administration degree with a concentration in emergency management. The M.A. and M.P.A was awarded in December 2010.

Mr. Waynick is a member of Gamma Theta Upsilon, Pi Gamma Mu, Alpha Phi Omega, and he is an Eagle Scout. He was the 2010 Saarinen Student Paper Award winner for the Environmental Perception and Behavioral Geography Specialty Group of the Association of American Geographers. His home address is 5605 Buddingwood Dr., Greensboro, North Carolina. His parents are Jim and Martha Waynick, of Greensboro, North Carolina.