Legislative Budget and Finance Committee

A JOINT COMMITTEE OF THE PENNSYLVANIA GENERAL ASSEMBLY
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"Do Shotguns and Muzzleloaders Pose Less Risk Than Centerfire Rifles for Hunting Deer in Pennsylvania?"

Conducted Pursuant to
House Resolution 61 of 2005

March 2007

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March 2007

To the Members of the General Assembly:

House Resolution 61 of 2005 directed the Legislative Budget and Finance Committee to conduct a study on the use of rifles versus shotguns and to recommend whether special regulation areas (shotgun and muzzleloaders only) should be expanded within the Commonwealth.

Due to the specialized nature of this topic, the Committee contracted with MountainTop Technologies, Inc. (MTT), a research firm based in Johnstown, PA, to conduct the study.

The MTT report is contained herein. As with all LB&FC reports, the release of this report should not be construed as an indication that the Committee or its individual Committee members necessarily concur with its findings and recommendations.

Sincerely,

Philip R. Durgin
Executive Director

“Do Shotguns and Muzzleloaders Pose Less Risk than Centerfire Rifles for Hunting Deer in Pennsylvania?”

Spatial and Ballistic Analysis Conducted Pursuant to Pennsylvania House Resolution 61

February 2007

MountainTop Technologies, Inc.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

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1.0 INTRODUCTION AND REPORT CONCLUSION

This report was completed in response to the Commonwealth of Pennsylvania's House Resolution 61 (HR 61) directive to the Legislative Budget and Finance Committee to conduct a risk assessment on the use of rifles versus shotguns for hunting in Pennsylvania (See Appendix A).

1.1 Historical Context[1]

The Pennsylvania Game Commission (PGC) first restricted use of centerfire firearms in 1964 when it announced special regulations for that portion of southeastern Pennsylvania encompassing Delaware and Philadelphia Counties and portions of Bucks, Montgomery and Chester Counties. At the time, it became illegal to take deer through the use of any single projectile whether fired from a rifle or shotgun. The Commission directed that, in these areas, "deer may be taken only through the use of the long bow and arrow and with shotguns, including autoloading or semiautomatic shotguns loaded to full capacity, not smaller than 20 gauge with shot not smaller than No. 4 buckshot."

In 1979, the Commission acted to expand the Southeast Special Regulations Area and allowed for use of single projectile shotgun and muzzleloader ammunition. It was at this time that the Commission established another Special Regulations Area—Allegheny County in Southwestern Pennsylvania - where single projectile centerfire rifles were prohibited for the taking of deer. Unlike the Southeast Special Regulations Area, buckshot was not allowed for the taking of deer in the Southwest. In 1991, in response to expanding urbanization, the PGC acted to enlarge the Southeast Special Regulations Area to include all of Bucks, Chester, Montgomery, Delaware, and Philadelphia Counties.

Two specific incidents served to focus public and political attention on this subject. In 1996, two non-hunting Pennsylvania citizens in western Pennsylvania were struck and killed by bullets fired from deer hunters. In Beaver County, a woman was killed in her home while watching television with her children. A rifle bullet passed through a wall and struck the woman in the neck, fatally wounding her. In the other accident, a man was killed while driving in Washington County. A bullet passed through the vehicle's window, striking the driver. Hunters were implicated in both incidents.

At that time, the PGC directed its staff to investigate these incidents and the PGC Executive Director subsequently directed the agency's Deputy Executive Director to chair a special task force to study the issue. This committee met, conducted study activities, and issued a report in 1998. The report recommended designation of two additional areas as Special Regulations Areas and the prohibition of centerfire rifles for deer hunting in these areas. Because of the negative response from local hunters and sportsmen's groups in these areas, the PGC did not act on the

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[1] LB&FC (2005) This section is a summary of portions of the Request for Proposals document.

recommendation but instead decided to seek documentation of the contention that shotgun slugs would be safer than rifle bullets.

PGC staff began by checking with wildlife agency representatives from the states immediately surrounding Pennsylvania as well as from Michigan and Wisconsin. All have substantial areas where centerfire rifles are restricted and PGC staff sought to understand the motivation and factual basis upon which these states had made their decisions. Of Pennsylvania's approximate 900 miles of border with other states, it was found that the centerfire rifle was unlawful along the entire boundary with the exception of western Maryland. They found that in no case was any state able to provide definitive information upon which they based their decision. In fact, most reported that they simply responded to the public perception that shotguns were less dangerous than centerfire rifles. At that time, PGC staff found there was no data to support the contention that shotguns and muzzleloaders are any less risky than centerfire rifles. They found, instead, that in the "shotgun-only" states this appears to be "an issue driven by emotion and politics rather than sound scientific data."[2]

Beginning in 1998, the PGC staff also began to collect statistical data on all hunting-related shooting incidents in Pennsylvania where stray bullets struck personal property. The purpose of establishing this database was to give the PGC the ability to move forward with a professional risk assessment of the rifle versus shotgun issue.

The urgency of moving forward with this assessment was reinforced in the fall of 2004 when a stray bullet fired by a hunter hit and injured an 18-year old woman as she was sitting in a car in her mother's North Whitehall Township, Lehigh County driveway. In response to the incident, the victim, her family, and some state legislators then asked the PGC to expand Special Regulations Areas.

The General Assembly also reacted by adopting House Resolution No. 61 (HR61) during the 2005 Session. The resolution was introduced by Representatives Semmel, B. Smith, Browne, Dally, Harhart and Reichley and passed as amended on March 16, 2005. The resolution directed the Legislative Budget and Finance Committee to conduct a study on the use of rifles versus shotguns within the Commonwealth. The Resolution states that suburban sprawl and population density growth are expanding within the Commonwealth, and sportswriters have suggested expanding and designating additional special regulations areas in response to this growth especially in light of tragic incidents during recent hunting seasons. Further, the Resolution states that when comparing population densities in Pennsylvania's 67 counties, it appears to be inconsistent that center fire rifles remain lawful in counties with a population density in excess of some of the counties which are now included within a Special Regulations Area.

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[2] Schmit (1998).

To implement HR61, the House of Representatives directed the Legislative Budget and Finance Committee (LB&FC) to conduct a study on the use of rifles versus shotguns within the Commonwealth and recommend whether special regulation areas should be expanded and that the LB&FC contract with a risk assessment specialist to conduct the study in coordination with the PGC. The study was to include, but not be limited to, the following details:

- Ballistics
- Projectile construction
- Projectile type
- Topography
- Land use
- Population density
- Hunter density
- Structure density

The LB&FC was directed to prepare both a written and an oral report and present it to the Game and Fisheries Committee of the House of Representatives.

1.2 Methodology

MountainTop Technologies, Inc. (MTT) formed a team to respond to the LB&FC's Request for Proposals to conduct a spatial risk analysis of the use of rifles versus shotguns and muzzleloaders for hunting within Pennsylvania pursuant to HR61. The proposed work was structured into two phases with multiple tasks in each phase. On June 9, 2006 MTT presented a briefing to the LB & FC concerning the results of Task 1 of Phase 1. Based on the findings presented, the LB & FC decided to end the study after completion of Task 1, Phase 1. This task addressed the question,

> *Do shotguns and muzzleloaders pose less risk than centerfire rifles for hunting deer in Pennsylvania?*

Task 1 was conducted as an analysis of the historical record of property damage from errant projectiles associated with deer hunting in Pennsylvania and a comparison of the ballistics of the use of rifles versus shotguns and muzzleloaders for hunting deer. As part of the analysis, MTT reviewed pertinent information that was collected or produced by the PGC concerning the use of rifles versus shotguns and muzzleloaders for hunting within Pennsylvania. The review focused on reports and records of errant projectiles from firearms used in the conduct of legally hunting deer and did not include accidental or intentional firearm discharges not associated with hunting deer.

Statistical methods used by MTT included using crime mapping techniques and a computer simulation to model firearms-ammunition combinations. MTT employed a spatial statistics package known as CrimeStat III for the analysis of point data. The MTT team also utilized empirically derived computer models to render a comparison of the danger areas associated with various firearm-projectile combinations.

1.3 The Project Team

MTT, based in Johnstown, PA, formed a team uniquely qualified in project management, small arms ballistics, risk assessment, and Geographic Information Systems (GIS). *MTT* served as the prime contractor. The *Armament Research, Development and Engineering Center (ARDEC)* at Picatinny Arsenal and *Advanced Technology Solutions, Inc. (ATS)* in Lancaster, PA*,* served as subcontractors. MTT used a Cooperative Research and Development Agreement (CRADA) with ARDEC, the parent organization of Quality Engineering and System Assurance (QESA) and Armaments Engineering and Technology Center (AETC) to work collaboratively on this project. The team's qualifications included:

1.3.1 MountainTop Technologies, (MTT) Inc.

MTT, (www.mountaintoptech.com), founded in 1992, has core competencies in web-based training; distance learning; broadband wireless network design and development (including point-to-point and point-to-multipoint applications); aircraft evaluation; aircraft maintenance and fueling; and airport safety technology development. MTT's past performance includes work completed for the Department of Defense, the Department of Justice, the Department of Energy, the National Guard Bureau, the Office of Naval Research, and the Pennsylvania Department of Military and Veteran's Affairs. To facilitate some of its work, MTT has negotiated a CRADA with Picatinny Arsennal in New Jersey. It is through this CRADA that MTT was able to engage the services of some of the foremost experts in the world in ballistics modeling and range safety.

1.3.2 US Army Armament Research, Development and Engineering Center (ARDEC)

ARDEC (http://www.pica.army.mil/PicatinnyPublic/index.asp) provided ballistics expertise for this project. ARDEC is part of the U.S. Army Research, Development & Engineering Command (RDECOM) and has facilities located at Picatinny Arsenal, New Jersey. ARDEC is the United States Government center of excellence for armament systems and munitions technologies. QESA's System Safety Engineering Division and AETC's AeroBallistics Division are DoD's experts in small arms ballistic modeling for analyzing range safety and identifying necessary improvements. QESA and AETC have developed the state of the art probability model to evaluate the parameters contributing to the military's Surface Danger Zone (SDZ) designation. A SDZ is an exclusion area identified to protect personnel from weapons firing during training on military ranges.

1.3.3 Advanced Technology Solutions, (ATS) Inc.

ATS (www.atsincorp.com) worked in close coordination with MTT and ARDEC to provide GIS support activities. Responsibilities included data acquisition, data conversion, mapping, and coordinating with state agencies. ATS compiled the pertinent data sets and geocoded and mapped incident records.

1.4 Definitions

Pertinent definitions are contained in Appendix B.

1.5 Conclusion

1.5.1 Summary Statement

Conventional wisdom holds that shotguns are inherently less risky than rifles when hunting deer. This is evidenced by the fact that the PGC as well as other states have established shotgun only hunting areas. This study, however, has concluded that this is not always the case.

Stated in a few words, when considering extreme, high, and moderate firing errors (35, 10 and 5 degrees firing elevations), shotguns and muzzleloaders are less risky than the centerfire rifle. When firing with smaller or no aiming error (approximately 0-degrees firing elevation), a shotgun proved to be riskier than a centerfire rifle. The muzzleloader was always less risky than both the rifle and shotgun. Eliminating or controlling the ricochet seems essential if the shotgun is to be used as an effective risk management option. If ricochets could be controlled, then the shotgun and muzzleloader would be less risky in all cases.

1.5.2 Discussion

The study concludes that comparing risk using only the maximum range obtained at a 35-degree firing elevation and the corresponding danger area of the firearm-ammunition combination provides the policy maker an incomplete picture. When discharging the examined firearm-ammunition combinations with large (10-degree) and moderate (5-degree) aiming errors, the danger areas of the shotgun and muzzleloader are less than that of the rifle; hence, given this firing condition, the shotgun and muzzleloader are less risky than the rifle. However, shotguns firing modern saboted ammunition have a larger danger area than the .30-06 rifle when the angle of elevation is approximately level (0-degrees); hence, given this firing condition, the shotgun is riskier than the rifle. In other words, the typical hunter discharging a 12 gauge shotgun fitted with a rifled barrel firing a .50-caliber saboted slug at a deer on level terrain is riskier than a hunter firing a .30-06 with a 150 grain expanding bullet at the same deer. The muzzleloader proved to have less risk in all firing conditions.

The explanation for the last case where the shotgun is more risky relates to how the .30-caliber projectile interacts with the impact media at shallow (low) angles and its aerodynamic characteristics after ricochet. The smaller cross sectional area of the .30-caliber projectile and its shape contributes to a higher loss of energy on impact and after ricochet the .30-caliber bullet tends to tumble in flight with a high drag. Test data confirm that the .50-caliber projectile's larger cross sectional area and its shape contribute to less energy loss on shallow angles of impact and after ricochet the projectile exhibits less drag which results in a greater total distance traveled.

1.5.3 Recommendations

It is recommended that the PGC address the public perception that a shotgun with modern high velocity ammunition is less risky than centerfire rifles in all circumstances. This has some urgency since legally mandated Special Regulations Areas have promoted the assumption that shotguns are always less risky than a rifle for hunting deer. Frangible, or reduced ricochet, projectiles, for hunting firearms should be investigated as an alternative to the mandatory use of shotguns or muzzleloaders and as a means of managing risk in Special Regulations Areas. While the suitability of these projectiles for hunting deer remains unknown, the nature of these projectiles to break apart on impact would increase safety. The PGC should also enhance hunter education and continue to document and investigate incidents.

2.0 STUDY PURPOSE AND OBJECTIVE

2.1 Purpose and Objective

The purpose of this report is to examine if shotguns and muzzleloaders are less risky than centerfire rifles when used for hunting deer in Pennsylvania. As such, this report only addresses one question inherent in HR61. This question is: do *shotguns and muzzleloaders pose less risk than centerfire rifles for hunting deer in Pennsylvania?*

The objective of this study is to provide a scientific basis for policy pertaining to the mandatory use of shotguns and muzzleloaders for deer hunting in designated areas of Pennsylvania. The technique utilized to determine risk in the 1998 study conducted by the PGC was to compare the circular area around the hunter based on the firearm characteristics. This study assumes a similar definition of risk and compares the danger areas of firearm-ammunition combinations and representative cases of error when a round is discharged.

2.2 Not Included in This Study

This study is limited to the question in section 2.1 above. It does not:

- Provide a prediction of the risk associated with any particular geographic area of the Commonwealth.
- Take into consideration the factors of topography, land use, population density, hunter density, forest cover, and structure density.
- Provide specific recommendations to the Pennsylvania Game Commission and Pennsylvania General Assembly to consider on whether Special Regulations Areas should be expanded in Pennsylvania.
- Examine courses of action that might be considered to improve hunting safety in populated areas.
- Represent the safety circumstances of other hunting uses involving firearms in Pennsylvania.
- Provide a forensic analysis of the incidents or an empirical study of field tests of each firearm.

2.3 Important Assumptions

Several key assumptions were made as part of this study. These assumptions are:

- The typical hunter exercises reasonable care when discharging a firearm at a deer.
- Hunters will tend to maximize their chances of harvesting a deer by using the best available legal firearm-ammunition combination within reasonable economic means.
- The typical hunter will discharge the firearm at a height of three (3) feet to impact a standing deer at approximately 3 feet height above the surface.

- The projectile's trajectory will most frequently be approximately level with the general trend of the earth's surface (a zero (0) degree angle of elevation). However, a hunter may, on occasion, discharge the firearm above a zero (0) degree angle of elevation at a target positioned above the individual on the earth's surface or by accident. The majority of these discharges will be at an angle of ten (10) degrees or less but discharges at an angle delivering the maximum range (approximately 35 degrees) are possible but not frequent.
- The typical hunter firing from an elevated position, such as a tree stand, does not need to be examined since the angle of impact determines the probability and characteristics of the subsequent ricochet. Holding other factors constant, raising the shooter relative to the point of impact, increases the angle of impact in a fashion similar to raising the angle of elevation.
- The firearm-ammunition combinations used in this report are reasonably representative of those used to hunt deer in Pennsylvania.

2.4 Study Limitations

Several limitations were realized when preparing this report. These are:

- The spatial analysis relied on existing data that was gathered without foreknowledge of the analysis needs and techniques.
- Incident locations were obtained from the address matching process. This process is prone to excluding incidents in rural and recently urbanized areas.
- Vehicle incident locations were recorded only to the county of the event.
- There is no basis to determine an incident rate for a comparison between Special Regulations Areas and areas where rifles are allowed. It should be noted that the PGC made an assumption in 2004 of four shots for every deer harvested.[3] The PGC report is provided in Appendix C. This assumption was not used. As a result, there is no basis to determine an incident rate for a comparison between Special Regulations Areas and areas where rifles are allowed.
- Due to a lack of knowledge of the deer hunter's safety behavior, there are no facts concerning how soundly hunters identify their backstops or the size and likelihood of overshoots.

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[3] Schmit (2004).

3.0 UNDERSTANDING OF THE PROBLEM

3.1 Rifle/Shotgun Issue Special Regulation Area, Report: Pennsylvania Game Commission, January 13, 1998.

Below is a summation of the key findings of the "Rifle/Shotgun Issue Special Regulation Area, Report: Pennsylvania Game Commission, January 13, 1998"[4] that are relevant to this report.

During January 1997, the Pennsylvania Game Commission asked Executive Director Madl to investigate the issue of restricting the use of centerfire rifles in certain areas to increase public safety. Deputy Executive Director Michael Schmit was asked to chair a committee whose charge would be to bring recommendations before the PGC by January 1998. Part of the effort focused on determining what range of human population density warranted special regulation consideration. Other major efforts included understanding the factual basis for the use of the shotgun as a means of risk management and to examine the risk levels of various firearms commonly used by Pennsylvania deer hunters. The committee found no definitive information supporting the use of shotguns with single projectiles (slugs) as reducing the risk to the non-hunting public and most governmental entities established public policy requiring the use of shotguns simply based on the perception that shotguns were less dangerous than centerfire rifles.

According to the 1998 report, shotgun ammunition was "much more technologically advanced than its counterpart of just a few years ago." Not only is the ammunition changed to improve accuracy, but the shotgun has also changed. According to the report "many hunters choose to purchase sporting arms designed specifically for slug ammunition." Over the course of the study, individuals provided information or opinions. Some professed the shotgun to be more dangerous than the centerfire rifle.

Muzzle velocity, terminal velocity, maximum range, foot-pounds of energy, population density, land use, linear miles of roads, industrial centers, residential centers, urban centers, topography, soil type and much more were offered as criteria upon which to base decisions concerning Special Regulations Areas. It was felt that efforts to analyze every conceivable factor would paralyze decision-makers. As a result, ballistics information was obtained from ammunition manufacturers and the Sporting Arms and Ammunition Manufacturers Institute (SAAMI). Using this information, the committee compared risk, based on the potential danger area as determined by the maximum range of the projectile when the firearm is fired at approximately a 35-degree angle of elevation.

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[4] Schmit (1998).

The committee concluded that the number of people placed at risk is reduced when hunters are restricted to shorter range sporting arms such as shotguns. The committee also concluded that, “efforts to educate sportsmen to the hazards of improper firearm handling must continue no matter what the outcome of the current rifle/shotgun debate.” The PGC took no formal regulatory action at the January 1998 meeting but decided to gather scientific information in order to make an informed decision.

3.2 Pennsylvania Game Commission Regulations

As stated in the PGC hunting regulations[5] digest which is provided to licensees and the Game Commission Rules and Regulations as published in the Pennsylvania Bulletin, the following arms and ammunition are permitted for hunting deer in the Commonwealth:

- Centerfire rifles, handguns and shotguns with all lead bullet or ball, or a bullet designed to expand on impact. The “bullet designed to expand on impact” is generally interpreted to denote copper jacketed lead core projectiles with an exposed lead tip. Saboted shotgun ammunition and inline muzzleloaders are permitted.
- Centerfire rifles are not permitted for hunting in Special Regulations Areas, which include Allegheny County, Bucks, Chester, Delaware, Montgomery and Philadelphia Counties. Only bows and arrows are permitted in Philadelphia County. Buckshot is illegal, except in the Southeast Special Regulations Area. Shotguns 20 gauge and larger and Muzzleloading long guns 44-caliber or larger may be used in these areas.
- It is unlawful to hunt for, shoot at, trap, take, chase or disturb wildlife within 150 yards of any occupied residence, camp, industrial or commercial building, farm house or farm building, or school or playground without the permission of the occupants.

3.3 Shotgun and Muzzleloader Projectiles (Bullets) Used to Hunt Deer in Pennsylvania

3.3.1 Projectiles (Bullets)

The word "bullet" is often incorrectly used to refer to the combination of bullet, case, gunpowder, and primer; such an item is properly called a cartridge or round. A Sabot round, from the French for "shoe", is a cartridge that utilizes a smaller than bore diameter projectile held in a bore diameter sleeve. The use of this technique allows higher velocities since the projectile is much lighter than a projectile of the full bore’s diameter and has a large base area for the propellant gases to push against. It also provides ballistic advantages since the smaller diameter projectile will have a better ballistic coefficient and sectional density for a given weight. A common commercial use of this concept is the saboted 12 gauge round which fires a .50-caliber projectile.

[5] PGC (2006).

3.3.2 Shotguns

Early shotgun "slugs" were round, lead "pumpkin balls." The accuracy was poor and the firearm-ammunition combination had very poor ballistics characteristics. Demand for a projectile that could be fired from a smoothbore gun and used on deer resulted in the "rifled" slug. This is a short, blunt lead bullet that is solid in front and hollow in the rear, analogous to a badminton shuttlecock. The term "rifling" used here is actually a misnomer since it was cast into the slugs to purportedly impart a spin that would help stabilize the projectile. As such, they became known as the "rifled slug" which is a term in widespread use today. Rifled slugs are offered by most of the major ammunition makers in a variety of shotgun gauges. A smoothbore "slug gun" with rifle sights makes a satisfactory deer-hunting firearm at short ranges. However, today the term “slug gun” also connotes shotguns, with true rifled barrels like a centerfire rifle, designed to fire saboted projectiles. The 12 gauge saboted slug with a 385 grain .50-caliber projectile has an advertised muzzle velocity of 1900 feet per second from a 2 3/4" high-brass shell.[6] These shotguns with rifled barrels are equal to the .45-70 rifle cartridge. For example, a .45-70 rifle shoots a 405-grain bullet at a muzzle velocity of 1330 feet per second.[7] The reader is referred to Dave Henderson’s work, Shotgunning for Deer, for a detailed history of the use of shotguns for hunting deer and trends in shotgun and ammunition technology.

3.3.3 Muzzleloaders

A muzzleloader is any firearm into which the bullet is loaded from the muzzle of the gun. Modern muzzle-loading firearms range from reproductions of percussion long guns to inline rifles. The inline muzzleloader uses modern developments such as a closed breech, materials to withstand higher internal pressures, sealed primer, and rifling to allow for better accuracy at long ranges. The major distinguishing feature is that an inline muzzleloader uses a striker system similar to the firing pin/striker assembly found on modern bolt-action rifles. As such, the majority of inline muzzleloaders look like a modern rifle. These guns have barrels that are intended for use with a sabot or PowerBelt© projectile. Significantly, Savage has a bolt-action inline smokeless powder muzzleloading rifle. A hunter with a bolt-action style .50-caliber inline rifle using a moderate load of powder propellant will obtain ballistic performance similar to a .45-70 centerfire rifle.[8]

[6] See Appendix I: Ballistics of the Remington 12 Gauge Sabot Slug.
[7] Remington (2006).
[8] See Appendix J: Ballistics Information for the CVA .50 Caliber Powerbelt Bullet.

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4.0 SPATIAL ANALYSIS OF REPORTED INCIDENTS RESULTING IN DAMAGE TO PROPERTY

4.1 Incident Database

The PGC began to maintain a database of reported incidents in 1997. This data was collected by the PGC's six regional offices. Incidents involving projectiles striking structures were recorded by county, municipality, and street address. Incidents involving automobiles and animals were recorded by county and municipality only. Appendix D contains the data dictionary for the information collected and contained within the database. During the period of 1997 through 2005,[9] data concerning 464 incidents was collected. Of this number, 98 incidents were not used due to not being associated with hunting deer. Of the 366 remaining incidents:

- There were no rifle incidents in Special Regulations Areas.
- 19% of the incidents occurred in Special Regulations Areas.
- 75% of the incidents involved rifles.
- 21% of the incidents involved shotguns.
- 4% of the incidents involved muzzleloaders.

On an annual basis the maximum number of recorded incidents for any county was seven (7) and the maximum number of incidents in a county over the period of 1997 – 2005 was 23. (See Appendix E for data involving the 366 incidents) Many counties reported no incidents in a particular year and the number of annual incidents at the county level was much more variable than statewide. The reader is cautioned that the small number of incidents in many counties and the variability between years in some counties can give a distorted picture and any comparisons must be made with caution.[10]

4.2 Spatial Analysis of Incidents

A three-step process was used to map and examine the incident data. First, the incidents were located utilizing a process called geocoding (described below). The second step was to map the incidents to show patterns. The third step was to determine if there was a tendency for the incidents to statistically cluster into "hot spots". Hotspot mapping, a crime mapping technique, is an accepted approach for crime mapping to detect high-crime-density areas known as hot spots. The National Institute of Justice has found hotspot mapping technologies to have significantly improved the ability of analysts and researchers to understand crime patterns.[11]

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[9] One incident for 2006 was provided and included in the analysis.
[10] See Appendix E: PGC Incidents by County, 1997 – 2005+ for a summary of the data.
[11] Eck (2005) is dedicated to the use of hot spot analysis.

4.3 Geocoding

The PGC database includes the street address of the incidents, which were converted to coordinate data by the MTT team. Geocoding the incidents avoids aggregation of the incidents by county name. Geocoding, or address matching, compares the elements of each address to the attributes associated with each road segment until the number falls within the range of addresses associated with a particular street. The placement of the point is determined by interpolating the range of addresses to determine if the street number lies along the line segment. The street address may not match an address available within the street database because the street:

- Name does not exist.
- Was spelled incorrectly on the report.
- Number does not fall within a valid address range.
- Type is incorrect.
- Designation does not exist.

For example, the address may be a new subdivision that has not yet been included in the street database. Geocoding is seldom perfect and a match rate of 80 to 90 percent is typical. The MTT team's geocoding was 85.5% successful with 313 matches of the 366 incidents. Appendix F contains a table summarizing the address matches by county. Westmoreland County had the highest occurrence (6) of addresses that did not match.

4.4 Mapping Incidents

Figure 1 shows the incidents mapped as dots over a choropleth map showing the number of incidents for each county. The geographic distribution of incidents shows a higher density of incidents in the southeast and western portions of the state. The choropleth map was based on incident data aggregated to each county and includes data, such as vehicle incidents, that could not be address matched. The choropleth maps reflected a similar general trend as the dot map.

MountainTop Technologies, Inc.

Incidents

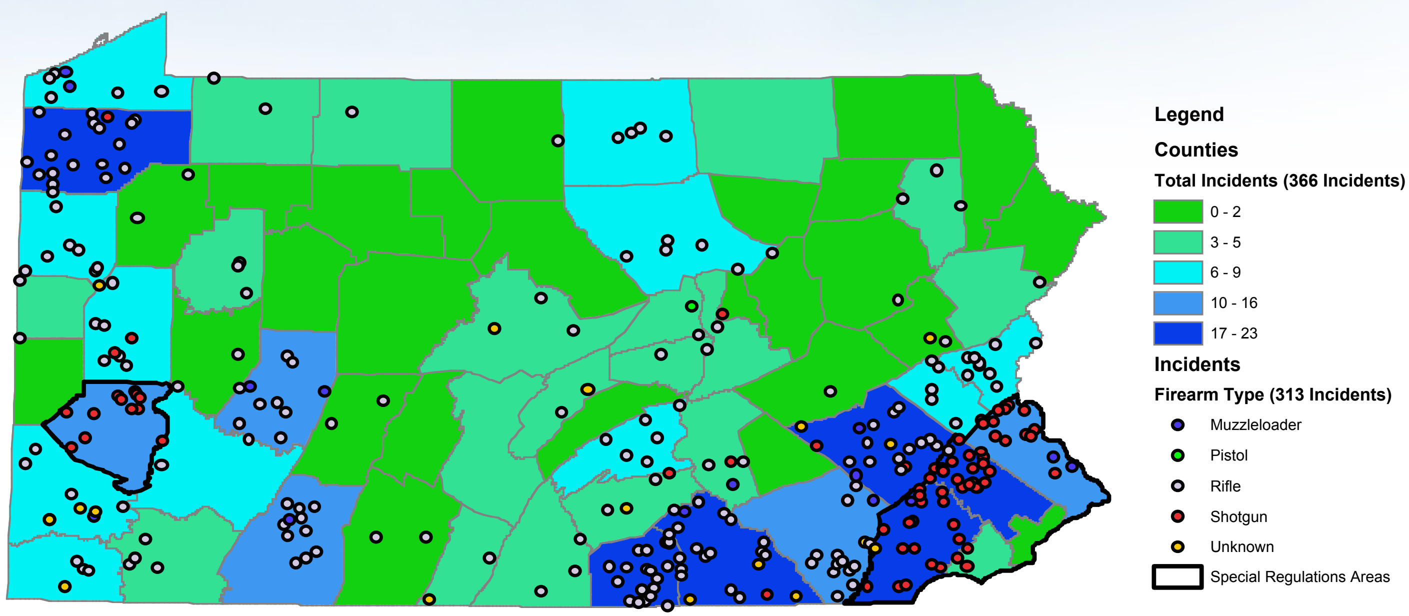

Figure 1: Map of incidents as points over the total number of incidents per county

4.5 Hotspot Analysis

Hotspot analysis is a spatial analysis technique contained in the *CrimeStat III* software. This software was developed for the National Institute of Justice, which serves as the research, development, and evaluation agency of the U.S. Department of Justice. The Nearest neighbor hierarchical (Nnh) spatial clustering routine is a clustering routine that groups points together on the basis of spatial proximity. A cluster is a geographically defined group of sufficient size and concentration that is unlikely to have occurred by chance.

The routine identifies first-order clusters (contained in Adams, Allegheny, Bucks, Cumberland, Lancaster, Lehigh, Montgomery, Northampton, Somerset, and York Counties) representing groups of points that are closer together than a threshold distance and in which there are at least five (5) points. A two standard deviation ellipse was calculated for each cluster to provide a regional view of the incidents. The first-order clusters are the grouping of incidents represented as points while second-order clusters are groupings of the first-order clusters.

Figure 2 shows first and second order clusters of incidents both inside and outside of the Special Regulations Areas[12]. Appendix G contains the tabular results of the hotspot analysis.

This analysis should not be taken to determine the relative levels of risk between Special Regulations Areas and non-Special Regulations Areas. The lack of a reliable estimate of the number of hunters in any particular area and a means to estimate the number of shots fired in an area hindered the determination. Deer harvest was considered as a surrogate measure but was not used since the deer harvest itself is an estimate by county. Additionally, the underlying geographic variation in topography, land use, and structure density between the areas needs to be taken into consideration for a meaningful comparison of the relative risk of the firearm-ammunition combinations.

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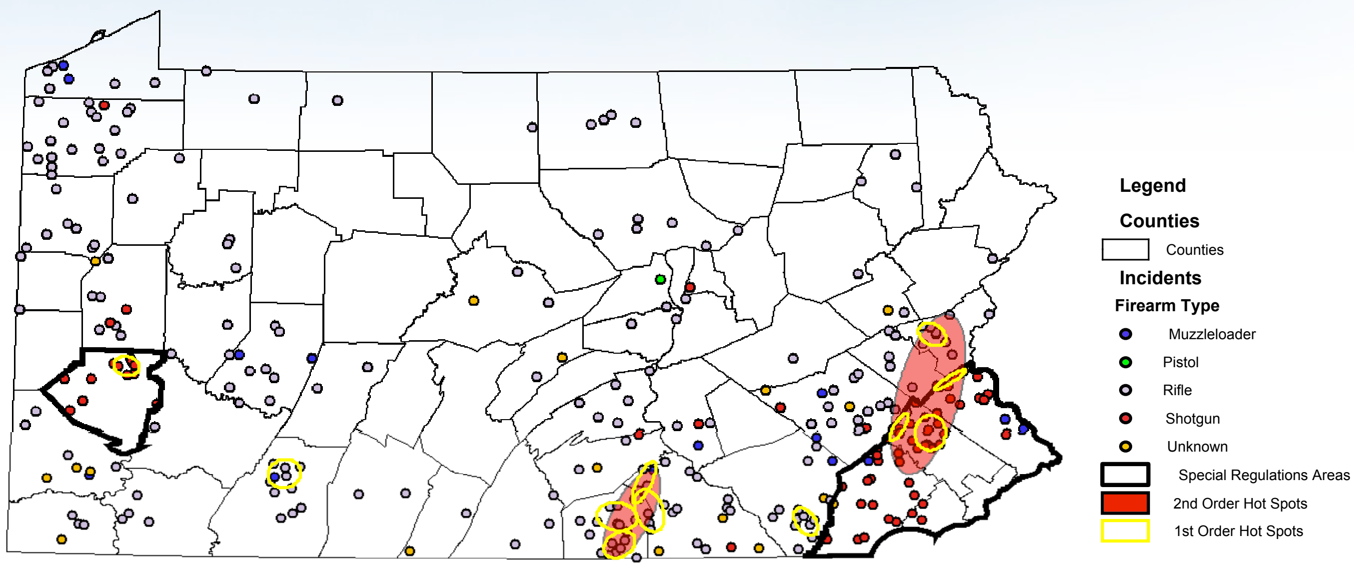
[12] Counties contained within or touched by second order clusters within a Special Regulations Area included Chester, Montgomery, Berks, and Bucks Counties. Counties contained within or touched by second order clusters outside a Special Regulations Area included Adams, York, Lehigh, and Northampton Counties.

Hotspot Analysis



Note: Hotspot analysis was performed using a program called *CrimeStat III,* developed for the National Institute of Justice

Figure 2: Results of the Hotspot Analysis

4.6 Rate Maps

Rate maps were examined as a means to show the ratio of the actual incidents and expected number of incidents by county. Rate maps were not included in this report because the population from which the incidents arose is unknown and thus no reliable rate of incidents per firearm type or geographic region can be calculated.

5.0 COMPARATIVE BALLISTICS OF SHOTGUNS, MUZZLELOADERS, AND RIFLES

A computer simulation was used to model the danger area of representative firearms-ammunition combinations suitable for deer hunting. The model is based on recent research of the small arms projectile ricochet phenomenon that has been developed for the US Department of Defense's program to establish Surface Danger Zones (SDZs) for firing ranges and weapons training facilities. SDZs are areas identified to protect personnel from weapons firing during training and can be related to the danger area in the study. ARDEC has pioneered a theoretical probability model to evaluate the various parameters contributing to the SDZ definition. Specific emphasis was placed on the effects of ricochet because of its significant impact on the shape and size of the SDZ. The particular firearm-ammunition system, ricochet, and aimer error provide the necessary parameters to produce probability-based SDZs.

The tool used to generate the exterior ballistic trajectories for this study was based on a modified point mass (MPM) trajectory model. The methodology used is referenced from the North Atlantic Treaty Organization (NATO) Standardization Agreement 4355 titled Modified Point Mass Trajectory Model. The document describes the equations of Newton's second law of motion[13] for the point-mass trajectory and is limited to modeling the projectile's aerodynamic drag force and gravity. The equations are solved numerically by a method known as a fourth-order Kunge-Rutta. The International Civil Aviation Organization (ICAO) atmosphere model is also employed to determine appropriate air density, temperature and pressure as a function of altitude above sea level. The term "modified" describing the model refers to the approximation of the yaw of repose, which is derived by simplifying the six degree of freedom trajectory equations. The yaw of repose provides an estimate of spin-drift and magnus effects.

The probabilities of ricochet stated in this study were established through the United State's Army's proving ground testing. This testing was required as part of the early development of the current SDZ simulation that utilizes the MPM model trajectory engine. The ricochet tests focused on small caliber ammunitions including the .45-caliber M1911 ammunition and the .50-caliber BMG ball ammunition. For both the shotgun and muzzleloader ammunitions, the M1911 ricochet data was utilized due to similar muzzle velocities and near hemispherical nose shape. The probability of ricochet was determined by empirically collecting data at various impact angles for both hard and soft impact surfaces. Impact angles were tested in 5-degree increments from 5 to 25 degrees. The .30-caliber projectile was empirically

[13] Newton's second law of motion explains how an object will change velocity if it is pushed or pulled upon. The relationship is expressed as an object's mass m, its acceleration a, and the applied force F as $F = ma$.

determined to have a lower probability of ricochet for the same impact angle range as compared to .45-caliber ammunition. While sporting projectiles will respond differently, data derived from tests with military ammunition establishes the upper boundary of ricochet potential and characteristics of flight, and thus provides for a valid comparison between the various firearm-ammunition combinations.

5.1 Representative Ammunition

The firearm-ammunition combinations used in the study are: (1) legal for hunting deer in Pennsylvania, (2) available through retail sporting good outlets in Pennsylvania, and (3) used by hunters in Pennsylvania. The following firearms and ammunition were used as representative of those used to hunt deer in Pennsylvania.[14]

- Rifle: 30-06 Springfield (7.62mmx63mm) with a soft point projectile weighting 150 grains and attaining a muzzle velocity of 2910 feet per second (fps). The .30/06 cartridge has been used on big game with bullets weighing anything from 100 to 200 grains; a typical bullet weight for game like deer is 150 grains. Appendix H contains the ballistics information of this round.
- Shotgun: 12 gauge with a sabot .50-caliber hollow-point semi-spitzer projectile weighting 385 grains and attaining a muzzle velocity of 1900 fps. This represents hunting in the Special Regulations Areas with a shotgun that is optimized for deer hunting with a rifled slug barrel and saboted ammunition. The PGC's 1998 report specifically referred to the emergence and use of this firearm-ammunition combination - which is the primary reason this combination was included. Appendix I contains the ballistics information of this round.
- Muzzleloader: .50-caliber CVA Powerbelt projectile weighting 348 grains and attaining a muzzle velocity of 1595 feet per second. This represents a hunter purchasing an inline muzzleloader to take advantage of special seasons or to meet the requirement of the Special Regulations Areas. Appendix J contains the ballistics information of this load.

[14] The firearms-ammunition combinations were approved with the PGC as reasonable representations of those used to hunt deer in Pennsylvania prior to beginning this study.

5.2 Relevant Ballistic Concepts

5.2.1 External and Terminal Ballistics

There are several sub-sciences to the science of ballistics including *internal ballistics,* which concerns the combustion, friction and pressure within the firearm; *external ballistics,* which concerns the flight, speed and energy of the projectile; and *terminal ballistics,* which concerns the study of the behavior of a projectile when it hits its target[15]. The most frequently used term from the realm of external ballistics is muzzle velocity. Muzzle velocity is the speed at which the projectile exits the barrel. Muzzle velocity is expressed at the rate of feet per second (fps) in the United States. Muzzle velocity is typically measured at a distance of few feet from the muzzle because of the large amount of hot gas and material that is expelled along with the projectile. Muzzle velocity is reported as an average of a number of tests. The term velocity refers to the speed of the projectile, which is a variable that decreases the further it is measured from the muzzle. Trajectory refers to the path of the projectile from the muzzle to impact with the ground and is perhaps the most fundamental concept of external ballistics. Trajectory is linked to muzzle velocity because the faster the muzzle velocity of a projectile, the flatter the trajectory of that projectile in flight. Trajectory can best be illustrated by the example of a household water hose with a nozzle emitting a small, powerful stream. The first couple of feet of the stream are almost flat. Past the point where the water is almost flat, the water stream drops drastically, eventually falling almost straight down where the stream strikes the ground.

Not considering the influence of ricochets, Table 1 illustrates that lower angles of shooting nearly obtain the maximum range of the firearm-ammunition combination discharged three (3) feet above the surface of the earth. Approximately 50 percent of the maximum range can be obtained at an elevation of 5 degrees and 70 percent of maximum range can be obtained at a 10-degree angle. For example, a .30-06 with a 13,926-foot (2.6 miles) maximum range would travel 71.8 percent of its maximum range or 10,004 feet at a 10-degree angle.[16]

Table 1: Comparison of Firing Angles and Ranges

Firearm-Ammunition	5-Degree Angle of Elevation	10-Degree Angle of Elevation
.30-06	53.8% of Maximum Range	71.8% of Maximum Range
Shotgun	49.3% of Maximum Range	69.0% of Maximum Range
Muzzleloader	47.4% of Maximum Range	67.9% of Maximum Range

[15] Rinker (2005), p. 3.
[16] The ballistics were provided by ARDEC.

5.2.2 Projectile (Bullet) Design

When considering projectiles, or bullets, the construction and shape are important to the terminal ballistics. Frangible type projectiles break up into very small pieces upon impact with the target or the backstop. The penetration of this type of projectile is limited and the inflicted damage is typically near the surface of the target.[17] Non-expanding (FMJ) bullets typically retain their general shape as the bullet penetrates and passes through the target. Non-expanding FMJ bullets are illegal for deer hunting in Pennsylvania. Expanding or "controlled expansion" bullets are designed to deform or "mushroom" as the bullet penetrates and passes through the target. Most expanding hunting bullets have a lead core protected by a jacket of some harder metal. The term "soft point" refers to the lead exposed at the tip of the bullet, which helps to initiate bullet expansion upon impact.

Traditional full-bore diameter rifled shotgun “slugs” and muzzleloader projectiles have a poor ballistic coefficient[18] and sectional density[19] as compared to a rifle bullet’s ballistics performance and therefore a shorter maximum range. The newer saboted projectiles used in rifled shotguns and muzzleloaders have a much better ballistic performance and will retain velocity longer and therefore have a greater maximum range.

5.2.3 Ricochets

A ricochet is a bullet rebounding, bouncing, or skipping off of a surface and is one of the primary dangers of shooting. After bouncing off an object, the projectile that ricochets poses an unpredictable and serious danger to bystanders, animals, objects, or even the person who fired the shot. Bullets are more likely to ricochet off flat, hard surfaces such as concrete or steel but ricochets can occur on almost any surface including grass, soil, and water.[20] The likelihood of ricochet is dependent on many factors, including bullet caliber (diameter) and length, nose shape, velocity, and the angle of impact. Characteristically, if a projectile strikes at a small impact angle to the surface and does not disintegrate, it will ricochet in the general direction of the line of fire.[21]

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[17] Mullins (2001).
[18] Defined in Appendix B.
[19] Defined in Appendix B.
[20] Hoxha (1995), Mullins (2001), Rinker (1999).
[21] Discussions with Sami Hoxha and Ernesto B. Vazquez, Systems Safety Office and Armaments Technology Division, Picatinny Arsenal, NJ, May 2005.

5.3 Comparison of Approaches

As Figure 3 illustrates, the PGC's1998 study computed danger areas based on the maximum ranges of various firearm-ammunition combinations.[22] In this case, ballistics information used by the PGC in the 1998 study was obtained from ammunition manufacturers and the Sporting Arms and Ammunition Manufacturers Institute (SAAMI). It is worth noting that the maximum range in the atmosphere is best gained through empirical tests and most hunting cartridges have not been tested while military calibers, have been extensively tested.

This study uses an alternative method of developing danger areas both in technique and assumptions. The maximum range does not provide a complete basis to evaluate the comparative firearm-ammunition risk since most discharges are likely to have a significantly smaller aiming error. Using the maximum range is akin to that of a hunter firing 35 degrees to the right or the left of a deer - which is a rare to improbable occurrence and produces an arbitrary view of comparative risk. While the1998 PGC study method assumed abnormal behaviors or accidental acts, the approach taken in this study examines normal events and the measurable variations about these normal behaviors. The probability based danger areas in this study assume reasonable hunting behavior with normal variances. The danger areas produced under this methodology are based on the concept of probability and actually produce a probability zone around the hunter. Table 2 lists the firing error conditions examined in this study.

[22] Schmit (1998).

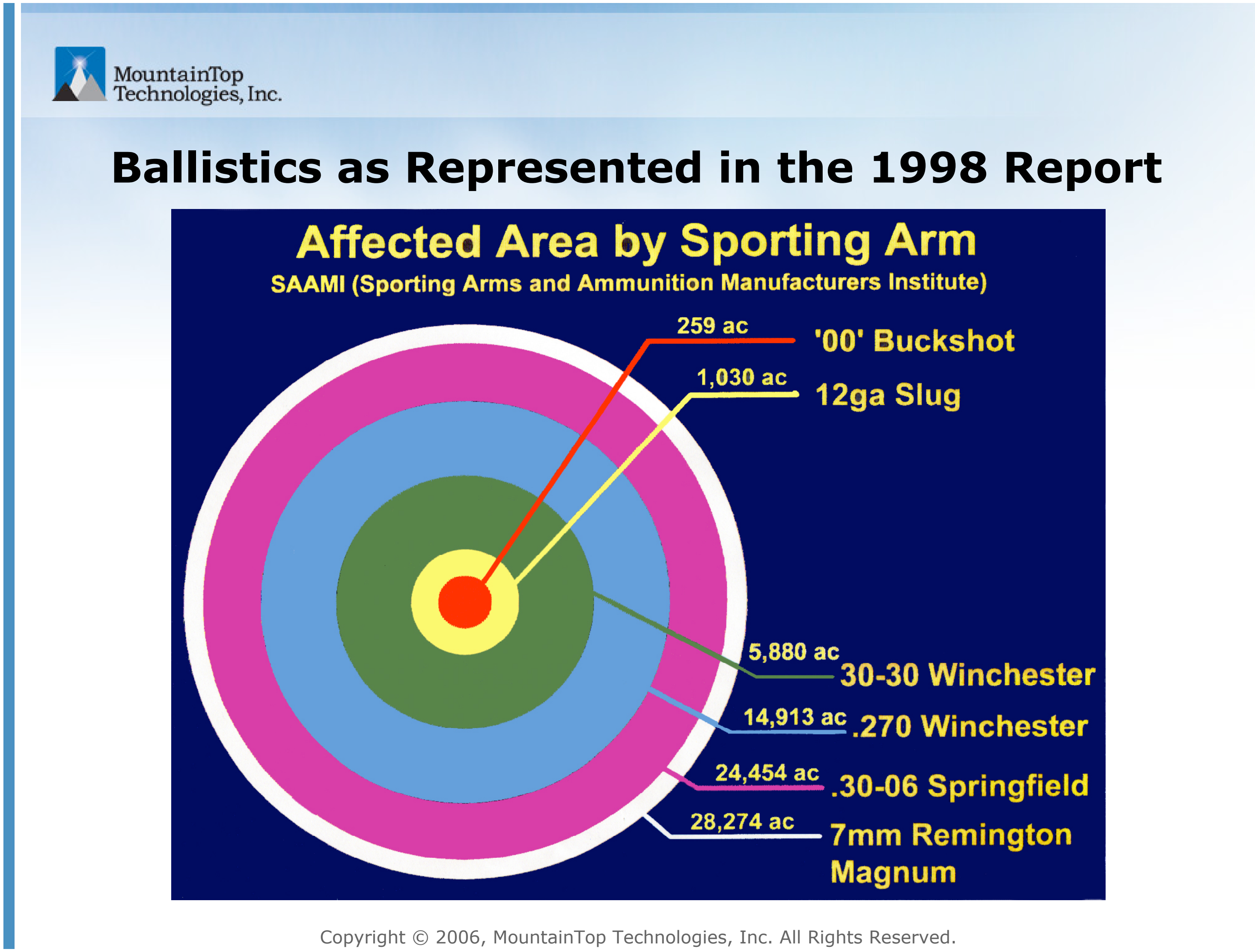

Figure 3: Ballistics as Represented in the 1998 PGC Report (Schmit (1998))

5.4 Approach

The model discussed in this report was designed to represent different firing angles, the corresponding impact angles, the particular firearm-ammunition used, the effects of ricochet, and the potential danger areas associated with these angles. When determining danger areas, two distances are taken into consideration as a total distance. These distances are:

- The distance to the initial impact with the surface of the earth at various firing elevations.
- The distance the projectile will subsequently ricochet.

5.5 Initial Conditions

Several initial conditions, or parameters, are necessary to properly define the danger area for a particular firearm-ammunition combination. Some of these parameters are independent, but most are dependent, and actually are inputs defining other parameters. For example, flight dynamics not only define the ballistic capabilities of a projectile, but also are necessary to trace ricochet patterns. The parameters of flight dynamics, aimer error, and ricochet are important in defining danger areas. The following paragraphs will discuss the importance of each in the danger zone determination and explain how this information is gathered and where it is available.

- Flight dynamics data provides the necessary ballistic information to calculate the flight pattern of a particular projectile before and after ricochet. This data was developed during technical testing and reduced to proper format by the Firing Tables Branch, ARDEC. Test procedures for collecting this data are defined in TOP 3-2-601, and the Firing Tables Branch used computer programs and data reduction capability to properly reduce this test data. For shotgun and muzzleloader ammunition, drag curves for the complete Mach number flight regime were generated using Aerodynamic prediction codes.

- Aimer error defines the dispersion about the line of fire vertically, and is influenced by the firearm, ammunition, and the shooter. This provides the necessary information to define a hit probability density function about the center of the target or a point on the ground. The significance of this information is that it establishes the point from where ricochets are determined. ARDEC previously completed a study of aimer error for small arms and provides system/aimer error data as population standard deviation on the horizontal and vertical planes with respect to target range. This data was used to define the hit probability about the center of the target or a point on the ground. The shooter (hunter) and target height (deer) were set at 3 feet above the earth's surface. Firing elevations were varied for 35, 10, 5, and approximately 0 degrees above the base of the trajectory. These firing elevations represent approximately 100, 70, and 50 percent of the maximum ranges of the firearm-ammunition combinations. Table 2 illustrates the nature of this error:

Table 2: Nature of Representative Firing Conditions (Errors)

Firing elevation simulated (degrees)	Firing condition	Line of Departure (Feet) above a standing deer at a range of 300 feet	Approximate Percent of Maximum Range
35	Errant shot	210 ft	100%
10	High error in aiming	53 ft	70%
5	Moderate error in aiming	26 ft	50%
~0	Aiming at target	0 ft	10%

- Ricochet testing and analysis was conducted by ARDEC. A comprehensive ricochet test program was developed to establish new and improved procedures for conducting ricochet testing. This effort included defining the test setup, the parameters to be measured, and the type of instrumentation to use. It also included actual testing of several bullets to allow demonstration of the probability model. Damp sand was chosen to be representative of soft surfaces and steel was selected to represent hard surfaces. To produce drag form factor data after ricochet required reducing radar measurements. The drag form, or how efficiently the projectiles move through the air, depends primarily upon the size and shape of the object after ricochet and is estimated by radar measurements of the ricochet path.
- A probability of ricochet was derived by computing the maximum likelihood estimate for a given confidence level using the test data for the number of rounds that did ricochet relative to the total number of rounds fired per impact angle. The probability of ricochet at selected angles of impact are provided in Table 3:

Table 3: Probability of Ricochet

Impact Angle (Degrees)	Probability of Ricochet (Percent)		
	.30-06	**Shotgun**	**Muzzleloader**
0	100.0	100.0	100.0
2	*	100.0	100.0
3	96.5	*	*
5	90.1	99.7	99.7
7	74.0	99.4	99.4
10	38.0	91.0	91.0
12	17.6	78.4	78.4
14	6.1	*	*
15	*	47.5	47.5
16	0.6	*	*
17	*	22.1	22.1
20	*	7.3	7.3
22	*	2.7	2.7

*** Data not available for the particular weapon system/impact angle**

5.6 Ricochet (or Total) Distance

Figure 4 illustrates the concept of the ricochet and the total distance a projectile will travel. The ricochet distance, or total distance, is the distance to the initial impact in addition to the distance of any subsequent ricochet. Stated another way, the projectile hits a point on the ground at an initial distance and it either remains there or it ricochets upon impact and continues its flight. The velocity and mass of a ricocheting projectile varies with every ricochet, however, ricochets can and frequently do retain sufficient energy to cause damage or be lethal.[23]

Ricochet data provides the necessary information to define the ultimate resting place of a projectile after it has struck a given object. The composition of these objects may vary significantly, ranging from hard substances such as steel to softer substances such as water. The ricochet substance is normally referred to as ricochet media and its composition will have significant impact on the ricochet variables after impact. In addition to the ricochet media, the impact angle with this media will also influence the ricochet behavior. The ricochet variables that are of interest are those that will allow calculating the projectile trajectory after ricochet. These include ricochet velocity, ricochet angles, and drag coefficient after ricochet. As these are directly dependent on the impact angle, they are measured with respect to that angle.

The angle of elevation, shooter height and target height are critical in determining the total distance the projectile will travel to yield a danger area. Both gun height and target height influence the probability of ricochet as well as the point where the ricochet trajectory begins, given that a ricochet occurs. In the examination of anticipated firing conditions, the shooter (hunter) and target height (deer) was set at 3 feet above the earth's surface. The firing angle of elevation was tested for 35, 10, 5, and approximately 0 degrees above the base of the trajectory.

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[23] Hoxha, Sami; Vazquez, Ernesto B, Surface Danger Zone (SDZ) Methodology Study, Probability Based Surface Danger Zones, Army Armament Research Development And Engineering Center Picatinny Arsenal N J Product Assurance Directorate, March 1995.

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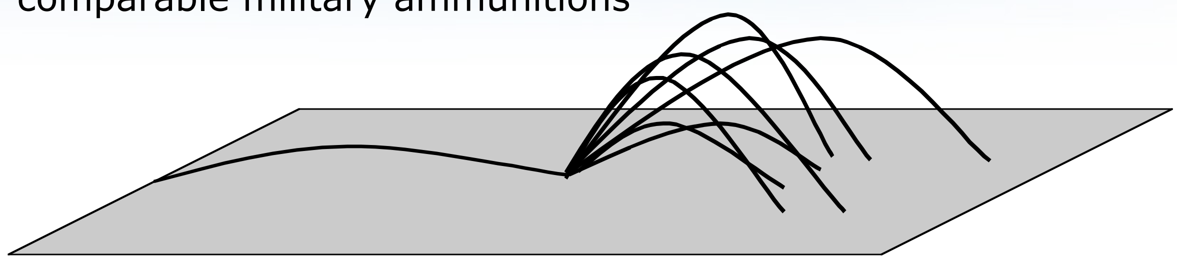
Ricochet Distance

- Once initial trajectories are computed, ricochet trajectories are simulated based on established ricochet databases from comparable military ammunitions



- Trajectory Plots are provided with both initial and maximum ricochet distances

Figure 4: Ricochet Distance

5.6.1 Firing Condition: 35-Degree Firing Elevation

Figures 5 and 6 illustrate the case representing the maximum range associated with abnormal behaviors and accidental acts. At a firing angle of elevation of 35 degrees the rifle, shotgun, and muzzleloader projectiles travel 13926, 10378, and 9197 feet respectively. The total initial distance and ricochet distances are the same since the angle of impact is not conducive to a ricochet. The shotgun and muzzleloader projectiles travel 25 and 34 percent less than the distance of a rifle projectile at this angle. Figure 5 illustrates these distances as radiuses, which are then used to create circular danger areas.

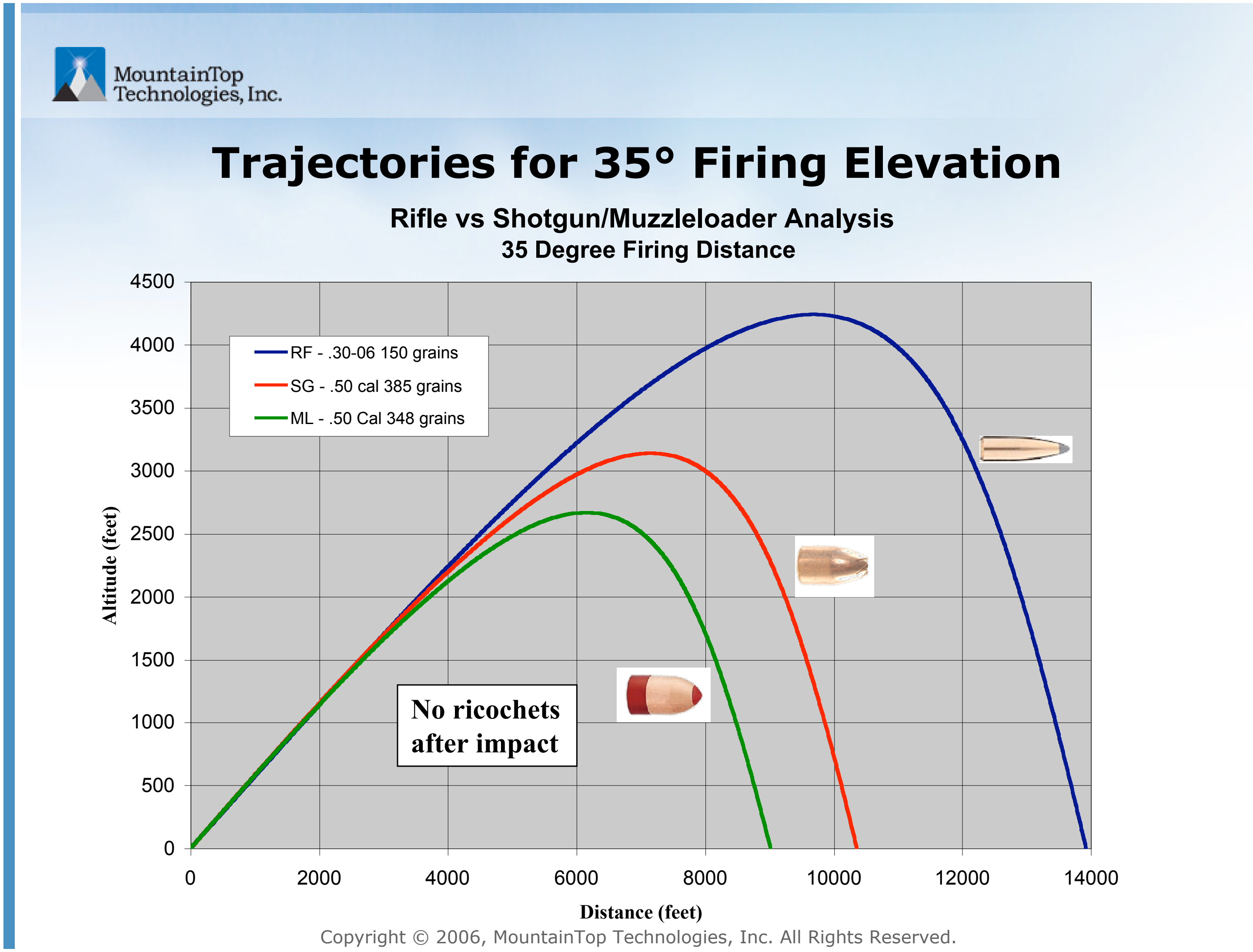


Figure 5: Trajectories for a 35-degree firing elevation

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Maximum Ranges

	Firing Elevation at 35 degrees				
Ammunition	Initial Impact Distance (ft)	Ricochet Distance (ft)	Difference Distance (ft)	% Less than Rifle	
				Initial	Ricochet
Rifle (.30-06 150 grains)	13926	13926	0	Initial	Ricochet
Shotgun (.50 cal 385 grains)	10378	10378	0	25%	25%
Muzzleloader (.50 cal 348 grains)	9197	9197	0	34%	34%

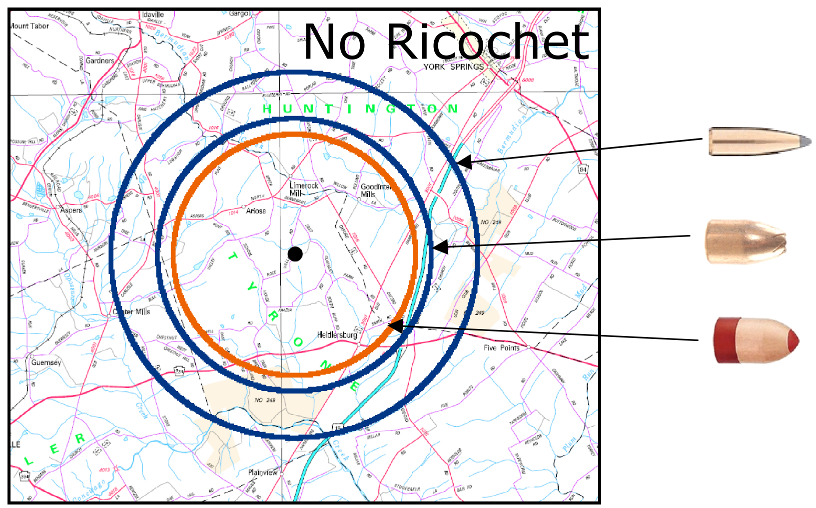

Figure 6: Maximum ranges for a 35-degree firing elevation

5.6.2 Firing Condition: Ten (10) Degree Firing Elevation

Figures 7 and 8 illustrate the case representing normal hunting behavior with a high aiming error. At a firing angle of elevation of 10-degrees elevation, the rifle, shotgun, and muzzleloader projectiles travel 10004, 7163, and 6247 feet respectively. This represents for the shotgun and muzzleloader 28 and 38 percent less than the distance of the rifle. There is a ricochet of 702, 949, and 913 feet respectively for the rifle, shotgun, and muzzleloader. The total distances the projectiles travel are 10706 feet for the rifle, 8112 feet for the shotgun and 7160 feet for the muzzleloader which represents 24 and 33 percent less than the ricochet distance of the rifle. Figure 8 illustrates these distances as radiuses used to create circular danger areas.

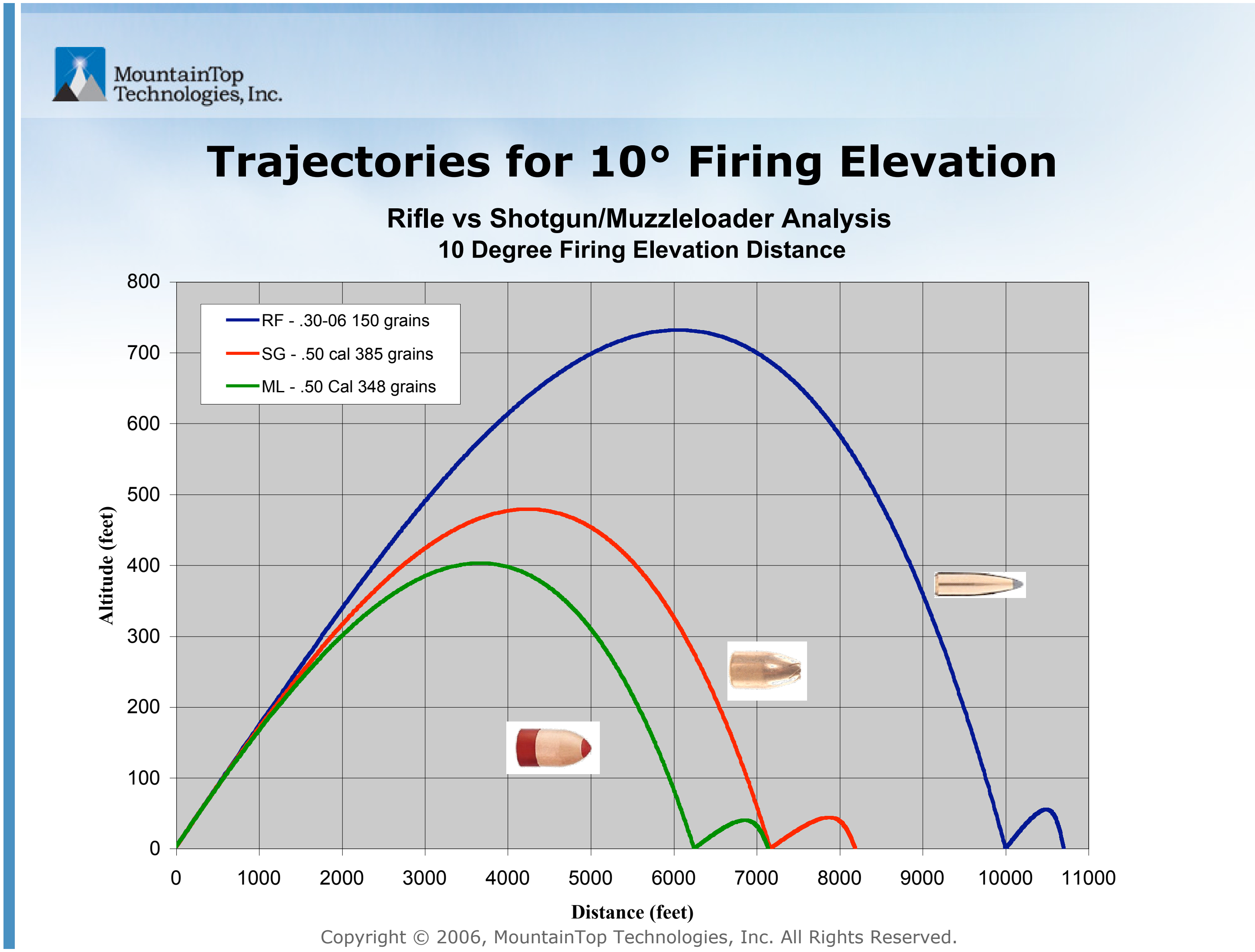

Figure 7: Trajectories for a 10-degree firing elevation

10º Elevation with Ricochet

Ammunition	Firing Elevation at 10 degrees: Initial Impact Distance (ft)	Ricochet Distance (ft)	Difference Distance (ft)	% Less than Rifle	
				Initial	Ricochet
Rifle (.30-06 150 grains)	10004	10706	702		
Shotgun (.50 cal 385 grains)	7163	8112	949	28%	24%
Muzzleloader (.50 cal 348 grains)	6247	7160	913	38%	33%

Band Thickness is Ricochet

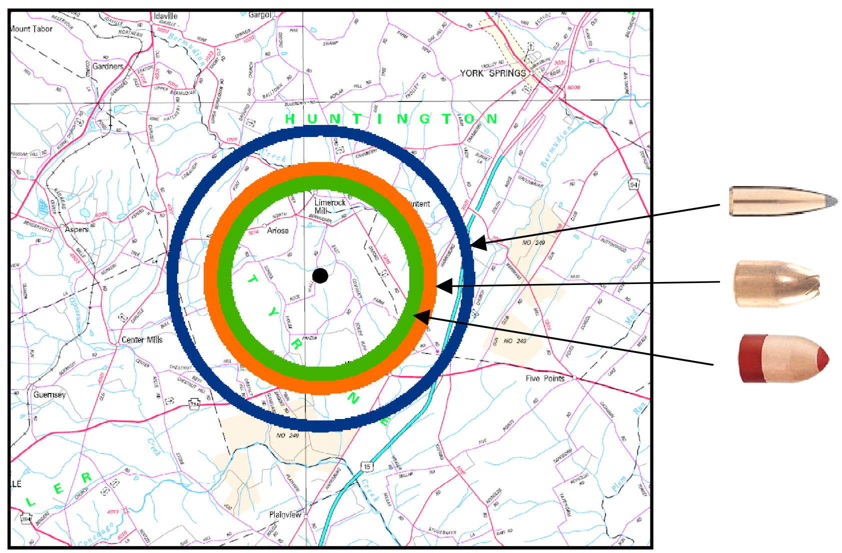

Figure 8: 10-degree elevation with ricochet

5.6.3 Firing Condition: Five (5) Degree Firing Elevation

Figures 9 and 10 illustrate the case representing normal hunting behavior with a moderate aiming error. At a firing angle of 5 degrees elevation, the rifle, shotgun, and muzzleloader projectiles travel 7504, 5118, and 4367 feet respectively. This represents for the shotgun and muzzleloader 32 and 42 percent less than the distance of the rifle. There is a ricochet distance of 1239, 1747, and 1643 feet respectively for the rifle, shotgun, and muzzleloader. The total distances the projectiles travel are 8743 feet for the rifle, 6865 feet for the shotgun, and 6010 feet for the muzzleloader which represents 21 and 31 percent less than the ricochet distance of the rifle. Figure 10 illustrates these distances as radiuses used to create circular danger areas. Note that the ricochets are increasing in distance and the ricochet (total) distances of the shotgun, muzzleloader, and the rifle are beginning to converge.

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Trajectories for 5° Firing Elevation

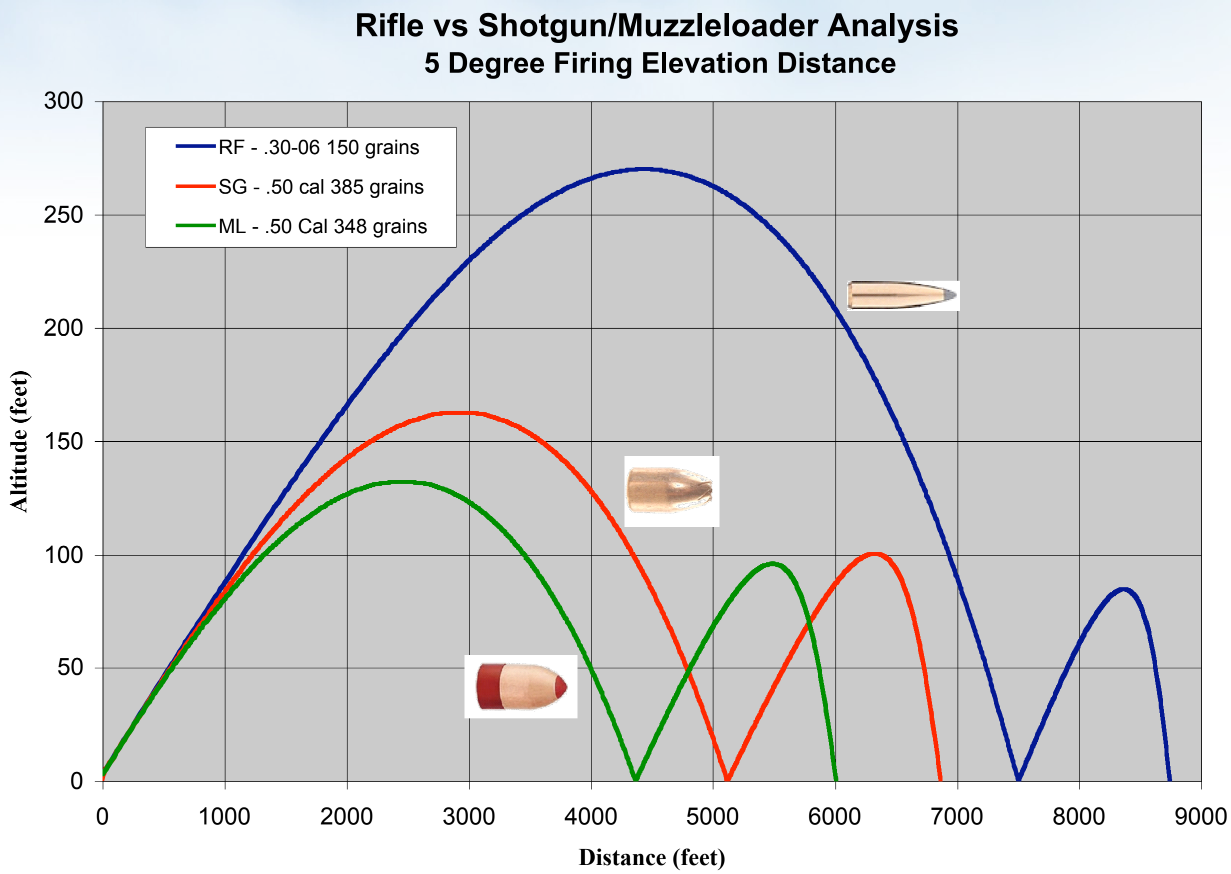

Figure 9: Trajectories for a 5-degree firing elevation

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5º Elevation with Ricochet

	Firing Elevation at 5 degrees				
Ammunition	Initial Impact Distance (ft)	Ricochet Distance (ft)	Difference Distance (ft)	% Less than Rifle	
Rifle (.30-06 150 grains)	7504	8743	1239	Initial	Ricochet
Shotgun (.50 cal 385 grains)	5118	6865	1747	32%	21%
Muzzleloader (.50 cal 348 grains)	4367	6010	1643	42%	31%

Band Thickness is Ricochet

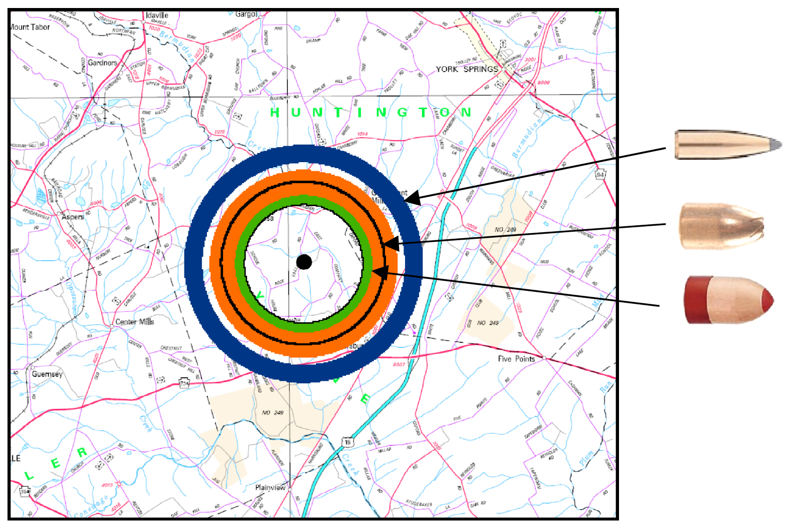

Figure 10: 5-degree firing elevation with ricochet

5.6.4 Firing Condition: Zero (0) Degree Firing Elevation

Figures 11 and 12[24] illustrate the case representing normal hunting behavior with no vertical aiming error. At a firing angle of approximately 0-degrees angle of elevation, the rifle, shotgun, and muzzleloader projectiles travel 1408, 840, and 686 feet respectively before impacting the surface. This represents for the shotgun and muzzleloader 40 and 51 percent less than the distance of the rifle. There is a ricochet of 3427, 4365, and 3812 feet respectively for the rifle, shotgun, and muzzleloader. Combining the ricochet with the initial impact distance, the total distances the projectiles travel are 4835 feet for the rifle, 5205 feet for the shotgun, and 4498 feet for the muzzleloader which represents -8 and 7 percent less than the ricochet distance of the rifle. It is important to note that the shotgun is a negative value, which means that the ricochet distance is actually **8 percent more than the rifle**. Figure 12 illustrates these distances as radiuses used to create circular danger areas.

[24] The graphics representing the distances of the various firearm-ammunition combinations are not overlaid in Figure 12 because the results are so similar as to preclude a clear representation.

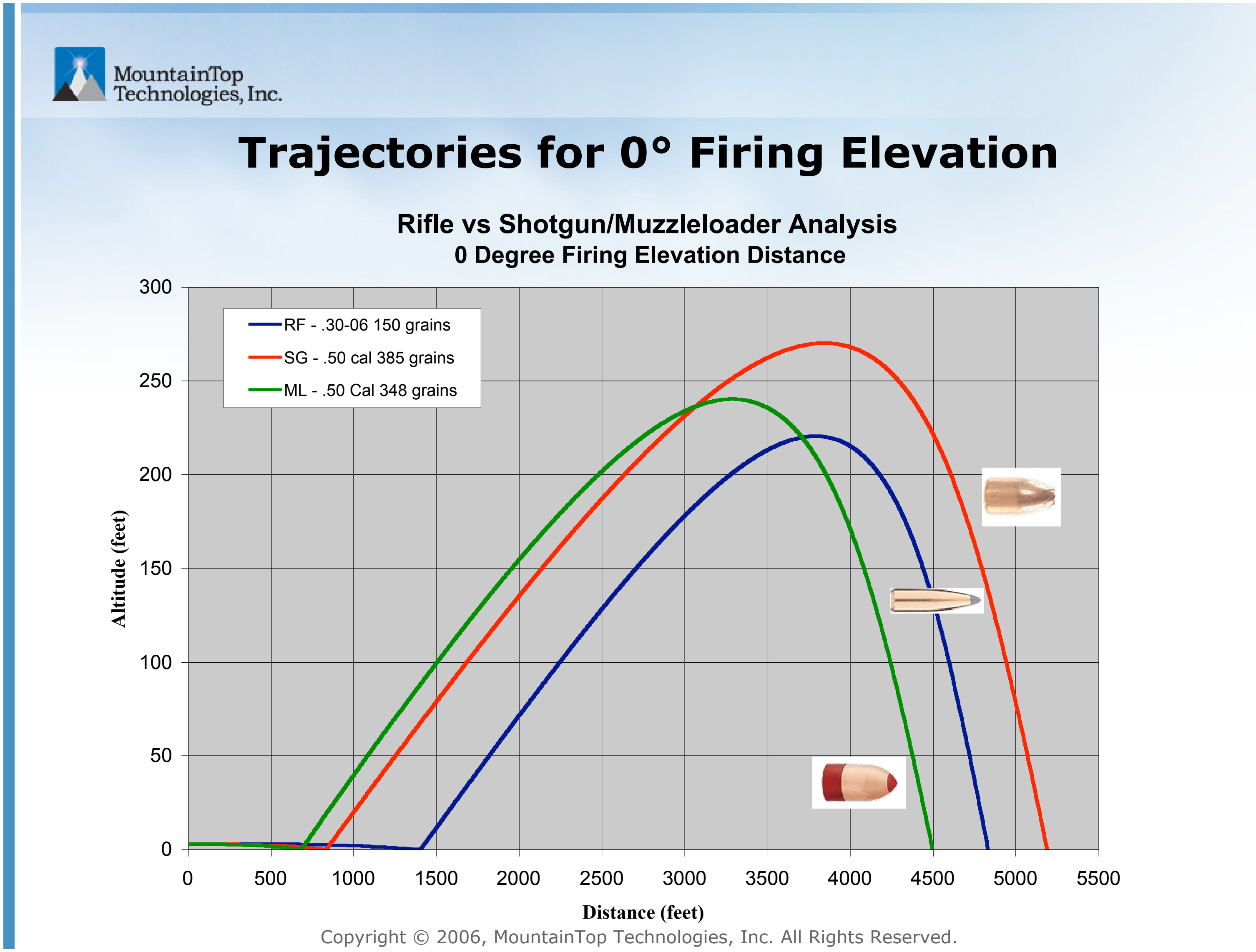

Figure 11: Trajectories for 0-degree firing elevation

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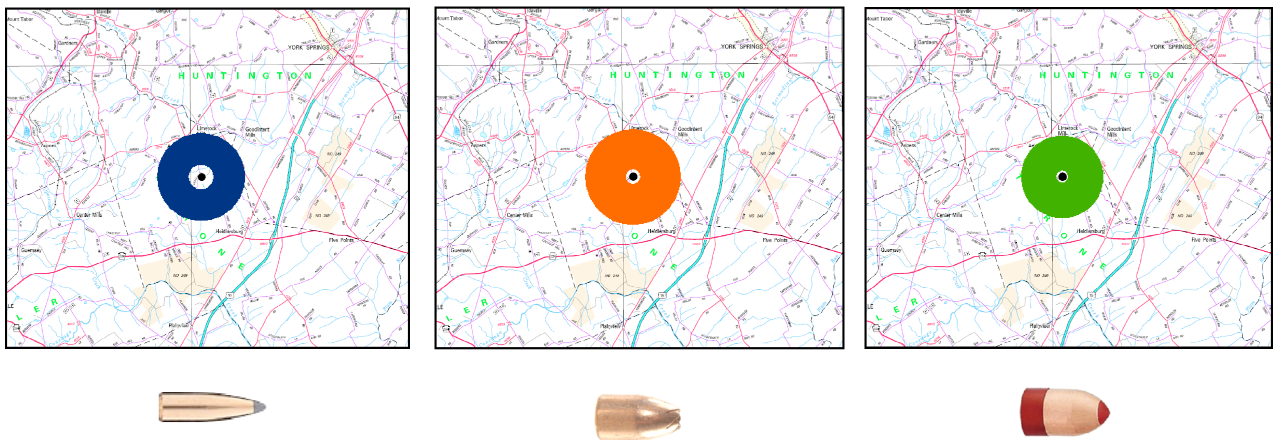
0º Elevation with Ricochet

Ammunition	Firing Elevation at ~0 degrees				
	Initial Impact Distance (ft)	Ricochet Distance (ft)	Difference Distance (ft)	% Less than Rifle	
Rifle (.30-06 150 grains)	1408	4835	3427	Initial	Ricochet
Shotgun (.50 cal 385 grains)	840	5205	4365	40%	-8%
Muzzleloader (.50 cal 348 grains)	686	4498	3812	51%	7%



Band Thickness is the Ricochet

Figure 12: 0-degree elevation with ricochet

5.7 Comparing Danger Areas

Like the PGC's1998 study, danger areas were computed using the distance the projectile travels for specific types of firearms under certain conditions. Comparing the danger areas associated with a 35-degree angle of elevation, the shotgun's danger area is approximately 56 percent of the danger area of the rifle, which supports the findings of the 1998 PGC study. Table 4 summarizes the statistics for the 35-degree firing elevation:

Table 4: Summary of Statistics for the 35-Degree Firing Angle

Ammunition	35 deg. Firing Elevation	
	Danger Area (Acres)	Percent of Rifle Danger Area
Rifle (.30-06 150 grain)	13987	100.0%
Shotgun (.50 cal 385 grain)	7768	55.5%
Muzzleloader (.50 cal 348 grain)	6100	43.6%

This study believes that hunter aiming errors of 10 degrees or less are more likely to occur and that the ricochets have a significant influence at angles of elevation less than 10 degrees. Considering the danger areas associated with large and moderate aiming errors, the shotgun and muzzleloader combinations still have a smaller danger area than the rifle. Tables 5 and 6 summarize these findings for a 10 and 5-degree firing elevation:

Table 5: Summary of Statistics for the 10-Degree Angle of Elevation

Ammunition	10 deg. Firing Elevation	
	Danger Area (Acres)	Percent of Rifle Danger Area
Rifle (.30-06 150 grain)	8266	100.0%
Shotgun (.50 cal 385 grain)	4746	57.4%
Muzzleloader (.50 cal 348 - grain)	3697	44.7%

Table 6: Summary of Statistics for the 5-Degree Angle of Elevation

Ammunition	5 deg. Firing Elevation	
	Danger Area (Acres)	Percent of Rifle Danger Area
Rifle (.30-06 150 grain)	5513	100.0%
Shotgun (.50 cal 385 grain)	3399	61.7%
Muzzleloader (.50 cal 348 grain)	2605	47.3%

At a firing angle of approximately 0-degrees elevation, Table 7 shows that the danger area for the shotgun is larger than the danger area of the rifle. In this case, the danger area of the shotgun is approximately 116 percent of the danger area of a rifle.

Table 7: Summary of Statistics for the 0-Degree Angle of Elevation

Ammunition	~0 deg. Firing Elevation	
	Danger Area (Acres)	Percent of Rifle Danger Area
Rifle (.30-06 150 grain)	1686	100.0%
Shotgun (.50 cal 385 grain)	1954	115.9%
Muzzleloader (.50 cal 348 grain)	1459	86.5%

Stated in a few words, when considering extreme, high, and moderate firing errors (35, 10 and 5 degrees firing elevations), shotguns and muzzleloaders are less risky than the centerfire rifle. When firing with no or a very small aiming error (approximately 0-degrees firing elevation), a shotgun proved to be riskier than a centerfire rifle. The muzzleloader was always less risky than both the rifle and shotgun. Eliminating or controlling the ricochet seems essential if the shotgun is to be used as an effective risk management option. If ricochets could be controlled, the shotgun and muzzleloader would be less risky in all cases.

6.0 CONCLUSION

Incident rates could not be standardized for a comparison of the risk of shotgun usage versus rifle usage when examining the PGC's incident data. Understanding this limitation, the data was useful in describing the geographic distribution of incidents and the spatial analysis shows significant clusters of incidents both inside and outside the Special Regulations Areas.

The 1998 PGC study utilized the maximum range to determine the danger area, which assumed abnormal behaviors and accidental acts. This study used an alternative method for developing danger areas both in technique and assumptions. The danger areas produced in this study are based on the concept of the probability of an aiming error and a subsequent ricochet. This approach produced a probable danger zone around the hunter and the risk was compared for the rifle-ammunition combinations by examining the resulting danger areas.

Contrary to the 1998 study, this study concludes that comparing risk using only the maximum range obtained at a 35-degree firing elevation and the corresponding danger area of the firearm-ammunition combination provides the policy maker an incomplete picture. When discharging the examined firearm-ammunition combinations with large (10 degrees) and moderate (5 degrees) aiming errors, the danger areas of the shotgun and muzzleloader are less than that of a rifle; hence, given this firing condition, the shotgun and muzzleloader are less risky than the rifle. However, shotguns firing modern saboted slugs have a larger danger area than the .30-06 rifle when the angle of elevation is approximately level (0 degrees); hence, given this firing condition, the shotgun is riskier than the rifle. In other words, the typical hunter discharging a 12 gauge shotgun fitted with a rifled barrel firing a .50-caliber saboted modern high velocity ammunition at a deer on level terrain is riskier than a hunter firing a .30-06 with a 150 grain expanding bullet at the same deer. The muzzleloader proved to have less risk in all firing conditions.

The explanation for the last case where the shotgun is more risky relates to how the .30-caliber projectile interacts with the impact media at shallow (low) angles and its aerodynamic characteristics after ricochet. The smaller cross sectional area of the .30-caliber projectile and its shape contributes to a higher loss of energy on impact and after ricochet the .30-caliber projectile tends to tumble in flight with a high drag. Test data confirm that the .50-caliber projectile's larger cross sectional area and its shape contribute to less energy loss on shallow angles of impact and after ricochet the projectile exhibits less drag which results in a greater total distance traveled.

It is recommended that the PGC address the public perception that a shotgun with modern high velocity ammunition is less risky than centerfire rifles in all circumstances. This has some urgency since legally mandated Special Regulations Areas have promoted the assumption that shotguns are always less risky than a rifle for hunting deer. Frangible, or reduced ricochet, projectiles, for hunting firearms should be investigated as an alternative to the mandatory use of shotguns or muzzleloaders and as a means of managing risk in Special Regulations Areas. While the suitability of these projectiles for hunting deer remains unknown, the nature of these projectiles to break apart on impact would increase safety.

7.0 SUGGESTIONS FOR FURTHER ACTION

7.1 Examine Other Projectile Types

The use of reduced ricochet (frangible) projectiles should be investigated as a means of reducing the risk of ricochets. Preliminary research reveals several manufacturers producing frangible projectiles. While the suitability of these projectiles for hunting deer remains unknown, the nature of these projectiles to break apart on impact would increase safety and help to make the mandatory use of shotguns a viable risk management option.

7.2 Enhance Hunter Education

Improve the education of the hunter to enhance awareness and reduce the risk of further incidents. It is recommended that the PGC begin a safety education program to address the perception that a shotgun with modern high velocity slugs is less risky than centerfire rifles in all circumstances. This has some urgency since it is likely that legally mandated Special Regulation Areas have promoted the assumption that shotguns and muzzleloaders are overall less risky than a rifle for hunting.

7.3 Continue to Document and Investigate Incidents

PGC staff should continue to collect data concerning errant projectiles. It is recommended that PGC staff provide coordinate locations for incidents and especially those involving vehicles or livestock. Investigations into the following areas would improve the understanding of the risk and improve public safety:

- The number of shots fired by a deer hunter with a particular firearm-ammunition combination.
- The number of hunters in specific areas.
- How hunters identify their backstops and the likelihood of extreme or moderate overshoots.
- Ricochet testing of specific sporting firearm-ammunition combinations.
- Collect forensic information concerning the direction of the projectile’s flight.

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APPENDIX A: HR-61

PRIOR PRINTER'S NO. 233 PRINTER'S NO. 1172

THE GENERAL ASSEMBLY OF PENNSYLVANIA

HOUSE RESOLUTION

No. 61 Session of 2005

INTRODUCED BY SEMMEL, B. SMITH, BROWNE, DALLY, HARHART AND REICHLEY, FEBRUARY 8, 2005

AS REPORTED FROM COMMITTEE ON GAME AND FISHERIES, HOUSE OF REPRESENTATIVES, AS AMENDED, MARCH 16, 2005

A RESOLUTION

Directing the Legislative Budget and Finance Committee to conduct a study on the use of rifles versus shotguns within this Commonwealth and recommend whether special regulation areas should be expanded.

WHEREAS, The Pennsylvania Game Commission was established in 1895 and was charged with the "duty to protect, propagate, manage and preserve the game or wildlife of the Commonwealth"; and

WHEREAS, The General Assembly, in the interest of public safety and proper game management, further charged the Pennsylvania Game Commission to prescribe the type of firearms, ammunition, bows and arrows usable in this Commonwealth to take game; and

WHEREAS, On June 1, 1979, the Pennsylvania Game Commission restricted firearm use in special regulation areas to the use of single projectile shotguns and muzzleloaders, enlarged the Southeast special regulation area and identified Allegheny County as a second special regulation area; and

WHEREAS, Suburban sprawl and population density growth are expanding within this Commonwealth, and sportswriters have suggested expanding existing special regulation areas and designating additional special regulation areas in response to this, especially in light of increasing tragic incidents during <-- recent hunting seasons; and

WHEREAS, For a number of years, many sportsmen have anticipated and supported the expansion of existing special regulation areas and the designation of additional special regulation areas; and <--

WHEREAS, When comparing population densities in Pennsylvania's 67 counties, it appears to be inconsistent that center fire rifles remain lawful in counties with population density in excess of some of the counties which are now included within a special regulation area designation; therefore be it

RESOLVED, That the House of Representatives direct the Legislative Budget and Finance Committee to conduct a study on the use of rifles versus shotguns within this Commonwealth and recommend whether special regulation areas should be expanded; and be it further

RESOLVED, That the Legislative Budget and Finance Committee contract with a risk assessment specialist to conduct the study in coordination with the Pennsylvania Game Commission; and be it further

RESOLVED, That the study shall include, but not be limited to, the following details:

(1) ballistics;

(2) projectile construction;

(3) projectile type;

(4) topography;

(5) land use;
(6) population density;
(7) hunter density; and
(8) structure density;

and be it further

RESOLVED, That the Legislative Budget and Finance Committee prepare both a written and an oral report, within 180 days of the adoption of this resolution, and present it to the Game and Fisheries Committee of the House of Representatives.

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APPENDIX B: Definitions

Accidental Discharge -- An unintentional firing of a gun, which is caused only by mechanical error.

Angle of Elevation -- The angle at the origin in a vertical plane from the line of sight to the line of elevation used to achieve the prescribed range to place the point of impact at the desired location.

Angle of Impact -- The angle at the point of impact between the line tangent to the fall of the projectile and a plane tangent to the surface the projectile will impact.

Barrel -- The metal tube through which the bullet or shot travels.

Backstop -- Any device constructed to stop or redirect fired projectiles. This is usually an earthen structure, placed between 16 and 20 feet in vertical height, built in accordance with NRA recommended standards.

Ballistic Coefficient -- A measure of bullet efficiency at overcoming air resistance during flight.

Buckshot -- A type of shotgun ammunition, which uses medium-sized to large-sized pellets. Buckshot comes in different sizes. Generally speaking, the larger the pellets, the fewer of them there are in each round of ammunition.

Bullet -- The solitary metal projectile, which is fired downrange. When shooters refer to the bullet, they mean only the projectile itself, not the complete package which holds the bullet before it is fired. The complete package, which includes the case, primer, powder, and bullet, is usually called a cartridge or a round.

Bullet Path -- The arc or trajectory of the bullet relative to line of sight.

Caliber -- The type and size of ammunition used by a given gun. It is usually the diameter of the bullet.

Cartridge -- The complete package, which makes up a single round of ammunition. It includes the case, primer, powder, and bullet.

Centerfire Rifle -- A rifle which utilizes ammunition in which the primer is located in a small cup in the bottom center of the case.

Danger Area -- The area around the hunter’s firing point that includes the intended projectile’s backstop and the impact point of any projectiles that pass over the backstop due to high angle shots (overshoots) or ricochets.

Drop -- The actual distance the bullet is pulled toward the earth's center relative to the line of sight.

Firearm -- A mechanism that throws projectiles using the energy produced through rapid, confined burning of a propellant.

Gauge -- The shotgun equivalent of caliber. Rather than being a direct measurement of bore size, gauge indicates how many lead spheres the same diameter as the gun's barrel would equal a pound.

Handgun -- A small firearm designed to be fired while held in one or both hands, rather than while braced against the shoulder.

Lead -- The metal from which bullets are traditionally made. They may also be made of steel, copper, or other materials.

Line of Sight -- A straight line out to infinity as represented by the firearm's sighting plane formed when the front and rear sights are aligned.

Line of Departure -- A line running down the center of the bore to infinity.

Muzzle -- The end of the barrel where the bullet comes out.

Muzzleloader -- A firearm design in which the ammunition and its propellant are loaded into the firearm from the front end. Sometimes called a black powder gun, after the type of propellant most commonly used. Some muzzleloaders are antiques, but there are many modern hunting firearms, which are loaded in this manner.

Overshoot -- A projectile (or bullet) that carries over, or beyond, a backstop. By definition, an overshoot projectile will not have struck any downrange object before the intended backstop or the backstop. Overshoots are distinctly different from ricochets.

Ricochet -- Projectiles (or bullets), which have struck a surface or object, and had their trajectory altered as a result. Ricochets may or may not clear the backstop and may result at the end of an overshoot.

Ricochet Distance (Range) -- The total distance a projectile achieves including the flight prior to striking a surface and the distance of one or more rebounds. A projectile that strikes short of its maximum ricochet range can skip on up to the maximum range of the firearm.

Rifle -- (1) A modern firearm designed to be fired from the shoulder, generally having a barrel more than 15 inches long. Its main characteristic is a rifled (knurled grooved) barrel that imparts a spin to a single projectile as it travels through the bore.

Rifling -- A continuous spiral groove cut along the inside surface of the barrel to improve the accuracy and range of the bullet by giving it a spin as it leaves the barrel.

Sabot -- A lightweight carrier in which a projectile of a smaller caliber is centered so as to permit firing the projectile within a larger-caliber weapon. The carrier fills the bore of the weapon from which the projectile is fired; it is normally discarded a short distance from the muzzle.

Sectional density -- The weight of a bullet in pounds to the square of its diameter in inches. Projectiles with higher sectional densities lose less energy in flight.

Shotgun -- (1) A firearm, designed to be fired from the shoulder, with a smoothbore barrel that fires shot shells possessing a varying number of round pellets. (2) Some barrels are designed to be used with rifled slugs and may be rifled.

Slug -- A single large projectile fired by a shotgun. It often has spiral grooves, called rifling, cut into the outer surface.

Target line -- A line parallel to the firing line along which targets are placed.

Trajectory --The path a projectile travels from the muzzle to the point of final impact.

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APPENDIX C: PGC Rifle/Shotgun Information Property Damage Report 1997 – 2003

Rifle / Shotgun Information

Property Damage Report
1997 – 2003

Commissioners requested in January 1998 for staff to begin collecting data on all known incidents of property damage caused as result of hunters accidentally damaging private property as a result of errant shots.

The stated intent was to collect data from a minimum of 200 shooting-related property damage instances… this being the minimum number required for a viable risk analysis whereby it might be determined whether shotgun restrictions do in fact reduce the risk of property damage or human injury.

Through June 30, 2004, Conservation Officers reported 359 known instances of property damage by gunfire, ranging from a low of 39 occurrences in 1999-2000 to a high of 68 in 2001-02. The seven-year average is 51 instances per year.

Twelve of Pennsylvania's 67 counties had more than 10 instances over the seven-year period. These were Adams (26), Allegheny (11), Berks (17), Bucks (17), Chester (17), Crawford (20), Erie (11), Indiana (14), Lancaster (15), Montgomery (23), Westmoreland (12) and York (17).

Adams	26	Chester	17	Fulton	2	McKean	5	Snyder	4
Allegheny	11	Clarion	3	Greene	5	Mercer	10	Somerset	10
Armstrong	2	Clearfield	2	Huntingdon	2	Mifflin	3	Sullivan	0
Beaver	0	Clinton	2	Indiana	14	Monroe	5	Susquehanna	2
Bedford	2	Columbia	1	Jefferson	3	Montgomery	23	Tioga	3
Berks	17	Crawford	20	Juniata	0	Montour	1	Union	3
Blair	0	Cumberland	4	Lackawanna	3	Northampton	5	Venango	4
Bradford	5	Dauphin	4	Lancaster	15	Northumberland	3	Warren	2
Bucks	17	Delaware	4	Lawrence	7	Perry	4	Washington	6
Butler	7	Elk	1	Lebanon	0	Philadelphia	0	Wayne	1
Cambria	3	Erie	11	Lehigh	2	Pike	0	Westmoreland	12
Cameron	0	Fayette	2	Luzerne	0	Potter	2	Wyoming	0
Carbon	2	Forest	0	Lycoming	7	Schuylkill	2	York	17
Centre	5	Franklin	3						

Of the 359 reported instances over the seven-year reporting period, 72 (20%) occurred in the 6 Special Regulation counties.

Of 265 total deer hunting incidents where the type firearm was determined, 67 (25%) were shotgun-related. This is nearly twice the ratio of shotgun hunters to rifle hunters during the deer season. In the 2002 Game Take Survey, we asked the question… “Do you use a shotgun for deer hunting?” Of 8,502 respondents, 7,403 (87.07%) responded “no” while 1,099 (12.93%) responded “yes”. While approximately one hunter in eight uses a shotgun, shotguns are the cause of property damage in one of every four deer-hunting incidents.

Of 311 incidents where the type firearm was determined (all species), 97 (31.2%) were shotgun-related and 214 (68.8%) were rifle-related. Another 37 incidents were caused by sporting arms other than centerfire rifle or shotgun, or were from unknown sources. A total of 14 instances occurred as result of muzzleloaders, 2 from handguns and 1 from an arrow.

It is interesting to note 256 of 359 (71.3%) instances occurred between the dates of November 20 and December 20 inclusive. The issue of hunting-related property damage by gunfire is primarily confined to the regular firearm deer season.

It would be a mistake to assume most instances of property damage occurs in areas where human population density is moderate to high. 134/359 (37.5%) instances occurred in areas inhabited by <100 people per square mile. 233/359 (65.3%) instances occurred in areas of <200 people per square mile, and 308/359 (86.3%) instances occurred in areas of < 300 people per square mile.

Population Density	# Incidents							
0 – 100	134	37.50%						
101-200	99		65.30%					
201-300	49			79%				
301-400	26				86.30%			
401-500	5					87.70%		
501-600	12						91%	
>600	32							100%

73.8% of known incidents (265/359) resulted in damage to an individual’s place of residence. This is not surprising in that a primary residence would surely be the most likely place where damage would become noticeable to the property owner.

Other than places of residence, damages included such items of personal property as barns and other outbuildings, business structures, an airplane, a backhoe, aboveground swimming pools, licensed vehicles, livestock, a boat and a garbage can.

It is important this information be placed into proper perspective, for while 359 instances of property damage is of concern, the ratio of instances to shots fired by hunters reflects a very safe picture.

Over the seven-year reporting period hunters harvested 3.125 million whitetails, an average of 446,000 per year. While it is not known how many total shots are fired during the deer seasons, for purpose of this thought I'll assume the figure is four shots fired for every deer harvested (includes all shots fired by all hunters… not just shots at deer ultimately harvested). This assumption of four shots per deer harvested would mean hunters fired 12.5 million shots over the seven-year period, resulting in 359 known instances of property damage for an occurrence rate of 1:34,818 (one occurrence per 34,818 shots fired).

While these figures and observations do not provide closure to the question of whether shotgun restrictions do in fact reduce risk of damage and/or injury, they do provide reason to question the oft-held assumption that shotguns pose less risk than do centerfire rifles.

Sufficient data now exists for the Commission to move forward with a professional risk assessment to finally answer the question.

MWSchmit/10/3/04

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APPENDIX D: Attributes of the Pennsylvania Game Commission Incident Data

Record No
Year
Regional Incident Number
First Name of Complainant
Last Name of Complainant Name
Street
City
County
Township
Zip Code
Telephone
Incident Date
Incident Setting
Type of Property Damaged
Describe Damage
Firearm Type
Firearm Caliber
Result of Hunting
Reporting Officer
Officers District Number
Reporting Date
Reporting Officer's Statement
Specie Hunted
Population Density

APPENDIX E: MTT Analysis of PGC Incidents, 1997-2005+[25]

Counties	Incident Year										Total
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	
ADAMS	7	2	0	1	3	4	3	0	3	0	23
ALLEGHENY	0	0	2	0	4	3	1	1	1	0	12
ARMSTRONG	1	0	0	0	1	0	0	0	0	0	2
BEAVER	0	0	0	0	0	0	0	0	1	0	1
BEDFORD	0	0	1	0	0	1	0	0	0	0	2
BERKS	2	1	3	1	0	1	5	3	3	1	20
BRADFORD	0	3	0	0	1	0	1	0	0	0	5
BUCKS	4	2	1	1	1	0	4	3	0	0	16
BUTLER	0	1	1	0	1	2	0	2	0	0	7
CAMBRIA	0	0	0	0	1	0	0	1	0	0	2
CARBON	0	0	0	0	0	0	2	0	0	0	2
CENTRE	0	0	0	1	1	2	0	1	0	0	5
CHESTER	2	0	4	2	2	2	3	0	3	0	18
CLARION	0	0	0	0	1	1	1	0	0	0	3
CLEARFIELD	0	0	0	1	0	0	0	0	0	0	1
CLINTON	0	0	0	1	0	0	0	0	0	0	1
COLUMBIA	0	0	0	0	1	0	0	0	0	0	1
CRAWFORD	1	4	4	0	5	0	4	1	1	0	20
CUMBERLAND	1	0	1	1	0	0	0	1	0	0	4
DAUPHIN	0	0	0	0	1	2	1	0	0	0	4
DELAWARE	1	0	0	0	1	1	0	0	0	0	3
ERIE	0	0	0	2	2	2	2	0	0	0	8
FAYETTE	0	0	1	0	0	0	1	1	1	0	4
FRANKLIN	1	0	0	1	0	0	0	1	0	0	3
FULTON	1	1	0	0	0	0	0	1	0	0	3
GREENE	2	0	1	1	0	1	0	1	0	0	6
HUNTINGDON	0	1	0	1	0	0	0	0	2	0	4
INDIANA	0	3	1	3	3	1	1	2	1	0	15
JEFFERSON	1	0	0	1	0	0	0	0	0	0	2
JUNIATA	0	0	0	0	0	0	0	1	0	0	1
LACKAWANNA	0	0	0	1	0	1	1	0	0	0	3
LANCASTER	1	1	1	0	1	4	4	3	0	0	15
LAWRENCE	0	1	0	2	1	0	0	0	0	0	4
LEHIGH	0	1	0	0	0	1	0	3	1	0	6
LUZERNE	0	0	0	0	0	0	0	2	0	0	2
LYCOMING	0	0	0	1	1	1	2	0	1	0	6
MCKEAN	0	1	1	2	0	0	1	0	0	0	5
MERCER	0	0	2	3	1	1	0	0	1	0	8
MIFFLIN	0	0	0	0	0	1	1	0	1	0	3
MONROE	0	2	0	1	0	1	0	1	0	0	5
MONTGOMERY	1	3	3	3	2	4	1	3	1	0	21
MONTOUR	0	0	0	0	0	1	0	0	0	0	1
NORTHAMPTON	2	0	0	0	2	0	0	2	3	0	9
NORTHUMBERLAND	1	0	0	1	1	0	0	0	0	0	3
PERRY	1	0	0	0	2	0	1	2	0	0	6
PIKE	0	0	0	0	0	0	0	1	0	0	1
POTTER	0	0	0	0	1	0	0	0	0	0	1
SCHUYLKILL	0	0	0	0	0	1	0	0	0	0	1
SNYDER	1	0	0	1	0	0	0	0	1	0	3
SOMERSET	0	1	1	0	2	2	4	1	0	0	11
SUSQUEHANNA	1	1	0	0	0	0	0	0	0	0	2
TIOGA	0	0	1	0	0	1	0	4	1	0	7
UNION	0	1	0	0	1	0	0	1	0	0	3
VENANGO	0	0	0	1	0	0	1	0	0	0	2
WARREN	0	0	1	0	1	0	0	1	0	0	3
WASHINGTON	1	0	0	1	1	2	0	2	1	0	8
WAYNE	0	0	0	0	1	0	0	0	1	0	2
WESTMORELAND	3	1	0	3	0	0	1	0	0	0	8
YORK	0	0	0	1	6	1	6	3	2	0	19
Total	36	31	30	39	53	45	52	49	30	1	366

[25] This table was compiled by MTT from data supplied by the PGC. Incidents not involving deer or thought to be duplicates of the same incident were not counted by MTT. See paragraph 4.1 for a discussion of the analysis.

APPENDIX F: Non-Address Matches by County

County	Frequency	Percent
ADAMS	1	1.9
ARMSTRONG	1	1.9
BERKS	1	1.9
BRADFORD	2	3.8
CENTRE	2	3.8
CLEARFIELD	1	1.9
CLINTON	1	1.9
CRAWFORD	1	1.9
ERIE	1	1.9
FULTON	1	1.9
GREENE	2	3.8
HUNTINGDON	4	7.5
INDIANA	3	5.7
JUNIATA	1	1.9
LAWRENCE	3	5.7
LUZERNE	1	1.9
LYCOMING	1	1.9
MCKEAN	2	3.8
MIFFLIN	1	1.9
MONROE	4	7.5
NORTHUMBERLAND	2	3.8
PIKE	1	1.9
SNYDER	1	1.9
SUSQUEHANNA	2	3.8
TIOGA	3	5.7
UNION	1	1.9
WARREN	1	1.9
WAYNE	2	3.8
WESTMORELAND	6	11.3
Total	53	100.0

APPENDIX G: Tabular Results of Hotspot Analysis

Clusters

CLUSTER ORDER	CLUSTER NUMBER	CLUSTER CENTER_X	CLUSTER CENTER_Y	AREA (SQ MILES)	INCIDENTS OR CLUSTERS WITHIN CLUSTER
1	1	2615065	354339	80.89	13
1	2	2135533	162798	61.60	10
1	3	2566895	364212	23.51	8
1	4	2131637	211611	83.68	6
1	5	1373238	468194	35.94	7
1	6	2645443	444767	17.97	7
1	7	1617462	284718	70.74	7
1	8	2422542	202989	44.09	7
1	9	2181012	221329	89.64	6
1	10	2173592	270322	48.93	5
1	11	2617857	521893	44.96	6
2	1	2611315	421303	754.32	4
2	2	2155443	216515	278.72	4

Projection: Pennsylvania State Plane, South

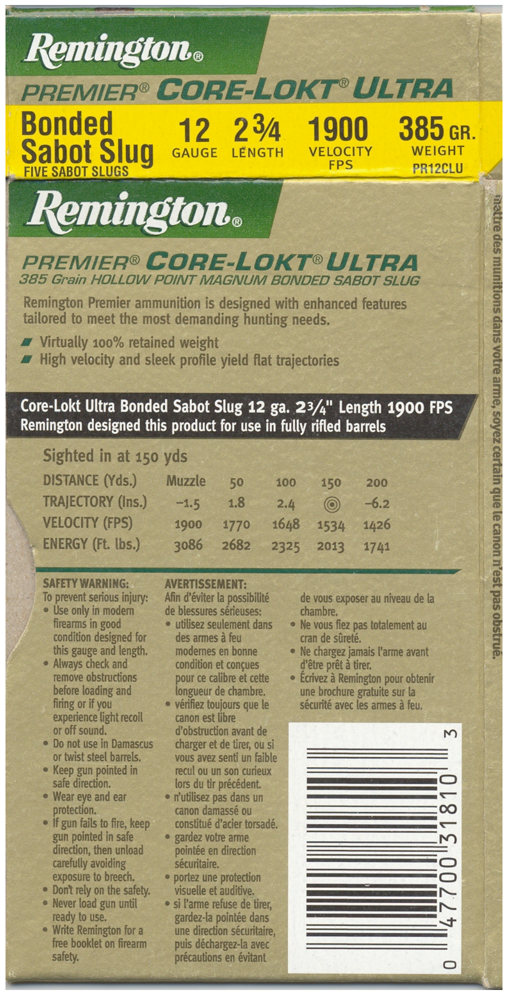
APPENDIX H: Ballistics of the Remington .30-06 Round

Velocity (ft/sec)

Cartridge Type	Bullet	Muzzle	100	200	300	400	500
Remington® Express®	125	3140	2780	2447	2138	1853	1595
Remington® Managed Recoil®	125	2660	2335	2034	1757	1509	1300
Premier® Scirocco™ Bonded	150	2910	2696	2492	2298	2111	1934
Premier® AccuTip™	150	2910	2686	2473	2270	2077	1893
Remington® Express®	150	2910	2617	2342	2083	1843	1622
Remington® Express®	150	2910	2656	2416	2189	1974	1773
Premier® Core-Lokt® Ultra	150	2910	2631	2368	2121	1889	1674
UMC®	150	2910	2617	2342			
Premier® AccuTip™	165	2800	2597	2403	2217	2039	1870
Remington® Express®	165	2800	2534	2283	2047	1825	1621
Premier® Core-Lokt® Ultra	168	2800	2546	2306	2079	1866	1668
Premier® AccuTip™	180	2725	2539	2360	2188	2024	1867
Premier® A-Frame	180	2700	2465	2243	2032	1833	1648
Premier® Scirocco™ Bonded	180	2700	2522	2351	2186	2028	1878
Premier® Core-Lokt® Ultra	180	2700	2480	2270	2070	1882	1704
Remington® Express®	180	2700	2348	2023	1727	1466	1251
Remington® Express®	180	2700	2469	2250	2042	1846	1663
Remington® Express®	180	2700	2485	2280	2084	1899	1725
Remington® Express®	220	2410	2130	1870	1632	1422	1246

SOURCE: Remington Online Ballistics, http://www.remington.com/Products/Ammunition/Ballistics/results/default.aspx?type=centerfire&cal=30

APPENDIX I: Ballistics of the Remington 12 Gauge Sabot Slug



SOURCE: Remington packaging

APPENDIX J: Ballistics Information for the .50-Caliber Powerbelt Bullet

POWERBELT BALLISTIC INFORMATION

28" Barrel with 100 grains of Pyrodex pellets

PowerBelt® Bullet	Velocity (FPS)						Kinetic Energy (Foot-Pounds)						Trajectory					
Distance (yards)	Muz.	50	100	150	200	250	Muz.	50	100	150	200	250	Muz.	50	100	150	200	250
.45 Cal. 175 gr. copper, AeroTip™, BC=.145	2161	1894	1654	1443	1264	1131	1815	1394	1063	809	621	497	-1.5	1.62	2.37	0	-6.44	-18.33
.45 Cal. 195 gr. copper, HP, BC=.152	2053	1783	1546	1340	1178	1069	1825	1377	1035	778	601	495	-1.5	1.97	2.77	0	-7.53	-21.21
.45 Cal. 195 gr. copper, AeroTip™, BC=.183	2053	1847	1658	1489	1337	1210	1825	1477	1191	960	774	634	-1.5	1.69	2.36	0	-6.21	-17.23
.45 Cal. 225 gr. copper, HP, BC=.176	2020	1809	1617	1445	1294	1173	2039	1635	1307	1043	837	688	-1.5	1.82	2.54	0	-6.58	-18.27
.45 Cal. 225 gr. copper, AeroTip™, BC=.211	2020	1843	1678	1528	1392	1271	2039	1697	1407	1167	968	807	-1.5	1.69	2.34	0	-5.9	-16.31
.45 Cal. 275 gr. copper, HP, BC=.215	1770	1614	1473	1344	1233	1145	1914	1591	1325	1103	929	801	-1.5	2.47	3.19	0	-7.91	-21.4
.45 Cal. 275 gr. copper, AeroTip™, BC=.258	1770	1639	1518	1406	1305	1216	1914	1641	1407	1207	1040	903	-1.5	2.36	3.02	0	-7.16	-19.56
.50 Cal. 223 gr. copper, AeroTip™, BC=.142	1861	1619	1409	1234	1109	1023	1715	1298	983	754	609	518	-1.5	2.58	3.41	0	-9.02	-24.83
.50 Cal. 245 gr. copper, HP, BC=.140	1823	1583	1375	1205	1088	1007	1808	1364	1029	790	644	552	-1.5	2.77	3.65	0	-9.6	-25.96
.50 Cal. 245 gr. copper, AeroTip™, BC=.161	1823	1612	1426	1266	1143	1057	1808	1414	1107	872	711	608	-1.5	2.57	3.36	0	-8.77	-23.9
.50 Cal. 295 gr. copper, HP, BC=.168	1670	1484	1321	1188	1093	1022	1827	1443	1143	925	783	684	-1.5	3.2	4.05	0	-10	-27.1
.50 Cal. 295 gr. copper, AeroTip™, BC=.186	1670	1501	1350	1223	1126	1054	1827	1476	1194	980	831	728	-1.5	3.06	3.83	0	-9.57	-25.73
.50 Cal. 348 gr. copper, HP, BC=.198	1565	1416	1285	1177	1097	1035	1893	1550	1276	1071	930	828	-1.5	3.57	4.4	0	-10.45	-27.87
.50 Cal. 348 gr. copper, AeroTip™, BC=.220	1565	1430	1309	1206	1127	1064	1893	1581	1324	1124	982	875	-1.5	3.45	4.22	0	-9.82	-26.76
.50 Cal. 405 gr. copper, HP, BC=.231	1435	1318	1218	1139	1077	1027	1852	1563	1334	1167	1043	949	-1.5	4.19	4.93	0	-11.5	-29.9
.50 Cal. 405 gr. copper, AeroTip™, BC=.257	1435	1329	1237	1161	1101	1051	1852	1589	1376	1212	1090	994	-1.5	4.07	4.79	0	-10.92	-29.14
.50 Cal. 444 gr. copper, HP, BC=.253	1330	1236	1159	1098	1048	1006	1744	1507	1325	1189	1083	998	-1.5	4.86	5.61	0	-12.7	-33.1

28" Barrel with 150 grains of Pyrodex pellets

PowerBelt® Bullet	Velocity (FPS)						Kinetic Energy (Foot-Pounds)						Trajectory					
Distance (yards)	Muz.	50	100	150	200	250	Muz.	50	100	150	200	250	Muz.	50	100	150	200	250
.45 Cal. 175 gr. copper, AeroTip™, BC=.145	2469	2176	1908	1666	1454	1272	2369	1840	1415	1079	822	629	-1.5	0.98	1.65	0	-4.71	-13.57
.45 Cal. 195 gr. copper, HP, BC=.152	2362	2064	1794	1555	1348	1183	2416	1845	1394	1047	787	606	-1.5	1.21	1.92	0	-5.44	-15.76
.45 Cal. 195 gr. copper, AeroTip™, BC=.183	2362	2135	1923	1728	1551	1392	2416	1974	1602	1293	1042	839	-1.5	1.01	1.63	0	-4.49	-12.53
.45 Cal. 225 gr. copper, HP, BC=.176	2248	2020	1809	1617	1445	1294	2525	2039	1635	1307	1043	837	-1.5	1.26	1.92	0	-5.18	-14.43
.45 Cal. 225 gr. copper, AeroTip™, BC=.211	2248	2057	1877	1710	1557	1418	2525	2114	1761	1461	1211	1005	-1.5	1.15	1.77	0	-4.67	-12.81
.45 Cal. 275 gr. copper, HP, BC=.215	2111	1931	1763	1608	1467	1339	2722	2277	1898	1579	1314	1095	-1.5	1.44	2.09	0	-5.33	-14.56
.45 Cal. 275 gr. copper, AeroTip™, BC=.258	2111	1960	1818	1684	1560	1445	2722	2346	2019	1732	1486	1275	-1.5	1.33	1.95	0	-4.92	-13.31
.50 Cal. 223 gr. copper, AeroTip™, BC=.142	2321	2035	1774	1544	1344	1185	2668	2051	1559	1181	895	696	-1.5	1.27	1.97	0	-5.54	-15.85
.50 Cal. 245 gr. copper, HP, BC=.140	2268	1982	1724	1497	1302	1153	2799	2138	1617	1219	922	723	-1.5	1.4	2.13	0	-5.9	-17.01
.50 Cal. 245 gr. copper, AeroTip™, BC=.161	2268	2018	1789	1582	1399	1244	2799	2216	1742	1362	1065	842	-1.5	1.28	1.97	0	-5.37	-15.1
.50 Cal. 295 gr. copper, HP, BC=.168	1980	1762	1567	1393	1245	1133	2569	2034	1609	1271	1016	841	-1.5	1.98	2.72	0	-7.1	-19.64
.50 Cal. 295 gr. copper, AeroTip™, BC=.186	1980	1782	1603	1441	1298	1182	2569	2081	1684	1361	1104	915	-1.5	1.89	2.61	0	-6.66	-18.31
.50 Cal. 348 gr. copper, HP, BC=.198	1873	1695	1534	1389	1262	1160	2712	2221	1819	1491	1231	1040	-1.5	2.17	2.85	0	-7.25	-19.88
.50 Cal. 348 gr. copper, AeroTip™, BC=.220	1873	1712	1565	1431	1309	1207	2712	2265	1893	1583	1324	1126	-1.5	2.09	2.76	0	-6.98	-18.71

SOURCE: POWERBELT Bullet packaging