USFS, PACIFIC SOUTHWEST REGION 5, SIERRA NATIONAL FOREST

Evaluation of Human Factors/Leadership Training Effectiveness and Analysis of Prescriptively Implemented Training Approaches

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Preface

Currently, I am a second year District Fuels Management Technician on the Sierra National Forest in Region 5. I have been with the Forest Service since 2002. I started my career with the Groveland Hotshot crew on the Stanislaus National Forest, located in the central Sierra Nevada range of California. My initial intent, for my job with the Forest Service, was to support my college efforts at California State University, Chico, with my final goal to one day become a teacher. I became a permanent employee with the Hotshots in 2004 and the following year I graduated with a bachelor's degree in Liberal Studies with a minor in Manufacturing Technology, however I decided that my career path would be with the Forest Service. In 2006, while I was still with the Hotshot crew, I was selected to work as a detailed smokejumper in McCall, Idaho, this was the most demanding and exciting experience of my Forest Service career. In 2007, I promoted to the squad leader position back on the Groveland Hotshot crew where I enjoyed my time in this position. In 2008, I transferred to the Sierra National Forest in an effort to move closer to my family and home and I have been here since.

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Executive Summary

By investing in Human Factors/Leadership (HF/L) training the wildland fire service has attempted to develop error resilience within the wildland fire culture. The expectation of this training is that it would produce a positive culture change resulting in an incremental reduction in the likelihood of entrapment and or fatalities. Through statistical sampling and by using regression modeling techniques, this study attempts to determine the relationship, strength and significance of HF/L training contributions at reducing the probability of entrapments since its implementation in 2000. This study compares entrapment rate probabilities 6 years pre HF/L training implementation and 10 years post HF/L training implementation. HF/L training was considered effective if results showed (to a significance level of $\alpha \leq .05$) HF/L training is related to a decrease greater than or equal to 20 percent in the probability of entrapment per 1,000 person-hours exposed during the years of 2000-2009 as compared to the years 1994-1999. The initial intent of the study was structured to compare 10 years pre HF/L training to 10 years post HF/L training. Preliminary assessments found information from the National Situation Report Archive ranging from 1990-1993 unusable for this study as a result of differing formats.

Currently, entrapments make up 65 percent of on the ground fire line caused fatalities and for this reason entrapments were the focus of this study. Whenever mitigation strategies are applied to an identified problem it needs to be ensured that an acceptable monitoring/evaluation program accompanies it to measure the effectiveness and efficiency of the effort. The advantage to strategically and systematically monitoring/evaluating trends related to accidents will allow for adjustment and focused mitigation efforts.

Results from this study's regression modeling show that national entrapment probability rates have decreased by 80 percent during the training era and HF/L training is significantly related to this (p-value 0.000794). Federal entrapment probabilities have decreased by 73 percent during the training era, similarly, HF/L training is also significantly related to this decrease (p-value 0.0287). When comparing entrapment rates 6 years pre HF/L training, to the 10 years post HF/L training, results support the alternative hypothesis (to a significance level of $\alpha \leq .05$) that Human Factors/Leadership training, since implemented in 2000, has been effective in reducing the probability of fatal and non-fatal entrapments among wildland firefighters by ≥ 20 percent. Results related to the relationship strength and significant of HF/L contributions in reducing entrapment rates were identified through residual plotting and show strong relationships between entrapment rate reduction and the "ramping up" of HF/L training during the most recent 10 years of this study.

The analysis and evaluation technique that this study presents is intended as a preliminary method or tool to evaluate the effects of HF/L training. A more comprehensive evaluation over a longer study period needs to be made in an attempt to account for all the factors involved.

Introduction

Studies done by the Federal Aviation Administration's (FAA) Human Factors Division have noted that humans, by their very nature, make mistakes; therefore, it should come as no surprise that human error has been implicated in a variety of occupational accidents, including 70 to 80 percent of those in civil and military aviation (O'Hare, Wiggins, Batt, & Morrison, 1994; Yacavone, 1993). A similar study done by U.S. Department of Transportation's (DOT) National Highway Traffic Safety Administration (NHTSA) (2008) revealed that 85 percent of the nations motor vehicle accidents were a result of human performance issues such as recognition errors (41%), decision errors (34%) and performance errors (10%). Comparable studies done by nuclear power facilities, medical professions and the US Military provide similar trends that hold arguably true for nearly all other high-risk environment occupations.

The National Wildfire Coordinating Group (NWCG), which is represented by five federal agencies: The US Forest Service (USFS), Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), National Park Service (NPS) and Bureau of Indian Affairs (BIA), initiated the development of Human Factors/ Leadership (HF/L) training following the events of the 1994 South Canyon Fire. This fire killed 14 firefighters during on the ground suppression operations and following a number of investigations and incident reviews, human error and the absence of leadership was noted as major causal factors leading to the outcome of the disastrous event (Putnam *et. al.* 1996). These events initiated an outcry to develop a new skill set for firefighters relating to the human dynamics of firefighting. Spearheaded by the NWCG's newly formed Leadership sub-committee, this skill set expansion was embodied in the development of Wildland Firefighter HF/L Training, otherwise known as "L" series courses. Six "L" series courses have been developed to date by the NWCG and are currently delivered to federal wildland firefighters on a promotional based approach, and to other agencies on an as needed basis. Human Factors, related to firefighting, are the direct or indirect causal factors associated with human error. These factors range from skill based errors, perceptual errors, decision errors, effects from organizational influence and hazardous attitudes or un-recognized conditions that contribute to accident causation (NWCG, Safety and Health Working Team (SHWT) 2000).

By investing in HF/L training the wildland fire service has attempted to develop error resilience within the wildland fire culture. This training was expected to promote an outcome that would create positive culture change while effectively producing an incremental reduction in the likelihood of entrapment and or fatalities. As previously stated, evaluations conducted in comparable fields of study show that on average 70 to 85 percent of the causes associated with accidents are related to human factors. If the same holds true for fireline accidents, it is expected that since HF/L training has been implemented, a reduction in burnovers and entrapments has occurred.

The difficulty in assessing the effectiveness of this intervening strategy is the ability to evaluate how effective HF/L training has been in the form of quantifiable results. To date, however, the inability to discern a systematic and formalized method to evaluate the utility and theoretical similarities of human factors trends within the wildland fire service leads us to question how much of an impact HF/L training has actually made on fatal and non-fatal entrapment reduction. In order to be objective, strategic and quantifiable methods must be developed to evaluate the success or deficiencies of the training efforts. Furthermore, an examination of the strategic placement of these training courses, based off of information located in the current post accident database, may reflect the most logical and efficient method of HF/L training deployment. Having been based on empirical data, the advantage to strategically and systematically evaluating trends related to accidents will allow for adjustment and prescriptive placement of critical training based on quantifiable analysis. In essence, it is imperative to first assess if there has been a reduction in entrapments since HF/L training has been implemented to the wildland fire service, then, to assess the efficiency in which the courses are being deployed.

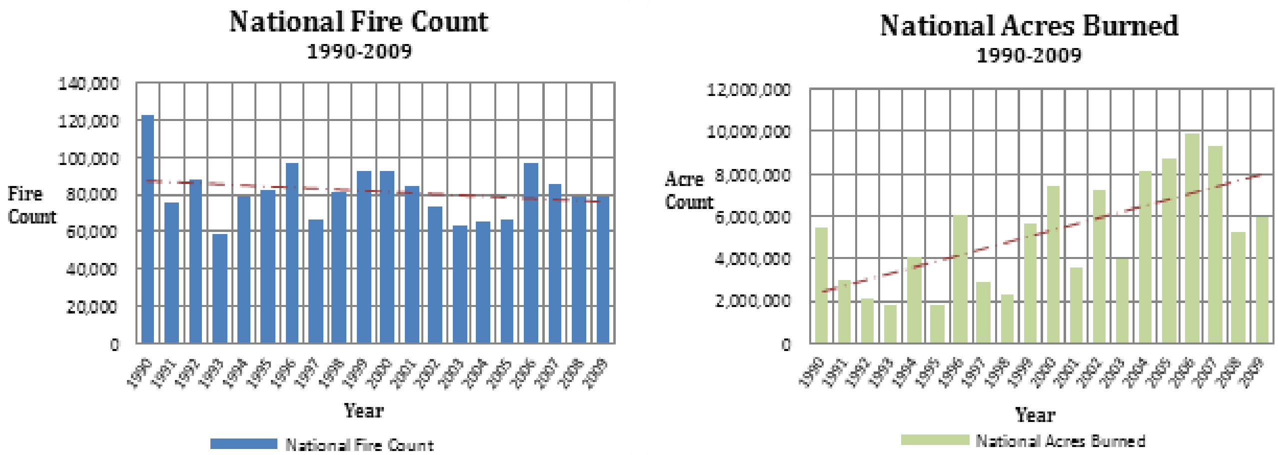
The purpose of this project is to test the hypothesis (to a significance level of $\alpha \leq .05$) that Human Factors/Leadership training, since implementation in 2000, has been effective in reducing the probability of fatal and non-fatal entrapments among wildland firefighters by 20 percent or greater. By evaluating rates of entrapments per person-hours exposed on the fireline we may be able to assess whether or not, and to what extent, these training strategies are proving effective. In addition, as a supplemental point of interest, this project will analyze the point in a firefighter's career that these six training courses are typically being deployed and if the current deployment approach is the most efficient from a statistical risk-based standpoint. By reviewing the wildland fire service post-accident database we may be able to prescriptively place error reducing interventions in the most logical and efficient manner.

Background and Significance

Human factors, as defined by the Federal Aviation Administration (FAA) System Safety Handbook (2000), is a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to systems, procedures, jobs, environments, training, staffing and personnel management to produce safe comfortable and effective human performance. The benefit of human factors is that it enhances the probability of increased performance, safety and productivity. Human factors are a component of the total systems performance; however, the FAA recognizes that it is a component that encompasses the largest percentage of total system failures. By increasing the probability that the operator can perform the tasks effectively in the appropriate environment, the total system performance and safety will increase significantly.

The wildland fire workforce regularly faces a work environment filled with adversity and uncertainty. A work environment that is as dynamic as a section of “hot line” requires specialty training that may assist firefighters to better gauge situations and personal capabilities. Ideally this training would eliminate or, more realistically, minimizing fire line fatalities. Motivated by the inherent danger, complexities and dynamics of the job, training policies and techniques are continuously evolving within the wildland fire service as more is learned about fire and the science that helps predict estimated outcomes. In recent years the perspective is that more complex decisions and tactics are being shouldered by fire line leaders due to the increasing complexities of wildland firefighting. These complexities have been largely attributed to urban interface, politics and larger fire sizes associated with increased fuel loading and dryer climactic conditions, see Figure 1 (Keeley *et. al.* 2008, TriData Report 1996). These complexities, which have become more prevalent, elevate the potential for decision, recognition and performance issues. The continual development and implementation of training has played a vital role in safety awareness and progression of the current wildland fire culture (DOI/USDA Report to Congress, Wildland Firefighter Safety 2010). Although policy changes and scientific research continues to evolve understanding and aspects of fire behavior and risk analysis, there is a human element that undoubtedly dominates the ability to use this information effectively. The emphasis that is placed on continuously refining this training has the ability to provide immense benefits in terms of fireline safety and entrapment avoidance.

FIGURE 1. Comparison of national fire count and acres burned statistics for the years of 1990-2009.



Since variables associated with complexities, as earlier stated, are considered a major contributor to potential exposure, the variables related to increased exposure will be addressed as this study's primary variables of interest.

The NWCG Glossary of Wildland Fire Terminology (2011) defines an entrapment and burnover as the following:

> ***Entrapment-*** "A situation where personnel are unexpectedly caught in a fire behavior related, life-threatening position where planned escape routes and safety zones are absent, inadequate, or have been compromised. An entrapment may or may not include deployment of a fire shelter for its intended purpose. These situations may or may not result in injury (or death). They include "near misses".
>
> ***Burnover-*** "An event in which a fire moves through a location or overtakes personnel or equipment where there is no opportunity to utilize escape routes and safety zones, often resulting in personal injury or equipment damage".

Entrapment, for the sake of simplicity, will be the term used throughout this paper to describe the above two events. This study is concerned with both events equally and because an entrapment is what occurs in either case; it will be used as the primary descriptor for the two events.

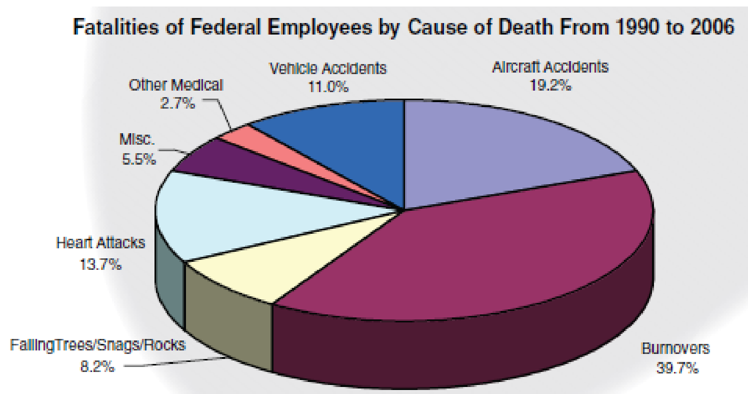
After The South Canyon Fire a major shift in the wildland firefighting culture began to take place focusing on the "human element" (Jim Cook, personal communication, May, 2011). Fire managers realized that the human condition played a vital role in a firefighter's ability to obtain increased awareness and decision making accuracy during adverse work conditions (Putnam *et al.* 1996). There was a need to improve training beyond fire science research and an undertaking was made to address the human element behind firefighting. A study done by an Army Research

Laboratory (1997) has realized substantial benefits in human error reduction by implementing Human Factors Integration Programs within particular systems of concern. This same approach of "human focused training" is what the NWCG felt was needed for the wildland fire workforce. By investing in HF/L training, the wildland fire service has attempted to develop error resilience within the wildland fire culture, effectively leading to an expected outcome that would produce an incremental reduction in the likelihood of entrapment and or fatalities (Larry Sutton, personal communication, May, 2011).

Comparable studies show that 70 to 85 percent of accidents in high risk environments can be attributed to human performance issues. However, it needs to be noted that many of the studies that have taken place, in regards to assessing accident causing conditions from the DOT (2008), FAA or US Navy/Marines (1977-1992) consider interaction between mechanical and human factors associated with accident causation, knowing this, a small portion of the overall accident probability will always be dedicated to broken parts, mechanical failures or malfunctions associated with automobiles, aircraft or machinery. Since on the ground wildland firefighting activities are almost exclusively human driven and lacks the mechanical failure aspect, it could be argued that the rate of accidents in the wildland fire service, attributed to human error, would be greater than the 70 to 85 percent mean and as a result a critical concern. It therefore appears, that intervening strategies aimed at reducing the occurrence and consequences of the human factor has potential to make a substantial impact on entrapment reduction. For this study, the focus will be on the rate change of fatal and non-fatal entrapments since intervening strategies have been implemented. This approach of measuring pre and post conditions is very common in medical studies where the response variable, probability "Y" of catching a disease (or dying), is based on whether the patient receives the explanatory variable(s) of treatment "X" (Bob Loveless, personal communication, May, 2011).

The Chair of the NWCG Leadership sub-committee is uncertain about whether the implementation of HF/L training, since inception, has been effective in terms of reducing the probability of fatal and non-fatal entrapments on wildland fires. According to the NWCG's Wildland Firefighter Fatalities in the United States Report (2007), 40 percent of the fatalities suffered by federal wildland firefighters between the years of 1990-2006 were from entrapments. Figure 2 shows the breakdown of federal fatalities during wildland fire activities, 1990-2006. This constitutes a larger percentage when looking at the causes of death primarily associated with on the ground suppression functions. If vehicle and aircraft accidents are omitted, then the percentage of burnovers is increased to 65 percent of the cause of death. For this reason, it seems imperative to address entrapments and their causal factors as a substantial and critical concern. Additionally, there is uncertainty about whether the current training distribution method is the most efficient in terms of providing critical training tools at the most logically efficient career point. Paraphrased, the Economic Glossary (2011) defines efficiency as the state of resource allocation that exists when the highest level of satisfaction is achieved from the available resources. According to the TriData Report Phase III* (1998), goal #64, the implementation approach for training is to develop a needs-based strategy for training across agencies (i.e., matching training availability to the quality and quantity of training needed). An economic approach would be useful in terms of maximizing the use of resource efforts (training) so the benefits obtained from efforts are realized to their full potential.

FIGURE 2. Causes of death percentages for 73 Federal Employees who died during wildland fire operations 1990-2006.



Cause	Total Personnel
Burnovers	29
Aircraft Accidents	14
Vehicle Accidents	8
Heart Attacks	10
4 suffered during pack test. Unrelated to fire operations	
Falling Trees/Snags/Rocks	6
Misc.	2
Other Medical	1
Total:	**73**

The current training distribution method of HF/L training, since inception, has been based on a logical promotional approach, meaning that, courses are made available to firefighters prior to their ascent to the next leadership position or qualification rank. The intent is to match training concepts to experience levels. The timing for the training is critical because the curriculum is designed so the training tools provided do not surpass the experience and skill of an advancing firefighter. As the firefighter advances, the level, complexities and concepts provided in the curriculum advances as well. As a secondary point of interest an assessment of HF/L training timelines will be performed within this study to identify actual training regiments.

***TriData Report**: *Wildland Firefighter Safety Awareness Study-This was a landmark safety study for the interagency wildland fire community that helped shape fire management direction during the past decade. TriData studies evolved from the 1994 South Canyon Fire fatalities and several of the NWCG Safety and Health Working Team (SHWT) projects and initiatives came out of this study as did the formation of the Wildland Fire Lessons Learned Center (LLC).*

The implementation of the HF/L training program has taken several years to deliver, and incorporate into the wildland fire culture. It should be mentioned that the HF/L program could not have been fully effective immediately and that we would have expected the effect of the program to phase in over a number of years following the implementation in 2000. Training programs need a significant amount of time between the program implementation and evaluations of effectiveness. There is some uncertainty as to if this study is premature on its attempt to evaluate successes of the HF/L training program. However, after 16 years of development and 12 years since HF/L training was implemented (2000), it is uncertain how effective the efforts have been thus far and whether the current approach is the most effective and efficient method of course implementation.

An efficiently implemented HF/L training program could be thought of as one that is providing training on a ***prescriptively based approach*** prior to as well as during the career phases when probabilities of risk are elevated. Studies done by R. Duffy and J. Saull on Risk Profiles for Nuclear Power (April 2004. 1 p.) state that, "We need to quantify the probability of human error for the system as an integral contribution within the overall system failure, as it is generally not separable or predictable for *actual* events. We also need to provide a means to manage and effectively reduce the failure (error) rate".

HF/L training is just one of the actions conducted within the wildland fire community that affects the occurrence of entrapment. The entire progression of entrapment reduction takes place within a larger context of culture and policy changes, prioritization of land management practices and situational awareness. Through dialog with numerous Subject Matter Expert (SME's), which are defined by Webster's Dictionary (2011) as, "An individual recognized by his or her peers as an authority on a specific topic", this study acknowledged five additional primary variables that have potentially made an impact on entrapment reduction. For this study SME's consisted of; Superintendants, Captains, Fire Management Officers, Battalion Chiefs, Regional Fire Staff and NWCG/NIFC Specialists. Other variables were identified through discussion in an effort to rationalize and identify additional contributors to entrapment reduction; however, this study will briefly address the five that according to SME's had the largest perceived contribution according to their professional opinion. The identified variables to HF/L training are as follows:

1) The sustained departure from full perimeter control tactics on wildland fires- *There is a growing number of fires that are not aggressively suppressed due to the natural resource benefit provided to a particular landscape. These fires often times require a reduced level of tactical engagement and reduced staffing.* ***Perceived benefit to entrapment reduction***- *Exposure and risk is minimized on these fires because of less aggressive tactics.*

2) Assignment Turndown Protocol- *An accepted method of declining a task or assignment from a supervisor.* ***Perceived benefit to entrapment reduction***- *Firefighters are empowered to make safer decisions without fear of reprimand, more hazardous assignments are being avoided.*

3) Higher level of oversight in regards to granting qualifications, training course development and distribution- *The development of a standardized procedural method to granting qualifications and training standards which encompasses a checks and balance system.* ***Perceived benefit to entrapment reduction***- *The likelihood of firefighters being placed into positions above their ability is reduced.*

4) Culture changes in the Wildland Fire Service- *The overall perspective that the wildland fire service has improved its safety awareness, technical job skills, leadership and accountability.* ***Perceived benefit to entrapment reduction***- *Culture change has created a more efficient safety conscious wildland fire workforce.*

5) Faster more accurate weather forecasts- *Through technology and concise processes, more accurate fire effecting weather forecasts are being relayed to on the ground fire resources in a timely manner.* ***Perceived benefit to entrapment reduction***- *Safer and more efficient fireline decisions are being made because they are being based off of current and expected weather conditions.*

Upon review of the above mentioned variables an observation was made that four of the five SME identified variables needed a human factor contribution to function and that some were more dependent on human factors than others. A matter then arises to the fact that the question specifically asked to identify other variables aside from human factors. The difficulty in doing so may suggest that human factors mitigations play an even larger role within the wildland fire culture and are implemented instinctively even when it isn't the primary focus. Additionally, the inability to quantify or place value on these identified variables made them unusable within the structure of this study.

A reduction in both fatal and non-fatal entrapments between the years of 2000 through 2009 would raise several questions in regards to what management efforts implemented during the same time period has had the greatest impact. There are continual efforts being made, aside from specific HF/L contributions, which are directly or indirectly related to a reduction in entrapment occurrence. Additional contributors to entrapment reduction may or may not have quantifiable but rather qualitative data to prove its case, but none the less need to be considered variables. HF/L training represents, in a larger context, the "culture shift" in wildland firefighting and there is no question that this culture shift has HF/L training as its flagship (Bob Loveless, personal communication, February, 2011)

The difficulty in validating HF/L effectiveness is the indeterminate nature of the question at hand as well as the imperfect state of the available information needed to make a valid judgment. Even with trends identified, it is difficult to predict or correct human nature. Clearly it is impossible to predict exactly when and where an accident may occur and under what circumstances, but through statistical analysis and high performing databases we can attempt to make a discovery of successes or deficiencies in intervention strategies in addition to high-risk periods and trends. In order to target optimal placement of intervening strategies (HF/L training), the discovery of high-risk periods or conditions needing attention during a typical firefighter's career can provide a starting point for a probabilistic and prescriptive based approach for HF/L implementation. It must be stressed that a reliable database system along with systematic assessments of trends would be crucial to the success of this methodology.

Among the perceived benefits to both the agencies and firefighting community, this approach has the potential to create a ***prescriptive method*** of positioning this critical training, supplemental to the current approach. Since comparable studies show that human error often times accounts for 70-85 percent of all accidents, and HF/L training is indirectly targeted to reduce these errors, optimal implementation directly before or during need or high-risk periods would seem to be the most effective and efficient method of supplemental training distribution in terms entrapment reduction.

Scope

This study is concerned with identifying a rate change in the probability of entrapments among the US wildland fire service per 1,000 person-hours exposed on the fireline per year. Analysis conducted between the years of 1994-2009 allows for comparisons six years pre- and ten years post-HF/L training deployment (HF/L was deployed in 1999-2000). Without quantifiable data on the rate changes of entrapments since intervening strategies were implemented, decision makers will be unable to continuously validate the effectiveness of training efforts in terms of entrapment reduction.

As a supplemental point of interest this study is concerned with the average positioning of the six HF/L courses during a wildland firefighter's career. A discovery of when these six HF/L courses are received by firefighters will allow for an assessment of how efficient the current system is at providing an approach for training that is needs-based, matching training availability to the quality and quantity of training needed.

The purpose of this analysis is to provide statistical information for the decision maker to use in continuously assessing the effectiveness and efficiency of the HF/L training program. The results obtained from this study reflect only a portion of the essential information that would be needed to generate an informed conclusion. This study should be considered a tool that may generate insight in an effort to support decision making. Effectiveness and relationships between intervening strategies and statistics are the primary focus of this study.

Decision Maker's Problem Statement

The Chair of the NWCG Leadership Sub-committee is uncertain about whether HF/L training has been effective in terms of reducing the probability of fatal and non-fatal entrapments by 20 percent or greater on wildland fires since implementation, additionally, there is uncertainty about how efficient the current training distribution method is in terms of providing critical training mitigations at the statistically verified positions in need or periods of high-risk during career points.

Management Goal

According to goal #64 of the TriData Study Phase III (1998), the implementation approach for training is as follows:

- To develop a needs-based strategy for training across agencies (i.e., matching training availability to the quality and quantity of training needed). Training programs need to be both effective and efficient.

Project Objective

This project will test the null hypothesis $\alpha \leq .05$, using generalized linear models, that Human Factors/Leadership training, implemented in 2000, has had little or no effect in reducing the probability of fatal and non-fatal entrapments among wildland firefighters against the alternative hypothesis that this training has been effective in reducing the entrapment probability of fatal and non-fatal entrapments. For this study the effectiveness of HF/L training is defined as a greater than or equal to 20 percent decrease in the probability of entrapment per 1,000 person-hours exposed during the years of 2000-2009 compared to the years 1994-1999.

As a supplemental point of interest, this project will analyze the point in a firefighter's career where HF/L training courses are typically being deployed, and if the current implementation method is providing training on a ***prescriptive based*** approach at critical times before or during the period where there is an elevated need.

Methods

This report presents a procedure for assessing the HF/L effectiveness and the efficiency in which training is currently being implemented to those who are regularly engaging in fire line activities. Through population sampling and observed historical variation the intent of this study was to examine the performance of HF/L training by analyzing two things,

1. Through regression modeling measure the effectiveness and relationship of the HF/L program since inception to entrapment probability reduction and quantify the level of effectiveness to a significance level of $\alpha \leq .05$. This method is similar to medical studies where drugs effectiveness is tested against disease.

2. Assess when HF/L training is being given to firefighters throughout their career to see if it is being provided at the most opportune time relative to high-risk or critical career periods.

The existing National Interagency Fire Center (NIFC) infrastructure along with input from the Lessons Learned Center (LLC), US Fire Administration, NWCG Risk Management Databases and published literature was utilized for information needs. Information gathered facilitated the statistical and quantifiable analysis that would help identify trends and deficiencies related to human factors interventions. Microsoft Excel (2007) was used to produce descriptive and stand-alone statistics while The R Foundation for Statistical Computing (2011) was used for multiple regression calculations and residual plotting. Of particular interest for this study were the statistics related to fatal and non-fatal entrapments rates and training implementation.

HF/L Effectiveness-Data Collection:

Data was collected and compared six years before and ten years after HF/L training was introduced in order to determine if a $\geq$ 20 percent reduction in entrapment probability/1,000 person-hours exposed has occurred since the implementation of the training in 2000. Person-Hours Exposed represents, the amount of time that firefighters spend on the fireline. More specifically it represents periods of time actively engaging in suppression activities or time spent exposed in a fireline situation where they may have potential to be involved in an entrapment situation during a typical shift. For this study HF/L training was effective if a $\geq$ 20 percent reduction in entrapment probability/1,000 person-hours exposed has occurred during the ten years post HF/L training.

National entrapment statistics were found on the NWCG's Safety and Health Working Team's annual report called a "Safety Gram" (http://www.nwcg.gov/branches/pre/rmc/safety-grams/sg-archive/safety-gram-archive.htm). The Safety Gram has tracked safety related data including entrapments both fatal and non-fatal since 1987. Entrapment rates were gathered from 16 years of data ranging from 1994-2009 to determine annual rates and means during the period of study.

National person-hour statistics for wildland firefighting was unavailable directly through NIFC infrastructure so a systematic and statistically valid sampling method of producing man-hour rates was developed. By using the National Situation Report (SIT Report) produced by NIFC as a foundational report person-hour rates were acquired. The SIT Report is a compilation of information that is provided through the country's 11 Geographic Area Coordinating Centers (GACC) relating to wildland fire activity and resource availability, see appendix C. According to NIFC intelligence personnel, it is estimated that 85-90 percent of the nation's wildland fire activity, related to resource commitment, is captured by the SIT Reports (Kari Boyd-Peak, personal communication, June, 2011).

Rates of entrapments per person-hours exposed provide decision makers with a quantifiable number that shows effectiveness in entrapment reduction since HF/L training efforts were implemented. Since person-hour statistics were untracked in any of the available databases, a systematic approach for developing person-hour statistics was created by using the following process:

Data Sampling and Processing:

1. Statistically process sample data and quantify the level of effectiveness. Methods and sample sizes operated under a significance level of $\alpha \leq .05$.

2. This study investigates a population sample by developing a grouping of months that captures the nation's wildland fire season divided into 3 strata. The criterion for month selection was that they had to encompass the combined fire season across the country. Months were chosen by viewing, on average, when SIT Reports began showing activity or loosing activity on a national level.

   By stratifying the population there is an ability to improve the quality of the random sampling process by accounting for trends in seasonal fire severity.

Selected: March, April, May, June, July, August, September, October, and November.

Strata Arrangement: *Strata 1*-[March-May] *Strata 2*-[June-Aug] *Strata 3*-[Sept-Nov]

3. By utilizing Raosoft online Sample Size Calculator (http://www.raosoft.com/samplesize.html), at a significance level of $\alpha \leq .05$ and with a confidence interval of 3.78 percent a population sample size of 600 was calculated from the study period's 5,520 total days. From each year within the 20 year study period a random sample of 30 days was selected to represent a sufficient sample size of that given year. Twenty years X 30 days per year equate to 600 sample days for the total study period. Ten days were randomly selected for each stratum to provide the total 30 day sample per year. A random sample generator was used to choose the individual 600 sample days. (http://www.random.org/integer-sets/).

Formula for determining an adequate stratified sample size:

$$nI,nII,nIII = \frac{N1}{N} * 30 = \text{Stratum Sample} \qquad nI,nII,nIII = \frac{92}{276} * 30 = 10$$

4. For each of the 600 sample days that were chosen the corresponding SIT Report was pulled from the NIFC archive. It needs to be noted at this point it was discovered that SIT reports from 1990-1993 although available, were un-useable for this study's methodology due to a change in data reporting formats starting in 1994. As a result of unavailable data four hundred and eighty sample days were carried through the remainder of the study instead of the original six hundred days that were planned. Along with other information, the SIT Report provides total personnel committed for a fire on any given day nationwide. See appendix C for SIT Report fire requirements. The total personnel committed for each sample day was summed from the SIT Reports for all fires in the country for that year and divided by 30 (the amount of sample days for the year) to give the mean for person-days committed for the specified year. The mean person-days committed was then multiplied by 276, which was the total number of days between March 1 and November 30, to give the mean for total for person-days committed for the given year. To further refine the accuracy an assessment of on the ground personnel committed was needed. Through statistical analysis it was discovered that 68 percent of the total personnel committed on a fire were actually fireline resources (as opposed to fire camp or administration personnel). The total personnel committed were then multiplied by .68 to represent the total personnel (person-days) exposed on the fireline.

5. In order to convert person-days exposed on the fire line to person-hours exposed, SME's weighed in to provide a viable number of actual hours spent exposed on the fire line. The average fire line exposure time was determined to be 8.5 hours. To obtain person-hours exposed the annual total for personnel exposed from step 4 were multiplied by the 8.5 hour exposure mean.

6. By utilizing annual entrapment totals the rate of person-hours exposed per one entrapment is figured by dividing person-hours exposed by the total number of entrapments for the specified year.

7. Divide annual person-hours worked per 1 entrapment by 1,000 to obtain the probability of entrapments per 1,000 person-hours exposed. See appendix A and B.

8. Utilize the National Incident Qualification and Certification System (IQCS) data base to discover training rates and training "ramp up" periods. Regression modeling was used to see if there was a relationship between HF/L training and a reduction in entrapment rates.

Statistical Method:

The statistical method follows a regression model where the Y is a "probability" between 0 and 1 and the X variables are HF/L training, acres burned and fire occurrence on a national/federal level. Variables were identified as potentially good candidates to explain the variation in Y. For this study the selected explanatory variables were from the national level and were identified as follows:

1. Training/No Training 2. Number of Fires 3. Acres Burned

This approach is very common in medical studies where the probability/response variable (Y) of catching a disease (or dying) is based on whether the patient receives treatment/explanatory variable (X) as well as other factors such as age overall health and gender among others. Due to the fact that the response variable in this study is count data, it is best analyzed with what is called a "*generalized linear model*". Because the response variable is counts, a link function is needed to make the residuals normally distributed.

This study modeled the probability of entrapment occurrence by the number of entrapments per 1,000 person-hours exposed. Simply put:

$$\frac{\boldsymbol{Entrap\ Count}}{\boldsymbol{1000\ hrs\ exposure}} = e^{f(\beta ixi)}$$

When the response variable is a count or rate data, as this one is, one option is to use the poisson regression as a special case for the generalized linear model, whether it is characterized as a causal model or not. For the poisson, the mean and variance are equal. In certain cases it may be discovered that there is "over-dispersion" which implies that there is more variability around the fitted values than is consistent with a poisson formulation (Berk & McDonald. 2007). During circumstances of over-dispersion utilizing the "quasipoisson" or negative binomial distribution is viewed as an option to the Poisson. All three link functions (poisson, quasipoisson and negative binomial) were examined for best fit as a part of this projects modeling effort.

Through the process of developing and selecting the appropriate regression model the intent is to model the probability of entrapment occurrence. Variables and interactions were run through the model and removed as determined insignificant, following the principals of Occam's Razor which says the simplest model that is adequate is best. Once the simplest and most appropriate model is revealed an assessment of the coefficients and p-values will provide an indication of the significance and relationship between variables.

Plotting Residuals-

By plotting the residuals against the predicted values (on the link-scale) a measurement may be made on the deviance contributed from each observation. In essence, it is used to check the model's over all goodness of fit at each observation for the generalized linear model. If the model is adequate there should be no structure in the scatter plot.

Plotting Standardized Deviance Residuals-

By plotting the standardized deviance residuals on the generalized linear model we may assess whether or not the probabilities are "normally" distributed. This means that when they are plotted they follow an approximate straight line in regards to formation ensuring that the model is adequate.

<u>HF/L Efficiency-supplemental point of interest:</u>

The distribution method for HF/L training has been based on a logical promotional approach, courses are made available to firefighters prior to their ascent to the next leadership position or qualifying rank, the intent is to match training concepts to experience levels. The timing for the training is critical because the curriculum is designed so the training tools that are provided do not surpass the experience and skill of an advancing firefighter. Each course builds from the foundational concepts in the subordinate courses and takes an individual through an upward spiraling development/self-awareness process (Jim Cook, personal communication, May, 2011).

For this study, the concern is whether or not HF/L training is being efficiently positioned throughout an average firefighting career related to career periods of high-risk or need. Since comparable studies show that up to 85 percent of all accidents are due to human miscalculation, it appears that intervening strategies aimed at reducing the occurrence and consequences of the human element has potential to make a substantial impact on entrapment reduction.

Trends that show at what point HF/L courses are distributed during a career may provide decision makers with quantifiable data that allows them to determine the efficiency in which HF/L training efforts are being distributed related to a need. A method for developing a systematic approach for discovering efficiency was created by the following:

Data Sampling and Processing:

1. Utilize the Incident Qualification and Certification System (IQCS) to validate the years during a firefighters career that the six "L" series courses are being deployed: L-180, L-280, L-380, L-381, L-480 and L-580. The IQCS system is a data base that tracks training and currency related qualifications for Interagency Wildland Firefighters. Interagency Wildland Firefighting community is represented by the US Forest Service, Bureau of Land Management, National Park Service, Fish and Wildlife Service and Bureau of Indian Affairs.

2. Identify the national average time gaps between "L" series courses. A query was performed in the national IQCS database to search all firefighters and the dates when they took "L" series courses. Processing this data provides a current average time gap (years) trend between when each course was taken.

3. By analyzing entrapment investigation reports and identifying trends during careers where the probability of an entrapment is elevated, the potential to identify a need, positioned on a career timeline based off of a high-risk of entrapment, may provide a more efficient training distribution method.

Assumptions

This study was completed under the following assumptions:

1. By investing in HF/L training, the wildland fire service has attempted to develop error resilience within the wildland fire culture, effectively leading to an expected outcome that would produce a reduction in the likelihood of entrapments and or fatalities.

2. Although HF/L training courses are officially titled “Leadership courses” this study operates under the assumption that human factors encompass large portions of leadership choices.

3. SIT Reports were used to derive trends relating to national man-hours exposed on wildland fires. From discussions with NIFC intelligence personnel it is assumed that approximately 85 to 90 percent of the nation’s wildland fire activity, related to resource commitment, is accounted for on the National Situation Report.

4. From results of statistical analysis it is assumed that 68 percent of the “Total Personnel Committed” on a fire is made up of engine and crew personnel and that this percentage is a constant across the entire study period ranging from 1994-2009.

5. Through surveys with fire line SME’s including: Hotshot superintendants, Hotshot Captains, Engine Captains, Smokejumpers, Assistant Fire Management Officers, Fire Management Officers, and Regional Fire Staff it is assumed that on average firefighters spend 8.5 hours exposed to direct fire line activities. It is also assumed that exposure rates were uniformed throughout the study period.

6. By analyzing the 20 year history captured in the National Sit Report archives, trends show that consistent fire reporting/activity occurs between the months of March through November. It was assumed that the national fire season could be reasonably defined as the months between March 1st and November 30th.

7. This study assumes that the quality and consistency of the data is continuous across the 20 year study period. In recent years agencies have become better at reporting, acquiring and processing data associated with wildland fire accidents. This has the potential to skew data in that if more details are being collected, it could look like entrapments are increasing when in reality agencies are just doing a better job in

collecting and reporting these incidents (Britt Rosso, personal communication, August 2011).

8. There are multiple variables potentially associated with rate changes in entrapment probabilities; however, this study assumes that HF/L training, fire occurrence and acres burned have had the greatest potential to act as a primary contributor in entrapment rate changes.

Results

Basic Statistics:

Initial results from basic national and federal statistic are shown in Table 1. Through comparative analysis it is revealed that there has been a decrease in entrapment counts and entrapment probability rates when comparing pre and post HF/L training eras. Of particular interest, national entrapment probability rates decreased by 68 percent while the Federal entrapment probability rate decreased by 69 percent. These percentage rates indicate the probability of entrapment occurrence per 1,000 person-hours exposed for each year of the study. Trends for the person-hours exposed category shows a nearly two-fold increase in exposure hours when comparing pre and post training eras.

TABLE 1. Trend Analysis for exposure hours, entrapment counts and entrapment probabilities for the years of 1994-2009.

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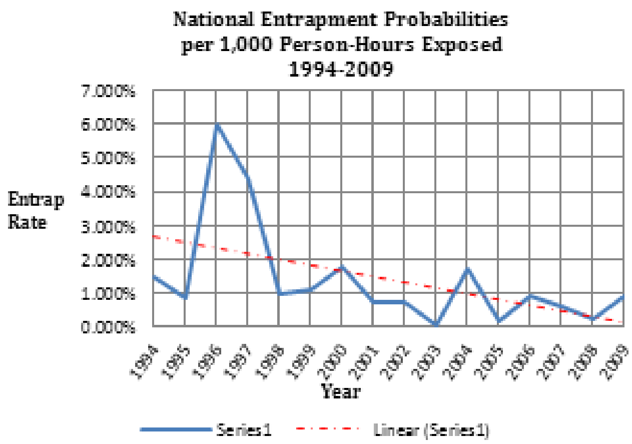
Year	Person-Hours Exposed	Number of Entrapments (Nationally)	National Entrapment Probability (per 1,000 Hours Exposed)	Number of Entrapments (Federal)	Federal Entrapment Probability (per 1,000 Hours Exposed)
1994	7,852,075	117	1.490%	113	1.439%
1995	1,048,631	9	0.858%	2	0.190%
1996	3,325,627	200	6.013%	105	3.157%
1997	660,552	29	4.390%	23	3.482%
1998	2,078,065	20	0.962%	0	0.000%
1999	3,611,873	44	1.135%	24	0.664%
6-yr. Total	**18,576,823**	**419**		**267**	
6-yr. Mean	**3,096,137**	**69.833**	**2.475%**	**44.5**	**1.489%**
2000	4,375,959	79	1.805%	35	0.799%
2001	4,305,076	32	0.743%	29	0.673%
2002	8,195,538	59	0.719%	27	0.329%
2003	8,616,958	6	0.069%	6	0.069%
2004	2,499,538	43	1.720%	34	1.360%
2005	6,734,794	14	0.207%	9	0.133%
2006	5,745,295	54	0.939%	34	0.591%
2007	8,407,232	53	0.630%	18	0.214%
2008	6,872,626	17	0.247%	4	0.058%
2009	3,671,643	34	0.926%	13	0.354%
10-yr. Total	**59,424,659**	**391**		**209**	
10-yr. Mean	**5,942,466**	**39.1**	**0.801%**	**20.9**	**0.458%**
Entrapment Rate Change Comparing 1994-1999 to 2000-2009			**Decrease 68%**		**Decrease 69%**
16-yr. Total	**78,001,482**	**810**		**476**	
16-yr. Mean	**39,000,741**	**405**	**1.638%**	**25.05**	**0.973%**

Figure 3 provides graphical comparisons and projected trend lines for entrapment probabilities within the study period. It is illustrated that since 1994 there has been a steady decrease in the probability of entrapment per 1,000 person-hours exposed.

FIGURE 3. Federal and National Wildland Firefighter entrapment probabilities and trends for the years of 1994-2009.



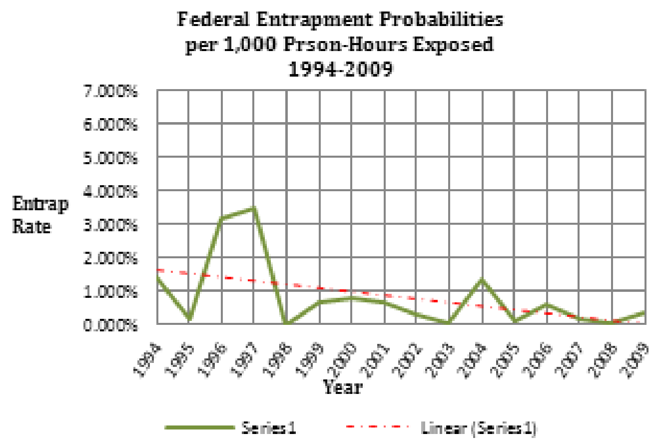
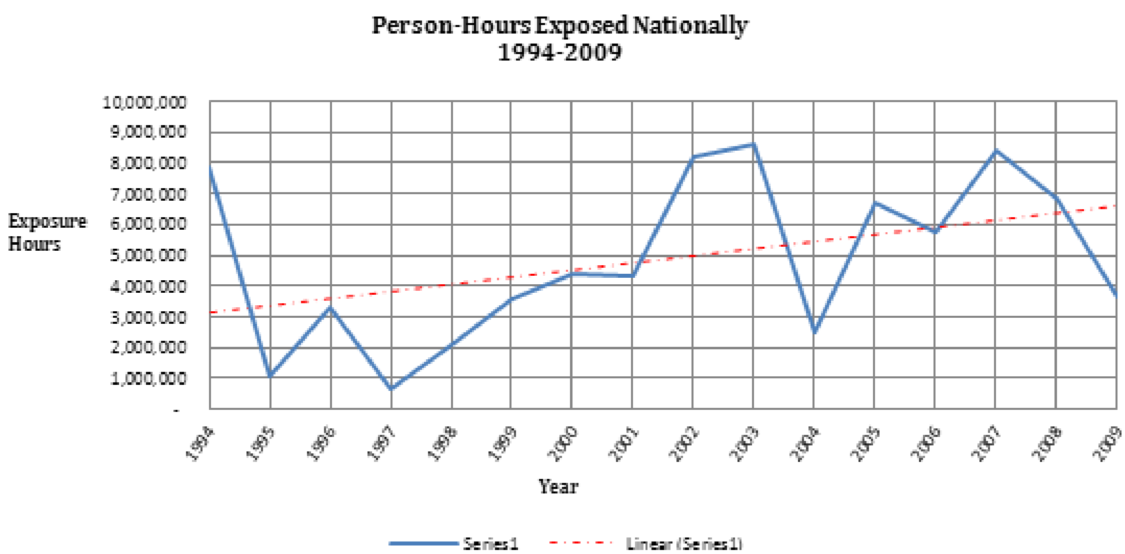


Figure 4 illustrates trends relating to person-hours exposed revealing that since 1994 there has been a constant increase in exposure hours for the nation's wildland fire fighters. The trend line shows that for every four years that passes, exposure hours have been increasing by approximately 1 million hours.

FIGURE 4. Exposure hours and exposure trends for all national wildland fire resources for the years of 1994-2009.



Regression Modeling:

For this study the negative binomial was appropriate as a link function as indicated from the large variability in the values below.

National Results: **variance(Entrapment Nationally)/mean(Entrapment Nationally)**
47.32543
Federal Results: **variance(Entrapment Federally)/mean(Entrapment Federally)**
36.91877

In an effort to rule out and or assess all possible effects from the explanatory variables on the response variable (Y), numerous interactions were run through the regression model using the project's selected variables. If there were existing interactions it would indicate that effect on the response variable for a given X depends on the level of another X. All interaction terms were tried and were highly insignificant (p-values larger than 0.21) and therefore were removed from consideration. Table 2 displays the insignificant and significant explanatory variables for both national and federal categories.

TABLE 2. National and federal values for significant and insignificant explanatory variables that were run through regression modeling.

Insignificant National Model

Explanatory Variable	Coefficient Estimate	Standard Error	p-value
Intercept	1.34310	0.49689	0.00687
Training	-1.35818	0.51105	0.000787
Number of Fires	0.05307	0.04462	0.23426
Acres Burned	0.11175	0.05445	0.04014

Insignificant Federal Model

Explanatory Variable	Coefficient Estimate	Standard Error	p-value
Intercept	0.55251	0.64413	0.3910
Training	-1.16990	0.66052	0.0765
Number of Fires	0.03810	0.05750	0.5076
Acres Burned	0.13456	0.07061	0.0567

Significant National Model - *Final Model*

Explanatory Variable	Coefficient Estimate	Standard Error	p-value
Intercept	1.87975	0.40340	3.17e-06
Training	-1.60114	0.47726	0.000794
Acres Burned	0.12271	0.05052	0.015134

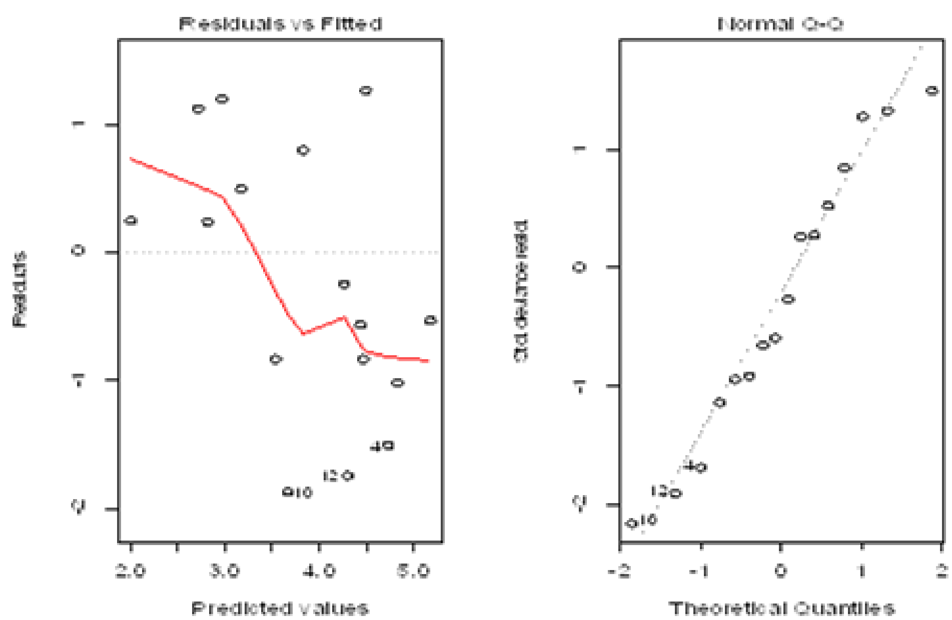
Significant Federal Mode l- ***Final Model***

Explanatory Variable	Coefficient Estimate	Standard Error	p-value
Intercept	0.9640	0.5142	0.0608
Training	-1.3127	0.6003	0.0287
Acres Burned	0.01365	0.0637	0.0327

The final models were created through a process of removing insignificant terms; those which were found inconsequential were omitted from inclusion. The insignificant models above are the full models with all potential variables in the equations. The “number of fires” variable was identified as insignificant and removed to arrive at the significant final models.

By plotting residuals from the national results an evaluation was made as to the model fit against the predicted values. The left panel in Figure 5 illustrates an inadequate model due to some structure in the scatter plot. The cluster of residuals in the lower right corner indicates variation that was unaccounted for. This shows that there are still some explanatory variables that weren’t collected. By plotting the standardized deviance residuals in the right panel an assessment is made as to whether or not the residuals are normally distributed. The national standardized deviance residuals follow an approximate straight line in regards to formation indicating that the negative binomial link function is in fact adequate.

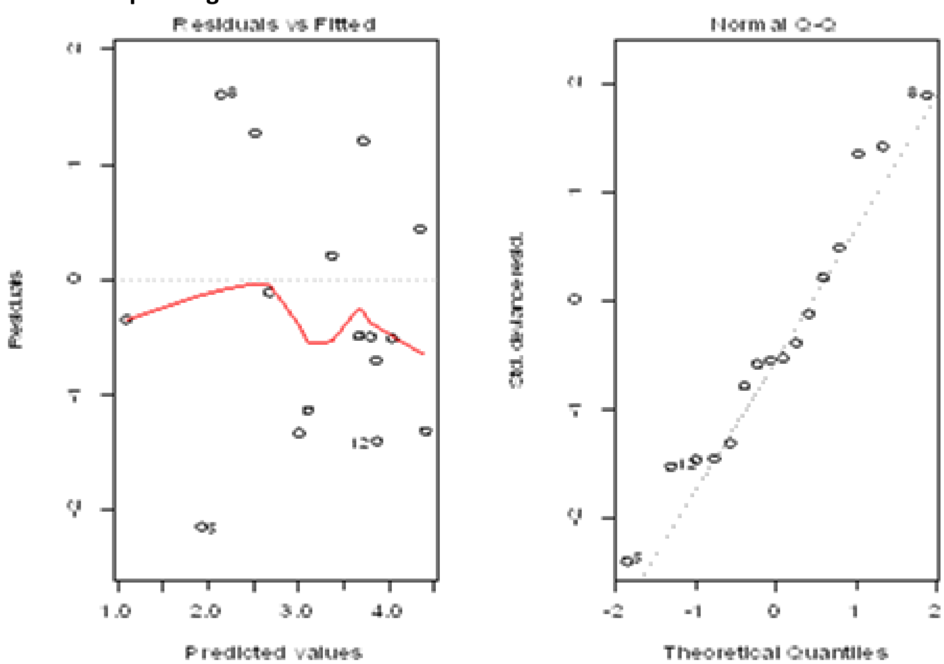
FIGURE 5. Residual plotting for national results.



This study was primarily interested in the coefficient for the “Training” factor. This factor was coded as 0 or 1 with 1 being the 2000-2009 training era. This value is a -1.60114 and is significant (p=0.000794). Additionally, $e^{-1.60114}$ is called the “rate ratio”. Calculated out this value is .202 which means the annual total for national entrapments for 2000-2009 is only 20 percent of pre 2000 levels for any fixed or constant level of exposure and acres burned. Simply put, through modeling the probability of entrapment occurrence these results show that there was an 80 percent decrease in annual total entrapments during the training era compared to the 1994-1999 non training era. The training factor was significant after accounting for the variation in exposure hours and acres burned.

Residual plotting from the federal results illustrates similar findings to the national plots. The left panel in Figure 6 reveals a lack of structure in the federal plotted residuals against predicted values indicating an adequate model fit. Standardized deviance residuals are plotted in the right panel and reveal that they are normally distributed. The approximate straight lined structure indicates that the negative binomial link function is adequate.

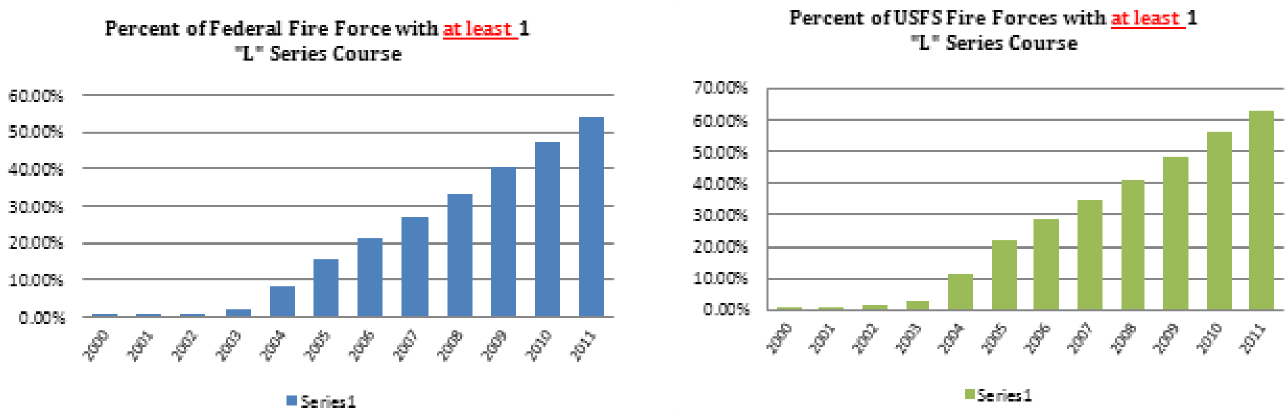
FIGURE 6. Residual plotting for federal results.



For the federal results, again the "Training" factor is one of interest. This coefficient value was -1.3127 and is significant (p=0.0287). The "rate ratio" ($e^{-1.33127}$) calculated out is 0.2691 meaning that the training era has only about 27 percent of the federal annual entrapments compared to 1994-1999 for constant levels of exposure and acres burned. Clearly stated, the results show that there was a 73 percent decrease in annual total entrapments during the training era compared to the non training era of 1994-1999 after accounting for the variation in exposure hours and acres burned.

Figure 7 illustrates the "ramping up" of HF/L training in recent years. For this study's time period cut off of 2009, 40 percent of the nation's Federal Wildland Firefighters have had at least one "L" series course while, as a comparison, US forest Service Wildland Firefighters were at 48 percent. The most recent data (2011) revealed that just over 50 percent of the nation's Federal Wildland Firefighters have had at least one "L" series course and just as a comparison, the US Forest Service has a slightly higher percentage at 63 percent. See appendix D for additional graphs and IQCS data query relating to "L" series "ramp up" trends.

FIGURE 7. Federal "L" series training "ramp up" trends since training implementation in 2000.



As a secondary point of interest this study analyzed the current "L" series training time line since 2000. Figure 8 shows the mean time period that occurs between each "L" series course. The national time line, as provided by the IQCS database, reveals the training regimen that is currently in place provides all six "L" series courses prior to a firefighters 12th year. Region 5 data was provided as a comparison.

TABLE 3. Federal "L" series training attainment time frames since 2000 as provided by the IQCS database.

	L-180 to L-280	**L-280 to L-380**	**L-380 to L-381**	**L-381 to L-480**	**L-480 to L-580**	**Mean time to complete 6 L-courses**
Region 5 Mean Period Between L-courses (n=5,340)	2.20 years (n=2,699)	1.09 years (n=2,186)	3.14 years (n=379)	3.00 years (n=67)	1.58 years (n=9)	**11.01 years**
Federal **(all agencies)** Mean Period Between L-courses (n=29,450)	1.96 years (n=16,135)	1.67 years (n=8,296)	2.81 years (n=3,736)	2.96 years (n=980)	2.12 years (n=303)	**11.52 years**

Discussion & Recommendations

When strategies are implemented to mitigate an unwanted condition there needs to be some way to measure the success of the strategy. The primary purpose of this study was to develop a method to measure the effectiveness of HF/L training. The secondary purpose was to analyze potential efficiency possibilities in regards to training distribution. To employ a mitigation action that is in-effective is a waste of time, money and resources, therefore, consistent monitoring needs to be done to ensure that the desired results and or objectives are in fact being realized and to assess to what degree they are proving successful. Once the effectiveness of a strategy has been established it would be advantageous to then determine the efficiency in which it is being implemented in an effort to maximize benefits.

This study utilized a generalized linear model in an attempt to analyze the effectiveness of HF/L training. By modeling the entrapment counts (Y) as number of events observed from exposure, the results from the parameters that were outlined, rejected the null hypothesis $\alpha = .05$ that Human Factors/Leadership training, implemented in 2000, has not been effective at reducing the probability of fatal and non-fatal entrapments among wildland firefighters by greater than or equal to 20 percent. Therefore the alternative hypothesis that Human Factors/Leadership training, since implemented in 2000, has been effective in reducing the probability of fatal and non-fatal entrapments among wildland firefighters was affirmed.

This study validates that HF/L training is not just intrinsically valuable to firefighter; rather, it is a confirmed quantifiable contributor to a reduction in the probability of entrapments since it was implemented in 2000. Entrapment probability rates decreased 68 percent nationally and 69 percent federally as observed from the basic statistics. The regression modeling revealed significant decrease in the modeled probability of entrapment occurrence during the training era of 2000-2009 as compared to 1994-1999 (national=80 percent, federal=73 percent). Among the analyzed variables the model showed with significance that entrapment rates for both national and federal groups were better estimated by the increase of the "training" variable. With this knowledge brought to light, it is recommended that HF/L training continue to be implemented and improved upon in an effort to further reduce the fatality rates related to entrapments. Supplementary improvements would be valuable in the form of more efficient/prescriptive deployment strategies. Although an efficiency model was not the primary focus of this study it is discussed as an example to initiate further research.

Entrapment Rates & Training-Effectiveness:

This project's analysis shows that there has been a significant decrease in entrapment probabilities among National Wildland Firefighters and Federal specific. Analysis appears to show that the presence of HF/L training has had an effect on reducing wildland firefighter entrapment probabilities. Although HF/L training was identified in this project as a significant variable it needs to be made clear that it is not the only variable responsible for the shift in entrapment reductions. Further analysis, supplemental to this study, should be preformed over a longer time period and with additional variables to assess relationships between training and entrapment reductions.

There is a question as to whether HF/L training has potential to influence the national fire culture as a whole. One explanation may lie in the fact that both Federal and National entrapment probabilities decreased in the post training era. Although not all of the nation's wildland firefighters receive regular doses of HF/L training, the results of this study indicates that the mandatory federal HF/L training regiment has had an effect on the national entrapment rate as a whole. Since the majority of the nation's wildland fire forces are represented by the NWCG it may be reasonable to say that the culture change endured by the NWCG's agencies, since HF/L training implementation, has produced wide spread benefits and entrapment reductions to cooperating wildfire resources. Such resources often do not have mandated HF/L training regiments, and the benefit may come from the fact that wildland fire incidents are almost always interagency endeavors. A more in depth analysis is recommended to validate this assumption.

Training Distribution-Efficiency:

As a supplemental point of interest, queries run through the IQCS data base provide some clarity to the actual current Federal "L" series training regimen. Figure 8 showed the mean timeframes between each "L" series course. According to the national trend, during a federal firefighters career completion of "L" series curriculum (six courses) will have been accomplished in 11.52 years. With this knowledge an assessment can be made as to whether or not this is the intended timeframe the NWCG Leadership Sub-committee had in mind for training deployment. Relating to a typical 30 year federal firefighting career it must be noted that the current distribution timeline provides large amounts of HF/L training up to about year 12, then, for the next 18 years HF/L specific training would then be absent. This too needs to be evaluated for desirability by the Leadership Sub-committee. As an observation from wildland fire SME's, higher qualifications and positions are typically attained around or after year 12 which leads to more critical decision making responsibility. Additionally, a study of fatal/near-fatal wildland fire accidents revealed that accident frequencies increase within years 10-15 (Dahl et al. 1980). If an absence of HF/L training is satisfactory during latter 18 years of a career then the current regimen should go unchanged, however, it seems that subsequent to year 12 is where the critical HF/L training need is, prescriptive supplemental HF/L training would be beneficial throughout the latter half of a career as well.

Prescriptive Training Distribution:

In order to develop a prescriptive method for training deployment it must first be agreeable that HF/L training is effective at minimizing accident probabilities. Having an effective mitigation strategy would provide a useful method for addressing critical issues or high-risk periods. This study has provided current training regiments (timelines, Figure 8) which represent half of the required data need to implement a prescriptive training program. The missing half of the data is an identification of critical need or high-risk periods during a firefighting career. Through data driven analysis the wildland fire service needs to identify career points where proven mitigation strategies may be effective at reducing an unwanted trend.

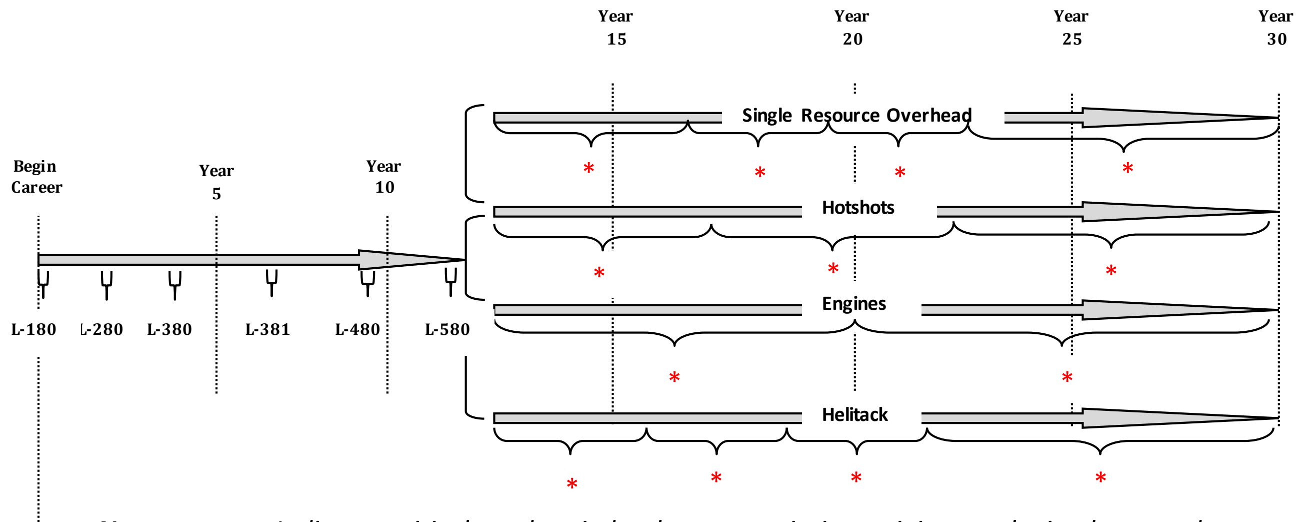
Hypothetical example-

- **Identified Trend/Critical Need Period**- Through federal accident database analysis trends show that between the years of 12-15 module leaders are more likely to be involved in an entrapment situation as a result of human factors issues during downhill line construction or structure protection.

- **Prescriptive Mitigation**- A prescriptive training program would provide targeted training for module leaders between the years of 10-15 of their career relating to effective human factors strategies for developing optimal downhill line construction or structure protection situations.

Ideally, critical trends needing attention would be pre-identified along the entire career timeline of the wildland firefighter and would branch off in to different career paths which would trigger a position specific training regimen, see Figure 9 for hypothetical trend discoveries. Prescriptive mitigations could then be implemented as targeted.

FIGURE 8. Example of hypothetical prescriptive training placement based off of identified trends/needs with in specific fire line positions.



Note: * *-Indicates critical need periods where prescriptive training can be implemented.*

Concluding Thoughts:

Difficulties in validating this study come from questions dealing with the inability to quantify, measure and identify the entire set of variables that may have an effect on entrapment rates. Additionally, difficulty came from a realization that there was occasionally missing or inconsistent data due to changes in data collection methods throughout the study period and differences in databases. Because there was a lack of needed data in the databases, a process had to be created to develop the project critical statistic of "Person-Hours Exposed". Ideally, these statistics would already be in the data base and factual rather than being created by sampling methods. Further efforts made to account for additional variables and inconsistencies in data would be recommended by doing the following:

- Develop a more comprehensive database specifically dedicated to on the ground fireline human factors analysis. Assess the potential use of the Human Factors Analysis and Classification System (HFACS), a process and database developed by Shappell & Wiegmann (2000), as a framework that provides investigators and analysts with a comprehensive, user friendly tool for identifying, classifying and compiling human causes in accidents. HFACS is currently been employed by the U.S. Navy, Marine Corps, Army, Air Force, and Coast Guard for use in aviation accident investigations. HFACS databases can be reliably analyzed to identify trends from which prescriptively implemented human factors mitigations can be applied to specific data-driven objectives.

- Through HFACS utilization identify priority/high-risk periods or positions within a wildland firefighting career. Develop and implement prescribed training in accordance to trends.

- Assess current training timelines and distribution methods to ensure the right courses are being developed and provided in accordance to goal #64 of the TriData Study (1998). Training should be delivered on a needs-based strategy across agencies, matching training availability to the quality and quantity of training needed. Training programs need to be both effective and efficient.

- Trainings need to have clear objectives related to both contents and target audiences. Objectives need to be regularly assessed for consistency ensuring that they are producing the desired results.

Research has shown that in most cases, the post-accident databases typically are not conducive at providing a comprehensive user friendly tool for identifying and classifying the human causes of accidents. In order to objectively monitor and make judgments on training effectiveness, efficiency and trend occurrence, it is highly critical that specific detailed databases are implemented and regularly assessed. The following questions must be asked:

- Will the database eventually lend its self to focused and specific scientific analysis?

- How frequently and systematically is this data analyzed to look for possible problem areas or trends?

- Who provides the expertise to conduct the investigation and what makes them an expert in human factors?

- Who provides the expertise to conduct such analysis?

Organizations must seek out safety critical information rather than waiting for opportunities to analyze adverse events. An organization safety culture is a result of human factors/leadership awareness. Safety is a result of strong leadership and the awareness of the potential human contributions to accidents.

Even with increasing exposure hours and rising complexities, according to this study's results, the wildland fire service has managed to create a safer work environment in terms of reducing the probability of fireline entrapments. Difficulties in validating this study come from questions dealing with the inability to quantify, measure and identify the entire set of variables that may have an effect on entrapment rates. Further analysis is suggested in this realm. However, we must also look at the largest efforts or contributions that were made in recent years up to this point relating to the federal and national fire culture, this is where the development of HF/L mitigations trumps any other fireline specific training modification that has been made thus far.

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Appendices

Appendix A:

Stratified Man-Hours Master Sheet

2009 Random Sample Days	Total Personnel Committed Nationally	2008 Random Sample Days	Total Personnel Committed Nationally	2007 Random Sample Days	Total Personnel Committed Nationally
3-Apr	458	14-Mar	855	9-Mar	421
22-Apr	503	21-Mar	1159	16-Mar	1135
27-Apr	1248	28-Mar	1159	28-Mar	372
28-Apr	1434	4-Apr	741	30-Mar	37
1-May	910	11-Apr	651	2-Apr	15
2-May	908	24-Apr	1869	5-Apr	50
6-May	951	25-Apr	1468	10-Apr	104
12-May	3842	30-Apr	2135	4-May	1923
19-May	530	8-May	1626	13-May	3721
20-May	136	29-May	291	20-May	4081
Strata Average	**1092**	**Strata Average**	**1195.4**	**Strata Average**	**1185.9**
17-Jun	612	2-Jun	154	23-Jun	1694
28-Jun	68	4-Jun	458	1-Jul	4545
29-Jun	275	16-Jun	6552	20-Jul	15841
3-Jul	590	19-Jun	5511	23-Jul	13192
10-Jul	2528	30-Jun	22689	26-Jul	12018
13-Jul	3842	7-Jul	20819	30-Jul	10837
20-Jul	3483	24-Jul	14649	1-Aug	10908
22-Jul	4224	1-Aug	14432	6-Aug	14377
4-Aug	9035	16-Aug	6791	22-Aug	17148
29-Aug	7121	29-Aug	5563	23-Aug	15887
Strata Average	**3177.8**	**Strata Average**	**9761.8**	**Strata Average**	**11644.7**
2-Sep	11317	9-Sep	2482	11-Sep	9722
13-Sep	2832	20-Sep	4582	18-Sep	6857
14-Sep	1759	4-Oct	2829	28-Sep	16
23-Sep	4432	5-Oct	2156	5-Oct	36
27-Sep	4648	6-Oct	1701	12-Oct	333
23-Oct	108	12-Oct	397	19-Oct	533
26-Oct	1045	17-Oct	2653	22-Oct	4871
13-Nov	49	21-Oct	646	23-Oct	6283
20-Nov	108	7-Nov	261	9-Nov	826
27-Nov	51	14-Nov	1964	23-Nov	319
Strata Average	**2634.9**	**Strata Average**	**1967.1**	**Strata Average**	**2979.6**
Sample Total	69,047	**Sample Total**	129,243	**Sample Total**	158,102
Mean per/day	2,302	**Mean per/day**	4,308	**Mean per/day**	5,270
09 Year Total Personnel	635,232	**08 Year Total Personnel**	1,189,036	**07 Year Total Personnel**	1,454,538
09 Year Total Handcrew/engine Personnel	431,958	**08 Year Total Handcrew/engine Personnel**	808,544	**07 Year Total Handcrew/engine Personnel**	989,086
2009 Man Hours Exposed	**3,671,643**	**2008 Man Hours Exposed**	**6,872,626**	**2007 Man Hours Exposed**	**8,407,232**
2009 Entrapments Fatal & Non-Fatal	34	**2008 Entrapments Fatal & Non-Fatal**	17	**2007 Entrapments Fatal & Non-Fatal**	53
Rate of Entrapment per exposure hours worked	107,990	**Rate of Entrapment per exposure hours worked**	404,272	**Rate of Entrapment per exposure hours worked**	158,627
Entrapment Probability	**0.009260159**	**Entrapment Probability**	**0.002473582**	**Entrapment Probability**	**0.006304096**

Appendix A: Cont.

Stratified Man-Hours Master Sheet

2006		2005		2004	
Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally
3-Mar	1528	11-Mar	106	12-Mar	356
12-Mar	472	18-Mar	685	19-Mar	176
20-Mar	588	25-Mar	129	7-Apr	773
21-Mar	555	1-Apr	178	8-Apr	471
30-Mar	789	8-Apr	572	9-Apr	296
21-Apr	632	15-Apr	342	1-May	307
29-Apr	334	22-Apr	381	6-May	4341
6-May	805	1-May	119	7-May	3451
12-May	523	13-May	308	9-May	1135
28-May	675	17-May	608	11-May	350
Strata Average	**690.1**	**Strata Average**	**342.8**	**Strata Average**	**1165.6**
1-Jun	972	25-Jun	6033	6-Jun	1190
6-Jun	359	4-Jul	5589	8-Jun	1802
17-Jun	4445	7-Jul	55398	13-Jun	1086
8-Jul	2635	13-Jul	3211	17-Jun	1580
15-Jul	8496	16-Jul	3677	19-Jun	2254
22-Jul	7196	5-Aug	5178	26-Jun	844
7-Aug	1317	7-Aug	4573	29-Jun	3505
16-Aug	14007	12-Aug	10981	2-Jul	4628
20-Aug	12473	13-Aug	9905	19-Jul	9226
25-Aug	14819	27-Aug	5528	25-Aug	4302
Strata Average	**6671.9**	**Strata Average**	**11007.3**	**Strata Average**	**3041.7**
5-Sep	13463	10-Sep	4548	2-Sep	1977
7-Sep	14380	13-Sep	1443	13-Sep	1138
3-Oct	3105	27-Sep	269	16-Sep	961
18-Oct	92	2-Oct	4235	21-Sep	68
23-Oct	0	8-Oct	1580	1-Oct	0
25-Oct	0	16-Oct	38	9-Oct	760
29-Oct	2868	19-Oct	11	5-Nov	8
10-Nov	301	23-Oct	10	12-Nov	0
17-Nov	51	18-Nov	185	19-Nov	20
24-Nov	163	25-Nov	831	26-Nov	0
Strata Average	**3442.3**	**Strata Average**	**1315**	**Strata Average**	**493.2**
Sample Total	108,043	**Sample Total**	126,651	**Sample Total**	47,005
Mean per/day	3,601	**Mean per/day**	4,222	**Mean per/day**	1,567
06 Year Total Personnel	993,996	**05 Year Total Personnel**	1,165,189	**04 Year Total Personnel**	432,446
06 Year Total Handcrew/engine Personnel	675,917	**05 Year Total Handcrew/engine Personnel**	792,329	**04 Year Total Handcrew/engine Personnel**	294,063
2006 Man Hours Exposed	**5,745,295**	**2005 Man Hours Exposed**	**6,734,794**	**2004 Man Hours Exposed**	**2,499,538**
2006 Entrapments Fatal & Non-Fatal	54	**2005 Entrapments Fatal & Non-Fatal**	14	**2004 Entrapments Fatal & Non-Fatal**	43
Rate of Entrapment per exposure hours worked	106,394	**Rate of Entrapment per exposure hours worked**	481,057	**Rate of Entrapment per exposure hours worked**	58,129
Entrapment Probability	**0.009398996**	**Entrapment Probability**	**0.002078757**	**Entrapment Probability**	**0.01720318**

Appendix A: Cont.

Stratified Man-Hours Master Sheet

2003		2002		2001	
Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally
6-Mar	0	8-Mar	394	2-Mar	174
21-Mar	0	15-Mar	147	23-Mar	223
24-Mar	55	22-Mar	133	6-Apr	110
2-Apr	76	29-Mar	84	13-Apr	318
21-Apr	2	6-Apr	607	20-Apr	601
28-Apr	53	12-Apr	415	24-Apr	476
4-May	44	25-Apr	808	26-Apr	726
8-May	0	29-Apr	498	28-Apr	409
23-May	198	9-May	1829	18-May	674
24-May	346	27-May	2979	28-May	1118
Strata Average	**77.4**	**Strata Average**	**789.4**	**Strata Average**	**482.9**
4-Jun	611	14-Jun	9236	15-Jun	1559
26-Jun	3695	20-Jun	10840	18-Jun	2404
29-Jun	3909	29-Jun	12069	1-Jul	1608
6-Jul	3945	3-Jul	11440	3-Jul	1387
12-Jul	6882	30-Jul	18575	9-Jul	1898
13-Jul	6445	4-Aug	15195	24-Jul	1398
20-Jul	12638	7-Aug	13961	27-Jul	3397
25-Jul	13288	15-Aug	12640	3-Aug	5012
4-Aug	7693	23-Aug	16664	10-Aug	5492
12-Aug	8699	28-Aug	11936	24-Aug	19917
Strata Average	**6780.5**	**Strata Average**	**13255.6**	**Strata Average**	**4407.2**
1-Sep	16177	3-Sep	10225	2-Sep	9207
3-Sep	13843	30-Sep	2501	10-Sep	7928
5-Sep	13844	6-Oct	1	14-Sep	5154
9-Sep	16231	20-Oct	411	25-Sep	4730
10-Sep	13574	30-Oct	0	29-Sep	2768
15-Sep	8527	1-Nov	0	18-Oct	60
25-Sep	4289	8-Nov	53	21-Oct	7
Oct	None Chosen	15-Nov	86	27-Oct	1356
4-Nov	6854	22-Nov	24	2-Nov	382
9-Nov	13	29-Nov	370	3-Nov	466
21-Nov	115	**Strata Average**	**1367.1**	**Strata Average**	**3205.8**
Strata Average	**9346.7**				
Sample Total	162,046	**Sample Total**	154,121	**Sample Total**	80,959
Mean per/day	5,402	**Mean per/day**	5,137	**Mean per/day**	2,699
03 Year Total Personnel	1,490,823	**02 Year Total Personnel**	1,417,913	**01 Year Total Personnel**	744,823
03 Year Total Handcrew/engine Personnel	1,013,760	**02 Year Total Handcrew/engine Personnel**	964,181	**01 Year Total Handcrew/engine Personnel**	506,480
2003 Man Hours Exposed	**8,616,958**	**2002 Man Hours Exposed**	**8,195,538**	**2001 Man Hours Exposed**	**4,305,076**
2003 Entrapments Fatal & Non-Fatal	6	**2002 Entrapments Fatal & Non-Fatal**	59	**2001 Entrapments Fatal & Non-Fatal**	32
Rate of Entrapment per exposure hours worked	1,436,160	**Rate of Entrapment per exposure hours worked**	138,907	**Rate of Entrapment per exposure hours worked**	134,534
Entrapment Probability	**0.000696301**	**Entrapment Probability**	**0.007199039**	**Entrapment Probability**	**0.007433086**

Appendix A: Cont.

Stratified Man-hours Master Sheet

2000	
Random Sample Days	Total Personnel Committed Nationally
10-Mar	1105
17-Mar	22
24-Mar	0
10-Apr	1
12-Apr	261
14-Apr	216
17-Apr	279
9-May	1080
24-May	711
28-May	2174
Strata Average	**584.9**
3-Jun	4059
22-Jun	1487
1-Jul	3887
2-Jul	3374
3-Jul	1797
5-Jul	2128
14-Jul	1372
17-Jul	3748
2-Aug	14033
9-Aug	17502
Strata Average	**5338.7**
12-Sep	5218
14-Sep	3973
17-Sep	4092
23-Sep	4659
29-Sep	1240
2-Oct	3329
28-Oct	174
29-Oct	312
17-Nov	0
24-Nov	59
Strata Average	**2305.6**
Sample Total	82,292
Mean per/day	2,743
00 Year Total Personnel	757,086
00 Year Total Handcrew/engine Personnel	514,819
2000 Man Hours Exposed	**4,375,959**
2000 Entrapments Fatal & Non-Fatal	79
Rate of Entrapment per exposure hours worked	55,392
Entrapment Probability	**0.018053184**

Appendix A: Cont.

Stratified Man-Hours Master Sheet

1999 Random Sample Days	1999 Total Personnel Committed Nationally	1998 Random Sample Days	1998 Total Personnel Committed Nationally	1997 Random Sample Days	1997 Total Personnel Committed Nationally
5-Mar	105	20-Mar	7	7-Mar	0
12-Mar	16	3-Apr	58	16-Mar	0
19-Mar	318	10-Apr	0	21-Mar	0
26-Mar	9	17-Apr	138	12-Apr	No Report
1-Apr	633	24-Apr	20	20-Apr	No Report
9-Apr	49	4-May	0	28-Apr	No Report
16-Apr	103	9-May	0	2-May	229
20-Apr	410	16-May	599	13-May	141
25-Apr	363	21-May	578	20-May	794
23-May	556	24-May	65	21-May	391
Strata Average	**256.2**	**Strata Average**	**146.5**	**Strata Average**	**155.5**
6-Jun	2094	21-Jun	1053	7-Jun	0
14-Jul	1810	22-Jun	1042	8-Jun	0
15-Jul	1278	23-Jun	1137	9-Jun	0
25-Jul	4577	29-Jun	1962	29-Jun	188
26-Jul	5477	7-Jul	4553	6-Jul	2014
31-Jul	935	12-Jul	4158	20-Jul	405
9-Aug	4308	15-Jul	2734	22-Jul	777
10-Aug	3202	21-Jul	2602	26-Jul	676
22-Aug	2501	13-Aug	1895	28-Jul	837
25-Aug	6203	16-Aug	1976	14-Aug	1772
Strata Average	**3238.5**	**Strata Average**	**2311.2**	**Strata Average**	**666.9**
1-Sep	9251	5-Sep	7969	7-Sep	1457
23-Sep	6117	17-Sep	1111	13-Sep	53
13-Oct	3509	24-Sep	0	16-Sep	200
23-Oct	3018	30-Sep	667	17-Sep	100
24-Oct	3332	6-Oct	1336	27-Sep	2039
27-Oct	4457	24-Oct	2221	8-Oct	0
3-Nov	1545	26-Oct	466	11-Oct	0
12-Nov	54	29-Oct	212	25-Oct	337
16-Nov	343	6-Nov	520	7-Nov	9
20-Nov	1350	20-Nov	0	21-Nov	3
Strata Average	**3297.6**	**Strata Average**	**1450.2**	**Strata Average**	**419.8**
Sample Total	67,923	**Sample Total**	39,079	**Sample Total**	12,422
Mean per/day	2,264	**Mean per/day**	1,303	**Mean per/day**	414
99 Year Total Personnel	624,892	**98 Year Total Personnel**	359,527	**97 Year Total Personnel**	114,282
99 Year Total Handcrew/engine Personnel	424,926	**98 Year Total Handcrew/engine Personnel**	244,478	**97 Year Total Handcrew/engine Personnel**	77,712
1999 Man Hours Exposed	**3,611,873**	**1998 Man Hours Exposed**	**2,078,065**	**1997 Man Hours Exposed**	**660,552**
1999 Entrapments Fatal & Non-Fatal	41	**1998 Entrapments Fatal & Non-Fatal**	20	**1997 Entrapments Fatal & Non-Fatal**	29
Rate of Entrapment per exposure hours worked	88,094	**Rate of Entrapment per exposure hours worked**	103,903	**Rate of Entrapment per exposure hours worked**	22,778
Entrapment Probability	**0.01135145**	**Entrapment Probability**	**0.009624338**	**Entrapment Probability**	**0.043902657**

Appendix A: Cont.

Stratified Man-Hours Master Sheet

1996		1995		1994	
Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally	Random Sample Days	Total Personnel Committed Nationally
4-Mar	365	11-Mar	No Report	4-Mar	0
15-Mar	320	22-Mar	No Report	11-Mar	0
22-Mar	6	6-Apr	No Report	18-Mar	0
12-Apr	61	22-Apr	No Report	25-Mar	0
19-Apr	129	25-Apr	No Report	15-Apr	0
6-May	2181	10-May	No Report	22-Apr	0
9-May	1879	11-May	No Report	24-Apr	0
11-May	605	16-May	No Report	26-Apr	0
15-May	753	19-May	No Report	29-Apr	0
20-May	1526	21-May	No Report	24-May	381
Strata Average	**782.5**	**Strata Average**	**0**	**Strata Average**	**38.1**
4-Jun	602	15-Jun	914	4-Jun	1106
18-Jun	2158	17-Jun	676	6-Jun	811
22-Jun	889	19-Jun	769	19-Jun	2272
24-Jun	4529	20-Jun	706	8-Jul	5459
10-Jul	2800	22-Jun	1285	10-Jul	2882
26-Jul	2372	10-Jul	1907	13-Jul	4217
28-Jul	5816	19-Jul	0	25-Jul	3840
30-Jul	2286	31-Jul	4180	15-Aug	16896
8-Aug	6271	1-Aug	3875	18-Aug	18700
20-Aug	18202	24-Aug	0	19-Aug	19185
Strata Average	**4592.5**	**Strata Average**	**1431.2**	**Strata Average**	**7536.8**
18-Sep	0	9-Sep	1248	3-Sep	17323
22-Sep	265	13-Sep	115	5-Sep	14102
24-Sep	95	14-Sep	306	7-Sep	12037
29-Sep	1194	28-Sep	591	10-Sep	10126
4-Oct	641	29-Sep	15	11-Sep	9037
10-Oct	1266	6-Oct	3133	1-Oct	7248
12-Oct	2729	13-Oct	0	11-Oct	1654
14-Oct	2550	9-Nov	0	21-Oct	0
1-Nov	50	17-Nov	0	21-Nov	0
15-Nov	0	24-Nov	0	24-Nov	386
Strata Average	**879**	**Strata Average**	**540.8**	**Strata Average**	**7191.3**
Sample Total	62,540	**Sample Total**	19,720	**Sample Total**	147,662
Mean per/day	2,085	**Mean per/day**	657	**Mean per/day**	4,922
96 Year Total Personnel	575,368	**95 Year Total Personnel**	181,424	**94 Year Total Personnel**	1,358,490
96 Year Total Handcrew/engine Personnel	391,250	**95 Year Total Handcrew/engine Personnel**	123,368	**94 Year Total Handcrew/engine Personnel**	923,773
1996 Man Hours Exposed	**3,325,627**	**1995 Man Hours Exposed**	**1,048,631**	**1994 Man Hours Exposed**	**7,852,075**
1996 Entrapments Fatal & Non-Fatal	200	**1995 Entrapments Fatal & Non-Fatal**	9	**1994 Entrapments Fatal & Non-Fatal**	117
Rate of Entrapment per exposure hours worked	16,628	**Rate of Entrapment per exposure hours worked**	116,515	**Rate of Entrapment per exposure hours worked**	67,112
Entrapment Probability	**0.060139035**	**Entrapment Probability**	**0.008582621**	**Entrapment Probability**	**0.014900521**

Appendix A: Cont.

Stratified Man-Hours Master Sheet

1993 Random Sample Days	1993 Total Personnel Committed Nationally	1992 Random Sample Days	1992 Total Personnel Committed Nationally	1991 Random Sample Days	1991 Total Personnel Committed Nationally
2-Mar	No Report	2-Mar	No Report	24-Mar	No Report
16-Mar	No Report	9-Mar	No Report	2-Apr	No Report
19-Mar	No Report	17-Mar	No Report	4-Apr	No Report
29-Mar	No Report	27-Mar	No Report	5-Apr	No Report
10-Apr	No Report	31-Mar	No Report	16-Apr	No Report
17-Apr	No Report	9-Mar	No Report	3-May	No Report
18-Apr	No Report	17-Mar	No Report	6-May	No Report
20-Apr	No Report	24-Mar	No Report	8-May	No Report
21-Apr	No Report	29-Mar	No Report	14-May	No Report
28-Apr	No Report	29-May	No Report	28-May	No Report
Strata Average	**0**	**Strata Average**	**0**	**Strata Average**	**0**
3-Jun	No Report	8-Jun	No Report	3-Jun	No Report
4-Jun	No Report	9-Jun	No Report	9-Jun	No Report
4-Jul	No Report	16-Jun	No Report	13-Jun	No Report
11-Jul	No Report	27-Jun	No Report	24-Jun	No Report
21-Jul	No Report	6-Jul	No Report	28-Jun	No Report
9-Aug	No Report	8-Jul	No Report	20-Jul	No Report
12-Aug	No Report	16-Jul	No Report	21-Jul	No Report
18-Aug	No Report	19-Jul	No Report	8-Aug	No Report
19-Aug	No Report	18-Aug	No Report	10-Aug	No Report
27-Aug	No Report	21-Aug	No Report	14-Aug	No Report
Strata Average	**0**	**Strata Average**	**0**	**Strata Average**	**0**
7-Sep	No Report	1-Sep	No Report	15-Sep	No Report
21-Sep	No Report	12-Sep	No Report	1-Oct	No Report
30-Sep	No Report	18-Sep	No Report	9-Oct	No Report
6-Oct	No Report	12-Oct	No Report	25-Oct	No Report
13-Oct	No Report	20-Oct	No Report	2-Nov	No Report
16-Oct	No Report	29-Oct	No Report	6-Nov	No Report
23-Oct	No Report	13-Nov	No Report	15-Nov	No Report
12-Nov	No Report	17-Nov	No Report	19-Nov	No Report
19-Nov	No Report	20-Nov	No Report	22-Nov	No Report
24-Nov	No Report	25-Nov	No Report	23-Nov	No Report
Strata Average	**0**	**Strata Average**	**0**	**Strata Average**	**0**
1993 Entrapments Fatal & Non-Fatal	38	**1992 Entrapments Fatal & Non-Fatal**	2	**1991 Entrapments Fatal & Non-Fatal**	29

Appendix A: Cont.

Stratified Man-hours Master Sheet

1990

Random Sample Days	Total Personnel Committed Nationally
4-Mar	No Report
7-Mar	No Report
10-Mar	No Report
12-Mar	No Report
17-Mar	No Report
6-Apr	No Report
14-Apr	No Report
19-Apr	No Report
21-May	No Report
29-May	No Report
Strata Average	**0**
1-Jun	No Report
18-Jun	No Report
19-Jun	No Report
25-Jun	No Report
11-Jul	No Report
16-Jul	No Report
6-Aug	No Report
19-Aug	No Report
21-Aug	No Report
25-Aug	No Report
Strata Average	**0**
1-Sep	No Report
11-Sep	No Report
21-Sep	No Report
24-Sep	No Report
30-Sep	No Report
23-Oct	No Report
6-Nov	No Report
10-Nov	No Report
11-Nov	No Report
17-Nov	No Report
Strata Average	**0**

1990 Entrapments
Fatal & Non-Fatal 31

Appendix B:

Entrapments by Year, Agency and Strata Grouping

2009			**2008**			**2007**			**2006**		
Date	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**
1-Feb	VFD	2	8-Jan	STATE	2				18-Feb	STATE	1
Above data is outside of this study's specified fire season											
3-Apr	VFD	3	25-Mar	VFD	4	28-Apr	STATE	1	1-Mar	VFD	2
9-Apr	TRIBE	2	19-Apr	STATE	1	23-May	STATE	1	2-Mar	VFD	3
22-Apr	STATE	2	**Strata Total**		5	**Strata Total**		2	2-Mar	VFD	4
6-May	COUNTY	3	10-Jun	METRO	3	26-Jun	FED	2	12-Mar	VFD	1
Strata Total		10	11-Jun	STATE	3	27-Jun	FED	8	19-Mar	STATE	1
22-Jun	STATE	5	11-Jun	FED	4	7-Jul	STATE	9	21-Mar	FED	1
3-Aug	FED	12	26-Jul	VFD	2	7-Jul	STATE	1	7-Apr	VFD	2
3-Aug	STATE	6	**Strata Total**		12	8-Jul	FED	2	12-Apr	FED	2
26-Aug	FED	1				28-Jul	FED	1	17-Apr	FED	1
Strata Total		24	**Strata Total**		0	7-Aug	FED	3	**Strata Total**		17
						12-Aug	CONTR.	2	18-Jun	FED	1
Strata Total		0				20-Aug	FED	2	27-Jun	STATE	5
						Strata Total		30	30-Jun	FED	2
						12-Sep	STATE	1	6-Jul	FED	4
						22-Sep	STATE	2	11-Jul	FED	9
						21-Oct	STATE	4	25-Jul	FED	6
						22-Oct	COUNTY	12	27-Jul	STATE	1
						12-Nov	COUNTY	2	17-Aug	FED	1
						Strata Total		21	23-Aug	FED	2
									23-Aug	CONTR.	1
									Strata Total		32
									26-Oct	FED	5
									Strata Total		5
Mar-Nov **Entrapments**		**34**	***Mar-Nov*** **Entrapments**		**17**	***Mar-Nov*** **Entrapments**		**53**	***Mar-Nov*** **Entrapments**		**54**
CY Entrapments		**36**	**CY Entrapments**		**19**	**CY Entrapments**		**53**	**CY Entrapments**		**55**

Appendix B: Cont.

Entrapments by Year, Agency and Strata Grouping

2005			2004			2003			2002		
Date	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**
21-Feb	FED	1	18-Feb	VFD	1						
			24-Feb	STATE	3						
Above data is outside of this study's specified fire season											
8-Apr	VFD	3				11-May	FED	3	24-Mar	FED	2
5-May	FED	1	**Strata Total**			15-May	FED	1	**Strata Total**		2
Strata Total		4	22-Mar	FED	1	**Strata Total**		4	15-Jun	FED	2
16-Jul	FED	3	28-Jun	VFD	2	22-Jul	FED	2	17-Jun	STATE	6
23-Jul	FED	2	2-Jul	FED	12	**Strata Total**		2	30-Jun	FED	5
10-Aug	FED	3	14-Jul	FED	21				3-Jul	VFD	1
Strata Total		8	**Strata Total**		36	**Strata Total**		0	13-Jul	FED	2
12-Nov	VFD	1	12-Sep	STATE	7				24-Jul	CONTR	17
30-Nov	VFD	1	**Strata Total**		7				12-Aug	STATE	3
Strata Total		2							**Strata Total**		36
									1-Sep	FED	16
									3-Sep	COUNTY	5
									Strata Total		21
Mar-Nov **Entrapments**		**14**	***Mar-Nov*** **Entrapments**		**43**	***Mar-Nov*** **Entrapments**		**6**	***Mar-Nov*** **Entrapments**		**59**
CY Entrapments		**15**	**CY Entrapments**		**47**	**CY Entrapments**		**6**	**CY Entrapments**		**59**

Appendix B: Cont.

Entrapments by Year, Agency and Strata Grouping

2001			2000			1999			1998		
Date	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**
						9-Feb	VFD	1			
Above data is outside of this study's specified fire season											
21-Mar	MILITARY	3	6-Mar	VFD	3	14-Mar	VFD	3	1-Apr	STATE	2
Strata Total		3	6-Apr	STATE	2	6-Apr	VFD	2	30-Apr	VFD	2
10-Jul	FED	14	7-May	FED	3	17-Apr	STATE	2	**Strata Total**		4
13-Aug	FED	2	24-May	FED	3	4-May	FED	2	16-Jun	STATE	1
Strata Total		16	**Strata Total**		11	**Strata Total**		9	18-Jun	STATE	1
25-Oct	FED	9	4-Jun	STATE	17	11-Jun	FED	7	22-Jun	STATE	1
10-Nov	FED	4	4-Jun	FED	17	2-Jul	FED	2	24-Jun	STATE	2
Strata Total		13	9-Jun	VFD	2	22-Jul	FED	5	20-Jul	STATE	1
			13-Jun	STATE	3	9-Aug	FED	6	22-Jul	VFD	3
			1-Jul	VFD	2	9-Aug	VFD	1	29-Jul	STATE	2
			7-Jul	CONTR.	1	15-Aug	STATE	2	**Strata Total**		11
			9-Jul	VFD	3	24-Aug	STATE	2	9-Sep	STATE	1
			31-Jul	FED	1	24-Aug	CONTR.	1	19-Sep	COUNTY	1
			2-Aug	STATE	4	**Strata Total**		26	14-Oct	VFD	2
			11-Aug	FED	2	14-Sep	STATE	2	18-Nov	STATE	1
			16-Aug	CONTR.	3	19-Oct	STATE	4	**Strata Total**		5
			23-Aug	FED	9	22-Nov	FED	2			
			25-Aug	STATE	1	**Strata Total**		8			
			Strata Total		65						
			3-Sep	STATE	1						
			12-Oct	STATE	1						
			1-Nov	VFD	1						
			Strata Total		3						
***Mar-Nov* Entrapments**		**32**	***Mar-Nov* Entrapments**		**79**	***Mar-Nov* Entrapments**		**43**	***Mar-Nov* Entrapments**		**20**
CY Entrapments		**32**	**CY Entrapments**		**79**	**CYl Entrapments**		**44**	**CY Entrapments**		**20**

Appendix B: Cont.

Entrapments by Year, Agency and Strata Grouping

1997			1996			1995			1994		
Date	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**
Above data is outside of this study's specified fire season											
5-May	STATE	2	15-Mar	VFD	1	4-Apr	STATE	1	1-Apr	FED	1
Strata Total		2	26-Apr	VFD	48	10-Apr	FED	2	3-Apr	VFD	1
6-Aug	FED	23	**Strata Total**		49	**Strata Total**		3	**Strata Total**		2
7-Aug	CONTR.	4	4-Jun	STATE	13	28-Jul	VFD	2	1-Jun	FED	3
Strata Total		27	21-Jun	FED	21	23-Aug	VFD	4	2-Jun	FED	1
			23-Jun	FED	2	**Strata Total**		6	14-Jun	FED	5
Strata Total		0	24-Jun	FED	2				25-Jun	FED	4
			6-Jul	FED	3	**Strata Total**		0	29-Jun	FED	7
			24-Jul	VFD	2				2-Jul	FED	5
			14-Aug	FED	4				3-Jul	STATE	3
			20-Aug	FED	3				6-Jul	FED	49
			25-Aug	FED	10				22-Jul	FED	8
			26-Aug	VFD	3				5-Aug	FED	22
			26-Aug	FED	53				13-Aug	FED	1
			28-Aug	FED	6				**Strata Total**		108
			31-Aug	FED	1				2-Sep	FED	4
			Strata Total		123				20-Nov	FED	3
			1-Sep	PRVT.	2				**Strata Total**		7
			4-Sep	FED	14						
			22-Oct	METRO	12						
			Strata Total		28						
***Mar-Nov* Entrapments**		**29**	***Mar-Nov* Entrapments**		**200**	***Mar-Nov* Entrapments**		**9**	***Mar-Nov* Entrapments**		**117**
CY Entrapments		**29**	**CY Entrapments**		**200**	**CY Entrapments**		**9**	**CY Entrapments**		**117**

Appendix B: Cont.

Entrapments by Year, Agency and Strata Grouping

1993			1992			1991			1990		
Date	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**	**Date**	**Agency**	**Qty**
						21-Feb	FED	1			
Above data is outside of this study's specified fire season											
10-Mar	STATE	1	17-Mar	N/A	1						
22-Apr	FED	16	**Strata Total**		1	**Strata Total**		0	**Strata Total**		0
27-May	FED	1	3-Aug	N/A	1	21-Aug	FED	3	26-Jun	STATE	11
Strata Total		18	**Strata Total**		1	**Strata Total**		3	27-Jun	STATE	17
17-Jun	FED	1				21-Oct	VFD	4	26-Aug	STATE	2
20-Aug	COUNTY	9	**Strata Total**			29-Oct	STATE	20	**Strata Total**		30
Strata Total		10				12-Nov	FED	2	15-Oct	STATE	1
23-Oct	FED	2				**Strata Total**		26	**Strata Total**		1
27-Oct	METRO	4									
2-Nov	STATE	4									
Strata Total		10									
***Mar-Nov* Entrapments**		**76**	***Mar-Nov* Entrapments**		**2**	***Mar-Nov* Entrapments**		**29**	***Mar-Nov* Entrapments**		**31**
CY Entrapments		**76**	**CY Entrapments**		**2**	**CY Entrapments**		**30**	**CY Entrapments**		**31**

Appendix C:

Situation Report Information

SIT Report Criteria (Requirements for inclusion in daily report:

- Fuel Models 1-6 ≥ 300 acres
- Fuel Models 7-13 ≥ 100 acres
- There is an Incident Management team assigned (even if acreage is less than stated above)

Categories of interest:

NORTHERN CALIFORNIA AREA INCIDENTS/LARGE FIRES:

YOLLA BOLLY COMPLEX, Mendocino National Forest. A Fire Use Management Team (Perkins) is assigned. This lightning-caused Wildland Fire Use (WFU) incident is being managed to accomplish resource objectives. This fire is burning 35 miles west of Red Bluff, CA in timber. Increased fire activity on the southwest flank, short uphill runs, and spotting were observed.

INCIDENT NAME	ST	UNIT	SIZE	% CTN	EST CTN	TOTL PERS	CRW	ENG	HELI	STRC LOST	$$$ CTD	ORIGIN OWN
YOLLA BOLLY COMPLEX – WFU	CA	MNF	1,050	N/A	N/A	93	4	0	2	0	495K	FS
LAVA	CA	MDF	220	100	--	1	0	0	0	0	3.0K	FS

MDF – Modoc National Forest

ROCKY MOUNTAIN AREA INCIDENTS/LARGE FIRES:

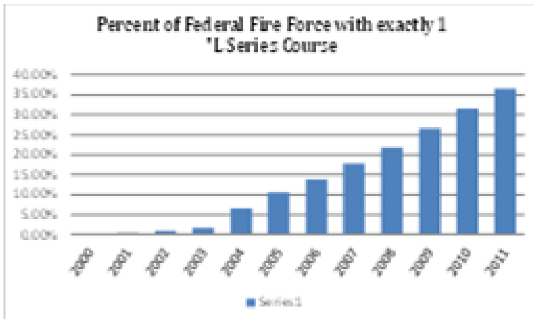
DRY MEDICINE CREEK, Bighorn National Forest. This fire is 30 miles east of Greybull, WY in timber. Minimal fire activity was observed.

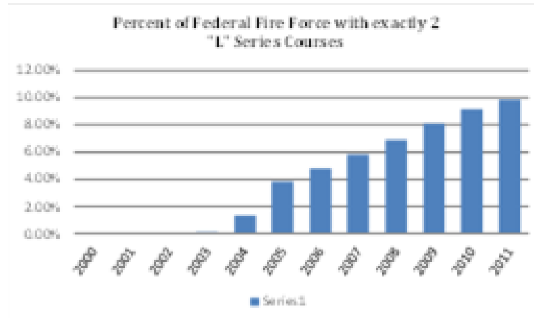
INCIDENT NAME	ST	UNIT	SIZE	% CTN	EST CTN	TOTL PERS	CRW	ENG	HELI	STRC LOST	$$$ CTD	ORIGIN OWN
DRY MEDICINE CREEK	WY	BHF	120	80	7/10	110	4	2	1	0	243K	FS
LITTLE VENUS – WFU	WY	SHF	715	N/A	N/A	15	0	0	0	0	183K	FS
FOUR BEAR	SD	CRA	2,093	100	---	11	0	19	0	1	22K	BIA
CLUBHOUSE	SD	CRA	907	100	---	7	0	3	0	4	52K	BIA
* 2900 ROAD	KS	KSX	800	100	---	37	0	10	0	0	NR	CNTY

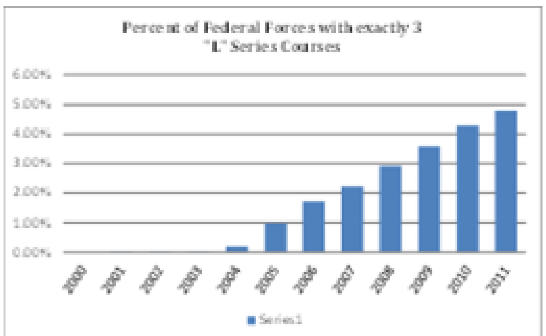
SHF – Shoshone National Forest
KSX – Kansas Counties
CRA - Cheyenne River Agency, Bureau of Indian Affairs

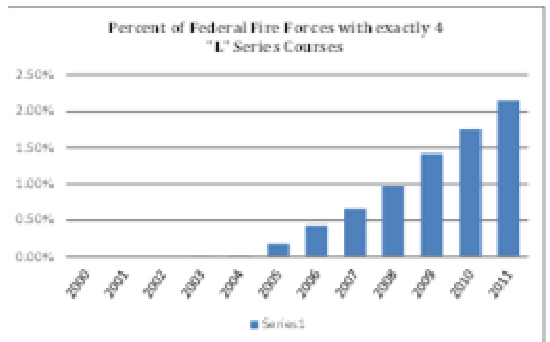
Appendix D:

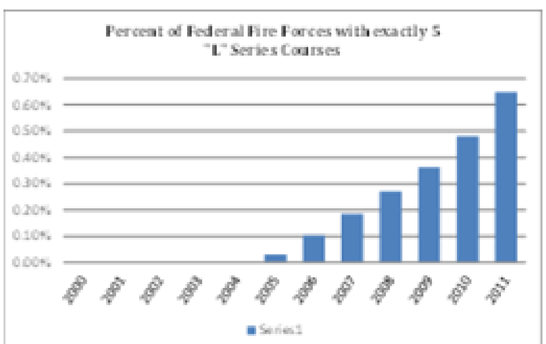
Federal "L" Series Training Course Attainment Percentiles

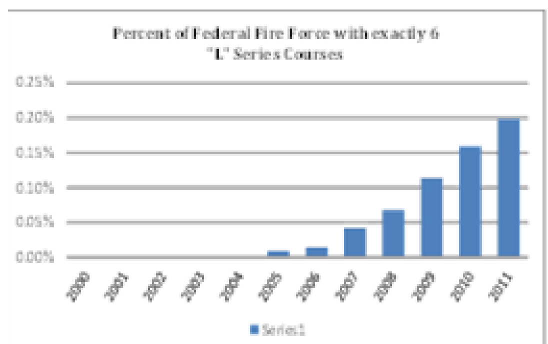


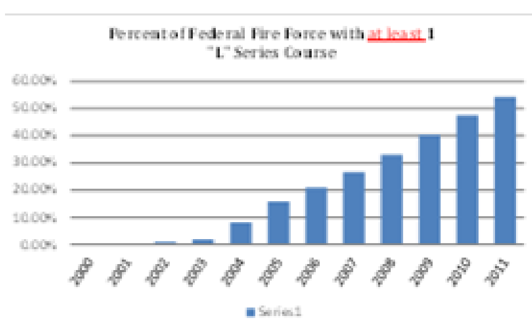






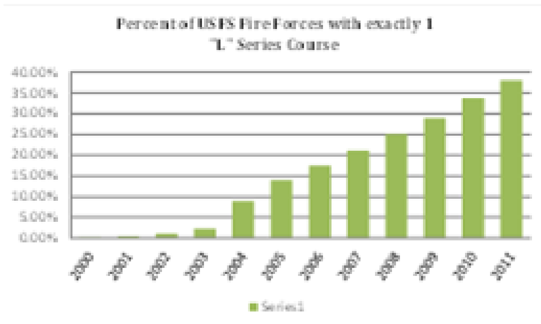


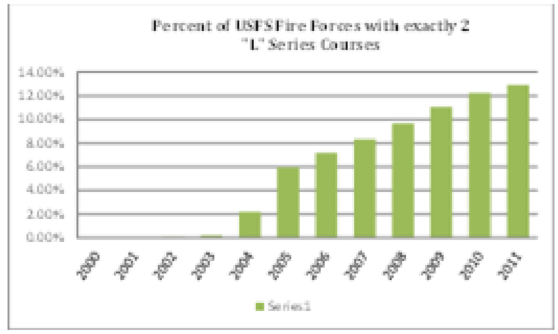


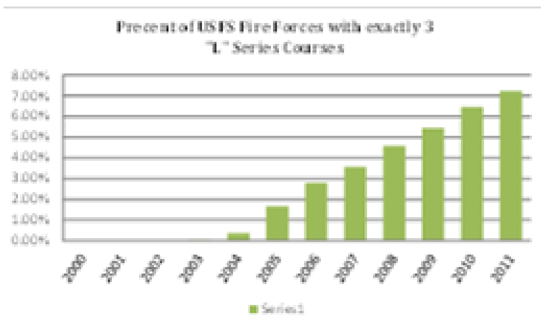


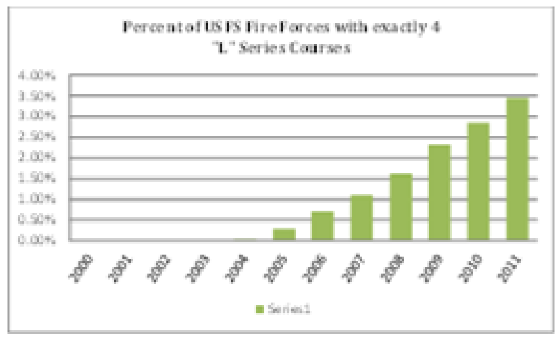
Appendix D Cont.:

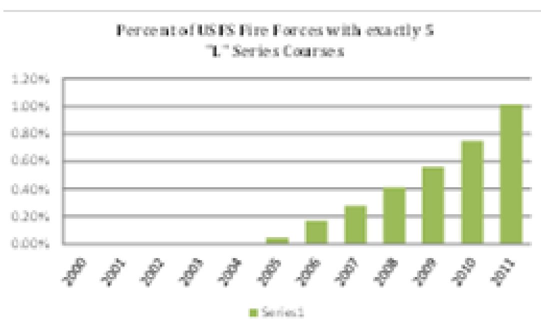
US Forest Service "L" Series Training Course Attainment Percentiles

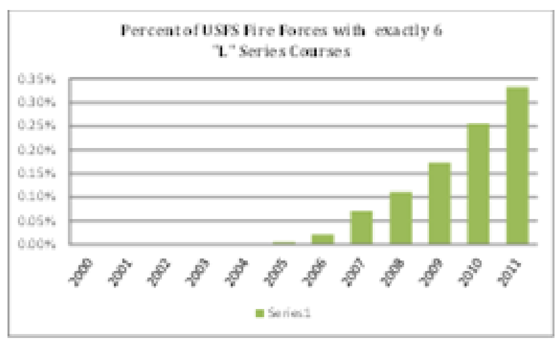


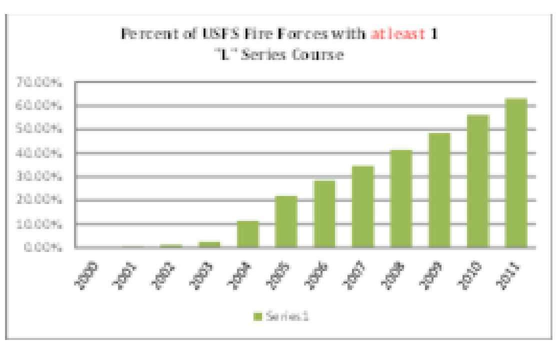












Appendix E:

"L" Course Attainment Time Frames

Note: Queries run by the IQCS database contained large amounts of data resulting in an omission of its data in this report. This data is available through the IQCS database or through this project's author upon request.