WILDLAND FIRE DATA: ISSUES AND PROPOSED SOLUTIONS

A Dissertation

by

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ABSTRACT

Wildfires occur all over the world. Many countries collect data on such fires. In an effort prevent and study wild fires, the sharing of this information is imperative. Information can best be shared through a wildland fire database. In order to create a wildland fire database in the United States, data integrity issues must be dealt with first. Data integrity issues became apparent during a wildland fire data warehousing project conducted at Texas A&M University for the National Association of State Foresters (NASF) from 2003-2009.

Two main issues emerged from this project. One was the lack of consistency in fire cause and the other was the location information provided was not accurate at the county level. In an effort to propose a solution to the lack of consistency in wildland fire cause, raw data from the NASF project was analyzed as to how to modify the nine statistical causes currently used by the United States Forest Service (USFS) to provide a more useful representation of the current state of wildland fires. In addition, it was hypothesized that location information in the United States Public Land Survey format was on average more accurate than other submitted location data (e.g. latitude /longitude).

It was found that the cause information could benefit by sub-dividing the current USFS especially for the causes of debris burning and miscellaneous in order to help determine the actually cause of a wildland fire. Using a χ^2 statistical test it was conclusively determined that USPLS information was the most accurate location

information submitted during the NASF project.

As a result of these two analyses, a new proof of concept data submittal system was also developed. The development of this system was based on the system that was utilized during the NASF project. However the new system incorporated autonomous data integrity checking at the front end of data entry instead of after the data had been submitted. The new submittal system was costly in terms of data processing time due to the lack of consistency in the data being submitted. The overall issue in wildland fire data is that there is a lack of consistent reporting methodologies and the data that is being submitted.

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CHAPTER I

INTRODUCTION

Globally hundreds of thousands if not millions of wildfires occur every year. Most if not all countries deal with wildfires on a regular annual basis. In the United States alone an estimated 4,319,546 acres burned in 2013, according to the National Interagency Fire Center (National Interagency Fire Center 2014). Wildfires are an increasing threat to the urban environment as well as the wildland urban fringe (Haines et al. 2005). With the threat of these wildland fires impacting the urban environment, there is an increasing need for the sharing of wildfire information between fire agencies (Bunton 1999; United States Fire Administration 2004). This information can best be shared through the use of a national wildfire database.

A good national database enables the sharing of data among fire agencies and others in need of fire information across the United States. This sharing of data enables the identification of potential problems with wildfire prevention programs and provides a stepping stone for determining management solutions to the identified problems (Bunton 1999; United States Fire Administration 2004). These solutions play a major role in the development of national wildfire policy (Bunton 1999).

Currently there exists one major well-documented national database that is capable of supporting multi-state wildfire information in the United States. The National Fire Incident Reporting System (NFIRS) was developed in 1974 in a national effort to help states create and maintain a local database system in addition to helping develop national fire policies (U. S. Senate 1974; United States Fire Administration 2004). Participation by the states in the system is strictly voluntary (United States Fire Administration 2012).

In October 2002, the National Association of State Foresters (NASF) directed its Fire Protection Committee to investigate alternative strategies to cost-effectively collect a minimum set of data from all members. In January 2003 the NASF Fire Committee and the State Fire Chiefs, Managers, and Supervisors Group agreed upon the use of 13 core variables, listed in Table 1, that would be collected and reported by each state on a quarterly basis. The Texas A&M Spatial Sciences Lab, working through the Texas Forest Service, developed a web-based submission and data warehousing strategy to accomplish this task.

Table 1 List of NASF core variables.

NASF Core Variables		
Cause	Ownership class	County name
Size (acres)	Homes threatened	Latitude/Longitude
Size class (derived)	Homes lost	Start time/date
Other structures threatened	Other structures lost	Number of injuries
Number of fatalities		

The project began with a proof of concept study to ensure that the objectives were feasible. Using historical data from 13 southern states, code was written to accept data submitted to a website. Files were stored into a structured file system. Submitted file types included Access databases, Excel workbooks, shapefile sets, and text files. Submitted fields differed widely. The approach taken was to call a long set of state-specific subroutines for each of the 13 test states. There were instances when some of the

13 subroutines called other common routines, such as for the processing of data for the U. S. Public Land Survey System (USPLS, also called the Public Land Survey System), but there was also a large amount of state-specific code. Other complications emerged, such as field names but sometimes the actual suite of included fields changing from year to year, even for a given state.

The proof of concept coding attempted to include error checking and automated corrections for such things as fires reportedly being out before they had begun, latitudes and longitudes being swapped, county names being misspelled, etc.

This attempt was ultimately abandoned with the realization that, even with the proof of concept subset of states, maintenance of the code would become unmanageable. Issues of maintenance of the submittal system then multiplied as more states submitted their data. The main issue was that there did not exist a standard submittal format for every state to use in their submission process. In addition to not having a standard format for data, the individual states had their own set of information that they would submit to the data warehouse. To solve these problems, the submittal system was restructured into a generic code that would process each individual state into the data warehouse. This generic code would be fed state specific code from the database itself to insert data in the correct format and without errors to the main wildfire data warehouse. This method of storing code in a database made the process of submitting data into the database very manageable.

Three major issues emerged from building a uniform wildfire database based on non-uniform data: identification of causes of wildfire, lack of error checking, and the use of multiple submission formats of location information. Concerning wildfire causes, many states use a nationally accepted set of nine wildfire causes while others use their own classification systems (NWCG 1998). Lack of naming standards creates data retrieval problems and can produce miscounts and mismatches. The lack of error checking in datasets posed a major problem when trying to maintain acceptable wildfire data. Some of the errors were simple to correct after the fact.

These simple errors included misspelling a county name, lack of consistent nomenclature within a particular field in a dataset, and latitude and longitude that were in reverse order. Other errors were more complex, such as coordinates that were not even in the state in which the fire was supposed to have started, fires that were posted as out before they even were started, etc.

The use of multiple submission formats for wildfire locations was a third major issue for building the uniform database. Although there existed an agreed upon criteria for submission of latitude and longitude, many states used USPLS, Universal Transverse Mercator (UTM), or block grid location information instead. The different submission formats made uniformity of pinpointing wildfire locations difficult if not impossible in some instances.

Through the course of this research, the three above mentioned fundamental issues of creating and maintaining a national wildfire database submittal and storage system for implementation in policy making decisions and research based questions were addressed. First, wildfire causes has been analyzed as to their effectiveness in categorizing wildfire events. Through this process, a new wildfire cause standardized classification system is proposed. Second, location information in particular was analyzed as to its accuracy and integrity of the wildfire event when more than one set of location information was present. Locations as submitted were correlated to improve pinpointing of wildfires from any format as seen in the past. Third, error checking has been moved from the back end of the system to the front end, which eliminated problems at the output stage. The checking will also further insure that the classification of data system is maintained. In combination, these three changes to the existing system will help to insure the integrity of the final product.

CHAPTER II

THE CLASSIFICATION OF WILDLAND FIRE CAUSE

Introduction

Information about wildfire occurrence has been collected on at least some lands in the United States for over a century. The USDA Forest Service began collecting information concerning fires originating on or near National Forest lands in 1905 (Donoghue 1982a). Since that time, other agencies and organizations have assumed the responsibility for collecting data and reporting information concerning wildfires occurring on other lands. Not all agencies have collected/reported the same pieces of information, and definitions have varied over time and from agency to agency (Short 2014). One thing that has remained constant is that fire cause has almost always been recorded. The recording of wildland fire cause provides a way for researchers to study and for managers to adapt policy and public awareness strategies to cause patterns at the national, state, and local levels (Jackson 2003; Short 2014).

During the course of the NASF project, we noted numerous areas in which the data submitted by different agencies, mainly by different states, were not consistent. Those issues must be resolved before a truly consistent national wildland fire database can be developed. In addition, there are variables such as weather, terrain, and cover, supplemental to the 13 core variables that could be fairly easily acquired and added at the central database end, leading to a more comprehensive database. Supplemental variables such as these would be of great value to researchers studying things such as fire behavior, or fire as related to climate change. Some states currently report these and other supplemental variables at the submissions end, though they were not included in the NASF Fire Reporting Database.

This chapter deals with cause, and the consistency issue of classification. To a lesser extent we will address the question of data quality. Without some consistent method for the classification, cause becomes fairly useless as a variable for cross-agency analyses. For example, two states uploaded at least one submission each for which the reported causes consisted largely of just words: “set”, “fireplace ashes”, “stupidity”, etc. Many of these could be categorized after the fact but often, without the context of the fire and the knowledge gained by responders who visited the scene, post-classification by individuals lacking that knowledge is suboptimal at best.

With a classification system in place, any described action by an individual that does not explicitly conform to a standard set of cause categories could result in a wildfire that could be placed in any of the non-natural cause categories. Without knowledge of the context and circumstances, post-classification must result in such a fire being dumped into the miscellaneous category, a category in all of the classification systems considered herein. One might even conceive of a hierarchical classification system where, at the coarsest level, fires are categorized as to (i) natural, (ii) accidental, and (iii) deliberate (Cemagref 2012). On the other hand, the words themselves sometimes provided valuable insight into what was responsible for the start of wildfires.

So pre-submission classification of fires by individuals with intimate or at least minimal knowledge of the context and circumstances of a given fire is essential, and in order to be of maximal use for cross-agency analyses, the classification system used should be consistent across agencies.

To be certain, there is currently an element of consistency among many of the states. That element can be traced to the USDA Forest Service's current classification system, which will be reviewed momentarily, and from which many of the state-level classification systems evolved. Indeed the coarsest version of that system is the classification system agreed upon for the NASF Fire Reporting Database. Yet the classifications used by the various states did not always fit nicely into that mold. Further, it was observed from the NASF submissions that the frequency of fires in some classes often differed from those in other classes by orders of magnitude. In an analytical context, when comparing frequencies across time or across space, a more even distribution is to be preferred. It can also be argued that, if the frequency of fires in one class, lightning excluded, is very large relative to that in another, then from a managerial perspective, say for the purpose of targeting prevention programs, perhaps more information can be gained by breaking the larger category into smaller, more specific categories.

The USDA Forest Service classification system is, in fact, partially hierarchical, as are those of roughly half of the states. It was observed that many of the subcauses were seemingly more prevalent than some of the super causes (we will adopt a different terminology shortly), with a good deal of consistency among those states using hierarchical systems. This would argue then that it might be possible to improve the consistency of a national classification system following an analysis of frequencies, overall and by state, for the systems currently in place. The purpose of this paper is to present the results of such analyses. The analyses are simple and accessible to individuals with minimal statistical background.

Wildland Fire Cause and the United States

The United States of America collects wildland fire information from a handful of federal agencies. One such agency is the USDA United States Forest Service (USFS). Wildland fire cause in the USFS is divided into three categories of classification (statistical, general, and specific cause) together with class of people, also considered to be cause related. The cause of a wildland fire incident that is recorded by the USFS is read as statistical, general and then specific (Donoghue 1982a).

A statistical cause is similar to that of the coarse cause terminology used throughout this paper. Statistical cause is defined as a cause that may be used for general reporting purposes (Donoghue 1982a). Historically there were originally eight statistical cause codes; later these eight were expanded to nine cause codes (Table 2) (Figure 1). However, throughout the evolution of the statistical cause codes, the definition of what a statistical cause code represents has remained the same.

The general cause of a wildland fire is defined as a cause to describe the specific land use associated with the statistical cause (Donoghue 1982a). This information is useful for wildland fire managers but will not be discussed in this paper. That being said the specific cause of a wildland fire is similar to that of the fine cause that is discussed in this paper. The specific cause is simply a more detailed description of the specific source of ignition as related to the statistical cause (Donoghue 1982a).

Table 2 General, statistical, and specific cause categories from Donoghue (1982a) and USDA Forest Service (1998).

Statistical Cause	General Cause	Specific Cause	
Lightning	Fishing	Aircraft	Fireworks
Equipment Use	Forest/Range Mgmt	Blasting	Grudge Fire
Camp Fire	Harvest Other Products	Brakeshoe	Insect/Snake Control
Debris Burning	Hunting	Burning Building	Job Fire
Railroad	Highway	Burning Dump	Land Clearing
Incendiary	Other Recreation	Burning Vehicle	Lightning
Children	Power, Reclamation	Cooking Fire	Logging Line
Smoking	Incendiary	Exhaust-Other	Power Line
Miscellaneous	Recreation	Exhaust-Powersaw	Pyromania
	Other	Field Burning	R/W Burning
		Repel Predatory Animals	Resource Management Burning
		Slash Burning	Smoking
		Smoking out Bees/Game	Stove Fuel Sparks
		Trash Burning	Warming Fire
		Repel Predatory Animals	Other

The system of categorizing wildland fire cause in the USFS has not changed much over the years. This system has several documented flaws by various critics. Chandler (1960) conducted a survey of how USDA Forest Service fire managers in California blindly categorized a set of 1956 wildland fires having causes known to Chandler. The land managers inconsistently categorized the statistical, general, and specific causes of the set of wildland fires. He noticed that the land managers had a bad habit of lumping unknown fires into the ’smoking’ statistical cause category. Later, Donoghue (1982b) surveyed USFS fire managers from 1974 to 1975 and determined that their level of confidence in the wildland fire information they had been providing was lower in certain areas than others. Of the various pieces of information, she found wildland fire managers were least confident in their categorization of wildland fire cause for all three USFS wildland fire cause classes. In an even later study, Donoghue and

Paananen (1983) found that there exists a major problem with the wildland fire cause categorization system. They found that wildland fire causes, in the various classes, were not mutually exclusive and their example of this was that of a dump fire that was categorized in seven different ways (Table 3).

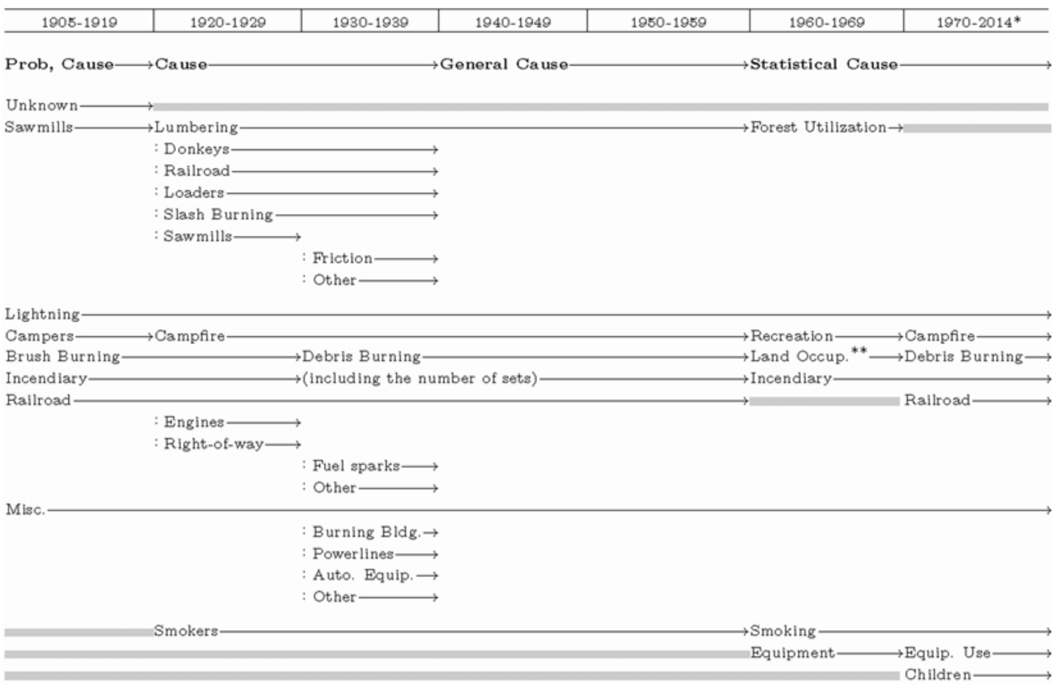

Figure 1 Time-lines of the USDA Forest Service "cause words"; adapted from Donoghue (1972a). The first, bold, line identifies the name used for this ``main'' category of cause-related fields (variables). Items from 1920 to 1940 that are preceded by colons are items that more fully qualify the broader category under which they fall; e.g., Railroad : Engines. Donoghue's time-lines only extended to 1981, but the current classes are essentially the same as they were at that time.
** Donoghue listed Land Occupancy as a separate class that existed during the '70s, she also had a gap in the Debris Burning category during that period. Examination of fires classed as Land Occupancy clearly indicates that it was a temporary name-change.

Table 3 Classification of dump fires in the United States from Donoghue (1982a, and Donoghue & Paanenen (1983).

Fire	Statistical Cause	General Cause	Specific Cause
1	Incendiary	Incendiary	Burning dump
2	Incendiary	Incendiary	Grudge
3	Debris burn	Other	Trash burning
4	Debris burn	Resident	Burning dump
5	Debris burn	Incendiary	Trash burning
6	Debris burn	Other	Burning dump
7	Miscellaneous	Resident	Burning dump

Both Donoghue (1982a) and Chandler (1960) suggest that one way of eliminating many of the problems associated with the current system of wildland fire cause classification in the USFS would be that of expanding the number of categories found in the statistical cause class.

The USFS is not the only agency that records wildland fire cause information. National Interagency Fire Management Integrated Database (NIFMID), includes fire data on all government land holdings and USFS fire data post 1970, and National Fire Incident Reporting System (NFIRS), maintained by the United States Fire Administration, are two other sources of wildland fire data. Both of these data repositories have not been around as long as the USFS data repository. NIFMID has the same cause classification system as the original USFS data, but the cause categories inside of the general and specific cause classes provide a more robust set of cause categories than that of the original USFS data system (Table 4).

Table 4 NIFMID database wildland module fire cause categories.

Statistical Cause	General Cause	Specific Cause	
Lightning	Other	Aircraft	Resource Mgmt Burning
Equipment Use	Timber Harvest	Burning Vehicle	R/W Burning
Camp Fire	Harvest Other Products	Exhaust-Power saw	Grudge Fire
Debris Burning	Forest/Range Management	Exhaust-Other	Pyromania
Railroad	Highway	Logging Line	Smoking out Bees/Game
Arson	Power, Reclamation	Brakeshoe	Insect/Snake Control
Children	Hunting	Cooking Fire	Job Fire
Miscellaneous	Fishing	Warming Fire	Blasting
Smoking	Other Recreation	Smoking	Burning Building
	Resident	Lightning	Power Line
		Trash Burning	Fireworks
		Burning Dump	Repel Predatory Animals
		Field Burning	Stove Fuel Sparks
		Land Clearing	
		Slash Burning	

Two major additions to the NIFMID general cause categories are the distinctions between the types of harvest, ’timber’ and ’other’, and the separation between ’hunting’ and ’fishing’ from ’recreation’ (USDA Forest Service 1998). Perhaps the most significant addition was the number of specific cause categories, however there were not any additions made to the statistical cause categories.

NFIRS unlike the other two systems only has two levels of wildland fire cause classes, wildland fire cause and heat source (FEMA 2013). NFIRS has made the biggest addition to the initial cause class (wildland fire cause) set of cause categories (Table 5). They have added the cause category ’undetermined’. Even though NFIRS only has two wildland fire cause classes in their cause class system, ’undetermined’ provides a place to categorize fires that the wildland fire manager simply cannot determine a cause for. In the USFS system there is no place to put an ’undetermined’ fire cause, other than ’miscellaneous’, yet the wildland fire manager is forced to fill in all data on the report.

This could explain Chandler's (1960) findings of how managers were lumping 'unknown' fires into the 'smoking' statistical cause category. Also Brown et al. (2002) found much of the NFIMID data contained 'blank' statistical cause categories despite the requirement of the fire managers to fill out all portions of the fire report. They hypothesized that managers must be placing 'undetermined' fires under 'miscellaneous' or simply leaving them 'blank'. In addition to the expansion of the initial cause class, NFIRS provides many more sources of ignition in the heat source cause class that is similar to that of the specific cause class. The heat source differs from that of the wildland fire cause in that they not only provide a broad source of ignition if the specific source is unknown, but they also provide some insight as to what the person was doing to start the wildland fire (FEMA 2013). An example of this is where a fire can be categorized with a wildland fire cause, 'Equipment', and its heat source, 'Spark, ember or flame from operating equipment'. This tells the researcher that the fire was not caused by simply friction from the operation of the equipment. The heat source provides very detailed information as to what started a fire.

Table 5 NFIRS database wildland module fire cause categories.

	Wildland Fire Cause	
Natural Source	Equipment	Smoking
Open/outdoor fire	Debris, vegetation burn	Structure (exposure)
Incendiary	Misuse of fire	Other cause
Undetermined		

Wildland Fire Cause and the European Union

The European Union has problems similar to those faced by the various states. With multiple entities collecting information there exists a lot of variation amongst the data, more specifically fire cause. Much as the United States systems of wildland fire cause classification, the European systems have their own flaws associated with them. Europe uses wildland fire cause for the creation of wildland fire policy (Jackson 2003). However, there exist problems with the certainty of wildland fire cause (Lovreglio et al. 2010). Jackson (2010) believes that a possible reason to the problems with the wildland fire data in Europe is due to the lack of coordination between the various agencies and countries involved in recording wildland fire data. So coincidently in 2008 the European Commission Joint Research Center commissioned Cemagref, a public research institution, to determine a method of consolidating all wildland fire cause information, from the countries that are a part of the European Union, into the single uniform system, European Forest Fire Information System (EFFIS) with minimal loss of information integrity (European Union 2009).

In the beginning of the project Cemagref determined that the best way to create this new system of wildland fire cause categorization was to base the new wildland fire causes on the frequency of their occurrence in a particular European country (Cemagref 2010). Through the course of this process they noticed that there existed much heterogeneity of wildland fire causes between the European countries. So decisions had to be made as to when to merge or split causes in order to develop a uniform product similar to what had to be done with the NASF data set in this paper. A major decision was made from the onset of the project. This decision was to take any cause that was coded as ’other’ and categorize that cause as ’unknown’ (Cemagref 2010). In addition to this major shifting of the data, they grouped the cause into six different classifications (unknown, natural, accident, negligence, arson, and rekindle) and further split this classification into certain or uncertain in order to start determining a final set of wildland fire causes. Ultimately this initial classification system resulted in a building block system comprised of 3 levels (Figure 2).

Coincidently they have clear precedence at the same time as the research presented in this paper. In their final report Cemagref remarks on a clear distinction between fire cause and fire motivation (Cemagref 2012). They define fire cause as how a fire was initially generated (human or non-human), and motivation is defined as why a human started a particular fire. They also remark that motivation does not play a role in fires which were resulting in an act negligence or accident by a human. This is reflected in the final rendition of the EFFIS cause classification system that contained only six main causes (unknown, natural, accident, negligence, voluntary, and rekindle) (European Commission 2012).

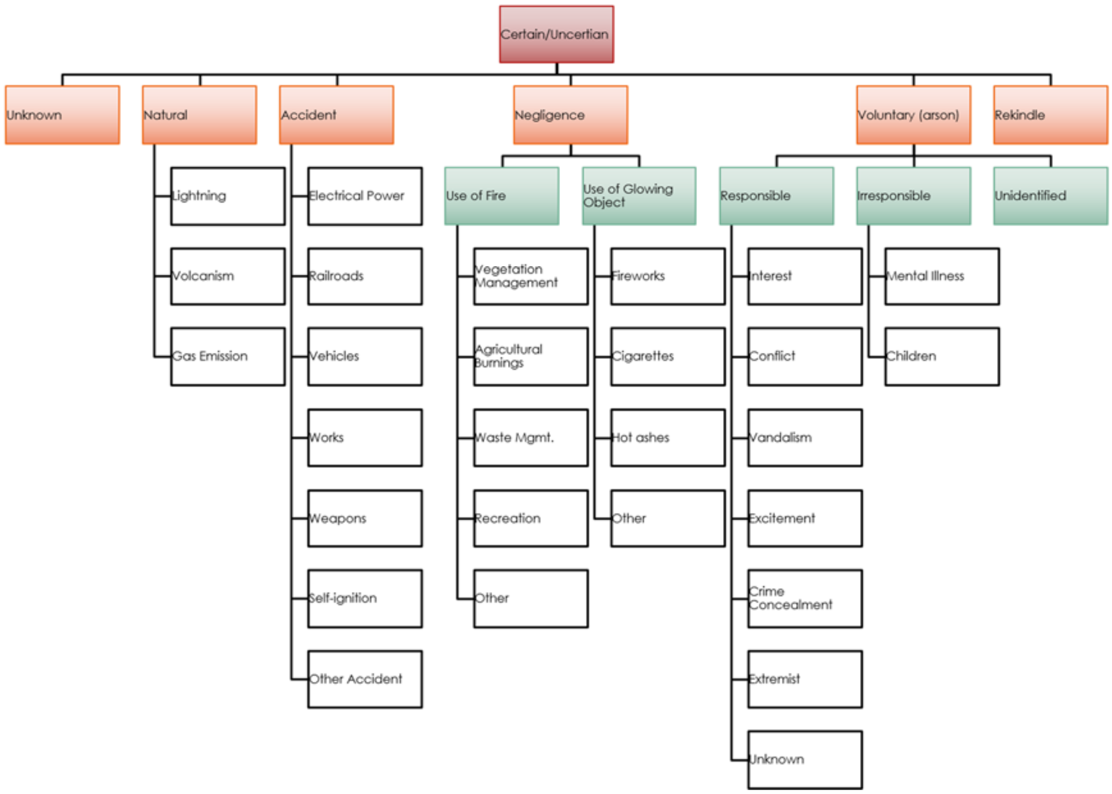

Figure 2 EFFIS wildland fire cause classification system; adapted from Cemagref (2012).

These main cause classifications are similar to those of the USFS statistical cause by their generality. One major note is that 'voluntary' was a change that the creators of EFFIS changed after Cemagref presented them with their suggestion of 'arson'. The sub-categories under the 'voluntary' (originally 'arson') field are a person's motivation rather that their action. This type of information is not clearly present in any of the United States classification systems. There may exist some cause categories that would suggest a person's motivation in the United States systems, but this would only occur by chance. On a final note, the EFFIS system is also very similar to a Building Block System that Donoghue (1982b) references as a possible solution to the United States wildland fire cause. But no other literature about such a proposed United States Building Block System can be found at the time of writing this research paper.

Methods

The study of wildland fire cause was conducted in two parts. We will refer to the broadest category of a classification system as the coarse cause. The first part of the study was to conduct a preliminary study of coarse cause only. The second part was to analyze the fine cause, any other information consistently provided by a state for a particular set of data submitted by a state in addition to coarse cause, of wildland fire and its interaction with coarse cause. The analysis of coarse cause was used to determine broad trends in the data that could then possibly be explained or defined better through the analysis of the fine cause of a wildland fire.

The wildland fire data used in this study was the data that individual states submitted through the course of the NASF project. Their data provided a total of 744,194 fires that occurred between 2000-2010. Of these fire records only 452,282 records were usable. The largest blocks of data that were omitted from the analysis were those of the entire state of California and the 2006 Texas volunteer fire department data. These two blocks of data were removed due to the duplication that existed in their submitted data. Other individual records were omitted from this study in addition to these large blocks of data, but these omissions will be discussed in further detail later.

Preliminary Data Processing

Data that was submitted to the NASF project came in a wide variety of formats. Ultimately, for the purposes of analysis, all data had to be translated to the same format. To do this data was processed individually by state and submission number.

To begin the processing of a particular wildland fire data submission, we first had to determine the general and fine cause data fields of a particular data submission, if such additional fields were present. The coarse cause of a particular data submission was determined by its relative consistency throughout the data set. By this we mean that if a given data set had two suspect cause fields, one of which had the same ten values repeated throughout the data set as compared to another suspect cause field which may have fifteen values repeated, then the group of ten values would be labeled the coarse cause field and the other labeled the fine cause.

Many times the fine cause field would not be this apparent as only a couple of states actually provided even the coarsest of data dictionary. An example of this was North Dakota (Table 6). North Dakota had three fields that were labeled cause in their data set. ’fire cause’ was determined to be that of the coarse cause field because 'fire cause II' and 'fire cause III' were sporadically filled with data compared to that of 'fire cause'. The 'explain' field in this case was determined to be that of the fine cause because 'explain1' and 'explain2' did not appear to always have a parent cause associated with them. Many of the states that submitted data had problems similar to these when gathering all of the cause information.

Table 6 North Dakota raw cause fields and field values.

Fire Cause	Explain	Fire Cause II	Explain1	Fire Cause III	Explain2
Open/out door fire	Controlled Burn	Other			
Other	Truck Fire				
Children	Bonfire	Open/outdoor fire		Other	Dead Trees
Debris, vegetation burning	Controlled Fire	Other			
Other	Fireworks		County Highway		
Equipment	Haying Equipment			Hay Swather	

The general and fine cause data were gathered while at the same time categorizing the coarse cause of a particular data submission for a particular state. Each data submission set of coarse cause was categorized as either the USFS standard nine, close to the USFS standard nine, or other. A data set was close to the USFS standard nine if its coarse cause values were close to an exact match (missing some of the nine values) or the coarse causes were an exact match with an additional one or two causes. A submission was classified as ’other’ if their coarse causes values were completely different that the USFS standard nine or had the standard nine causes but had many more causes in addition to the standard nine. This categorization process was done in order to compensate for the bias that would have been present in the coarse cause analysis that was created by the abundance of states that towards the end of the NASF project were ’massaging’ their data towards the NASF agreed upon standard nine cause classification system that was close to the USFS standard nine causes (T. Vonn, pers. comm., 2 March 2012).

After all data was placed in a single format and categorized, the omission process performed. Individual fire occurrences were omitted for two primary reasons. First, if there did not exist data in a general and specific fire cause for a particular fire occurrence, that fire was omitted. The reason for omitting this blank data was that no information could be gained from the occurrence data. Second, if the data itself could not be translated to a usable format. An example of this would be fire cause information that was in a numeric format that could not be translated to its meaning. Another example of unusable data would be that of apparent random keystrokes (like a numeric cause suddenly being a alpha key) in a cause field. The removal of unusable data was an essential step before any analysis could be performed.

Analysis of Coarse Cause

The coarse causes had to be grouped into new categories prior to any analysis taking place. The reason for this was that there existed 450 different values for coarse cause in the entire dataset. It was determined that this number of different coarse causes would not yield any usable results.

The recoding process was done by grouping the causes by similarity. An example of this grouping process can be found in Table 7, where causes associated with construction were grouped together. Given that no other information was provided to indicate specific activities that were occurring leading up to the wildland fire, causes in this case were grouped under ’construction’ because they all have something to do with construction. Many of the coarse cause groupings were done in this manner. Ultimately 34 new coarse causes were created (Table 8).

Table 7 Raw cause classifications that make up the coarse cause re-categorization of construction.

Construction	
Burning building material	Burning construction material
Burning construction waste	Const worker
Const/pipeline	Construction
Construction ?	Construction land clearing
Contractor	House construct

To determine the rank and frequency of the occurrence of coarse cause, the total number of occurrences of a specific coarse cause were calculated and then divided by the total number of wildland fire occurrences. To add another level of analysis, this was also calculated amongst the submission categories (standard nine, close to standard, other). This analysis produced a table in which the overall frequency of coarse cause regardless of submission category could be represented alongside that of the 'other' fire data submissions. The 'other' data submissions were chosen as a basis of comparison because as noted above, a number of states had begun to remap their original coarse causes to match the standard nine.

Table 8 All coarse cause classifications developed.

Potential Wildland Fire Causes		
agriculture	natural	ashes
camp fire	children	construction
unknown	debris burning	electric
false alarm	fire works	forest
vehicle	human	incendiary
lightning	matches	military
miscellaneous	mining	pest control
railroad	recreation	re-ignition
right-of-way maintenance	prescribed	slash
spontaneous combustion	structure	trash
equipment use	power line	smoking
undetermined		

Analysis of Fine Cause

In addition to the data problem already mentioned, in the beginning of the NASF project states submitted more than one cause in their wildland fire data submissions. However, towards the end of the NASF project some of the states that had been submitting more than one cause limited their submission to only one cause. Of the 50 states that submitted wildland fire data only 22 submitted a fine cause in addition to their coarse cause.

The analysis of fine cause was based on frequency like the analysis of coarse cause. Rather than a holistic approach of all states in one block of data, each state was analyzed as an individually. However, the analysis was conducted using the original coarse cause instead of the coarse cause that was created in the coarse cause analysis.

To analyze the contribution of fine cause to coarse cause, the coarse causes were totaled across a table with the fine causes and their contributions placed in the left side of the table (Table 9). Then in an iterative process the contribution of fine cause was subtracted from its corresponding coarse causes (Table 9). For example, in step 0 5000 is subtracted from 7075 because fine cause A represents 5000 fires of the coarse cause A. In step 1 the results of this transition can be seen when coarse cause A is now only representative of 2075 fires and the overall ranking of the causes was recalculated. The final result of each iteration (iter) yields the ranking of the causes as if a particular fine cause was a coarse cause. The results of each iteration also help to determine which fine causes are significant contributors to the overall ranking of fire cause in a particular state (Table 10).

Table 9 Fine cause analysis steps.

			Fine cause Analysis Step 0			
			Rank Before	1	3	2
			Rank After	0	0	0
Total	8853			7075	650	1128
Fine cause	Count	Rank Before	Rank After	Coarse cause A	Coarse cause B	Coarse cause C
** fine cause A	0	-	0	5000	0	0**
fine cause B	0	-	0	2000	12	0
fine cause C	0	-	0	0	300	0
fine cause D	0	-	0	2	12	5
			Fine cause Analysis Step 1			
			Rank Before	1	3	3
			Rank After	2	4	3
Total	8853			2075	650	1128
Fine cause	Count	Rank Before	Rank After	Coarse cause A	Coarse cause B	Coarse cause C
fine cause A	5000	-	1	5000	0	0
**fine cause B	0	-	0	2000	12	0**
fine cause C	0	-	0	0	300	0
fine cause D	0	-	0	2	12	5
			Fine cause Analysis Step 2			
			Rank Before	2	4	3
			Rank After	5	4	3
Total	8853			75	638	1128
Fine cause	Count	Rank Before	Rank After	Coarse cause A	Coarse cause B	Coarse cause C
fine cause A	5000	1	1	5000	0	0
fine cause B	2012	-	2	0	0	0
**fine cause C	0	-	0	0	300	0**
fine cause D	0	-	0	2	12	5
			Fine cause Analysis Step 3			
			Rank Before	5	4	3
			Rank After	5	6	3
Total	8853			75	38	1128
Fine cause	Count	Rank Before	Rank After	Coarse cause A	Coarse cause B	Coarse cause C
fine cause A	5000	1	1	0	0	0
fine cause B	2012	2	2	0	0	0
fine cause C	300	-	4	0	0	0
**fine cause D	0	-	0	2	12	5**
			Fine cause Analysis Step			
			Rank Before	5	6	3
			Rank After	7	5	3
Total	8853			73	26	1123
Fine cause	Count	Rank Before	Rank After	Coarse cause A	Coarse cause B	Coarse cause C
fine cause A	5000	1	1	0	0	0
fine cause B	2012	2	2	0	0	0
fine cause C	300	4	4	0	0	0
fine cause D	19	-	7	0	0	0

Table 10 Fine cause analysis final results.

	Iter 0		Iter 1		Iter 2		Iter 3		Iter 4	
Cause	Count	Rank	Count	Rank	Count	Rank	Count	Rank	Count	Rank
Coarse cause A	7075	1	2075	2	75	5	75	6	73	6
Coarse cause B	650	3	650	4	638	4	338	4	326	4
Coarse cause C	1128	2	1128	3	1128	3	1128	3	1123	3
fine cause A			5000	1	5000	1	5000	1	5000	1
fine cause B					2012	2	2012	2	2012	2
fine cause C							300	5	300	5
fine cause D									19	7

In the case of the example in Table 10, the significant contributors are fine cause A and fine cause B. These are considered significant because they cause a significant shift in the overall ranking of both coarse and fine cause steps 1 and 2 (Table 9). Such shifts throughout the analysis were recorded and noted as to which coarse cause they corresponded to. These shifts represent the shifting that would occur if one of these fine causes were adopted as a part of the standard nine causes that are present today. The final recommendations as to what changes to make to the USFS standard nine causes are based on these fine causes that shifted the rankings in a significant way.

Results

The analysis of wildland fire coarse cause was intended to provide a broad overview of the wildland fire causes across the United States. A little over twenty nine percent of wildland fires in the NASF data set were caused by debris burning (Table 11). Incendiary accounted for 16.0% of wildland fires and unknown accounted 11.4% of the overall fires. As a point of comparison the fire causes were ranked in the overall results that included all three cause categorical classifications and the other fire cause categorical classification of individual data submissions.

The other cause fire classification was defined a duplicated count of wildland fire cause that would occur if both fine and coarse causes were treated equally. When these were added debris burning fell from a rank of 1^{st} to 11^{th}. Miscellaneous fell from a rank of 3^{rd} to 7^{th}. Prescribed rose from 13^{th} to 6^{th} and power line rose from 16^{th} to 12^{th}. Unknown and undetermined causes rose to the top two ranks. The analysis of fine cause demonstrated similar results in shifting of the standard nine USFS causes as represented by the 'other' column in table 11.

Table 11 Count and percent of general wildland fire causes overall.

Coarse cause	Count	Overall	Other	Overall Percent of Total
debris burning	229588	1	11	29.4315
incendiary	124868	2	3	16.0071
miscellaneous	98290	3	7	12.6
unknown	89266	4	1	11.4432
equipment use	75301	5	5	9.653
lightning	38093	6	16	4.8832
undetermined	28226	7	2	3.6184
smoking	22839	8	29	2.9278
children	21207	9	10	2.7186
camp fire	13788	10	33	1.7675
vehicle	11049	11	4	1.4164
railroad	9926	12	28	1.2724
prescribed	4578	13	6	0.5869
false alarm	3108	14	8	0.3984
recreation	2441	15	9	0.3129
power line	2075	16	12	0.266
natural	1428	17	13	0.1831
human	1120	18	14	0.1436
re-ignition	988	19	15	0.1267
trash	625	20	17	0.0801
structure	368	21	18	0.0472
fire works	314	22	19	0.0403
slash	240	23	20	0.0308
electric	102	24	21	0.0131
forest	73	25	22	0.0094
ashes	65	26	23	0.0083
mining	33	27	24	0.0042
agriculture	28	27	25	0.0035
spontaneous combustion	20	29	26	0.0026
construction	17	30	27	0.0022
pest control	7	31	30	0.0009
matches	3	32	31	0.0004
right-of-way maintenance	3	33	32	0.0004
military	1	34	34	0.0001

The analysis of fine cause has been summarized in table 12 by only displaying the top 5 contributing fine cause categories. The superscript ranks represent the rank of the coarse cause before any fine causes were evaluated. The ranks not in superscript represent the resulting ranking after the top five fine causes were evaluated. Coarse causes in red represent the standard nine cause classifications of the USDA forest service. The full results of the fine cause analysis can be found in appendix A. Overall the coarse cause incendiary did not move in rank as much as compared to other coarse causes when the fine causes were added. Six states out of the twenty one states (Texas divided by volunteer and state forest service) had a drop in the rank of the coarse cause debris burning that was greater than or equal to 2 ranks. In Arkansas debris burning fell from 1st to 3rd due to the fine causes brush/leave, other, and trash. Other accounted for the 2nd overall after the top five fine causes were added into the analysis. In Florida debris burning fell from 1st to 4th. This can be accounted for by predominately yard trash, other, piled, power line, and trash. Georgia was different in that they only provided fine causes that were used to further sub-divide debris burning and this caused debris burning to fall from 1st to 7th. This was due to the fine causes brush/leave, agriculture, construction land clearing, escape prescribed burn, and slash disposal. In Louisiana debris burning fell from 4th to 9th; predominately, because of the addition of power line and break over. Debris burning in Nebraska fell from 1st to 6th overall. Fine causes that dominated were added were unknown, control burn, agriculture, and trash. Tennessee debris burning fell from 1st to 4th. The most dominate fine causes that were added were brush/leave, pyromania, and trash. Arkansas, Florida, Louisiana, Nebraska, and Tennessee had the fine cause trash ranked in the overall top 10 causes of a wildland fire after the analysis was done.

The fine cause miscellaneous also shifted rank in many states. In Texas, the volunteer fire department's (TX_VFD) original coarse cause miscellaneous shifted from 2nd to 10th. The dominant fine causes that attributed to this were power line and trash.

Table 12 Summary of the top five fine causes

Cause	AR count	AR rank	AZ count	AZ rank	CO count	CO rank	FL count	FL rank	GA count	GA rank	LA count	LA rank
arson			16	13$^{(8)}$								
camp fire	106	14$^{(9)}$	49	11$^{(6)}$			612	13$^{(8)}$	883	13$^{(8)}$	2	13$^{(7)}$
children	129	12$^{(7)}$	12	14$^{(10)}$			1102	8$^{(7)}$	1924	10$^{(6)}$	4	11$^{(6)}$
children (<12 yrs)												
debris burning	1240	3$^{(1)}$	151	6$^{(4)}$	328	4$^{(3)}$	1830	4$^{(1)}$	2512	7$^{(1)}$	15	9$^{(4)}$
electric fence												
equipment use	381	9$^{(4)}$	74	9$^{(5)}$	224	5$^{(6)}$	1714	5$^{(6)}$				
escaped prescribed burn											7	10$^{(4)}$
false alarm												
fire bug												
fireworks												
incendiary	744	6$^{(2)}$			134	11$^{(7)}$	3396	2$^{(3)}$	7548	2$^{(2)}$	16	8$^{(2)}$
lightning	451	8$^{(5)}$	371	3$^{(3)}$			5049	1$^{(2)}$	2063	9$^{(5)}$	2	13$^{(7)}$
logging												
machine use									7075	3$^{(3)}$	21	7$^{(3)}$
miscellaneous	548	7$^{(3)}$	214	5$^{(2)}$			628	12$^{(5)}$	3437	4$^{(4)}$	193	1$^{(1)}$
miscellaneous unknown												
misuse of fire					148	9$^{(8)}$						
natural source					431	2$^{(2)}$						
none												
open/outdoor fire					200	6$^{(5)}$						
other					163	8$^{(4)}$						
power line												
railroad	191	11$^{(6)}$	12	14$^{(9)}$			191	15$^{(10)}$	650	14$^{(9)}$	1	15$^{(10)}$
recreation												
re-ignition												
smoking	121	13$^{(8)}$	41	12$^{(7)}$	110	12$^{(9)}$	327	14$^{(9)}$	1128	12$^{(7)}$	3	12$^{(7)}$
smoking (adult)												
structure fire					3	15$^{(10)}$						
under invest												
undetermined			325	4$^{(1)}$	893	1$^{(1)}$						
unknown							3009	3$^{(4)}$				
agriculture									2531	6		
arson												
ashes					94	13						
auth yard trash							711	11				
breakover											48	3
brush/leaves	1195	4							8391	1		
burner												
burning												
burning vehicle			102	7								
camp fire												
construction land clearing									1348	11		
control burn											29	5
escape											24	6
escaped prescribed burn									3328	5		
excitement												
exhaust												
fireworks					77	14						
flame/torch used for lighting					142	10						
incinerator, burning barrel												
lightning					366	3						
miscellaneous												
mischief												
none												
open/outdoor fire (fine cause)												
other	1723	2	856	2			747	10				
piled							1344	7				
playing with fire												
power line							780	9			108	2
pyromania	3050	1										
recreationist												
residential												
running												
slash disposal	334	10	53	10					2283	8		
smoking												
spontaneous												
structure											32	4
trash	1178	5	89	8			1609	6				
uncontrolled unattended												
undetermined			2431	1	171	7						
unknown												
vehicle												
warming fire												
welding equipment use												

Table 12 Continued

Cause	MD count	MD rank	MI count	MI rank	MN count	MN rank	MT count	MT rank	ND count	ND rank
arson	4	$14^{(2)}$					2	$17^{(12)}$		
camp fire	68	$10^{(8)}$	155	$7^{(4)}$	1129	$10^{(7)}$	17	$14^{(4)}$	3	$21^{(16)}$
children	286	$4^{(5)}$	119	$9^{(7)}$	980	$12^{(8)}$	69	$8^{(8)}$	146	$6^{(7)}$
children (<12 yrs)										
debris burning	965	$1^{(1)}$	474	$1^{(1)}$	7155	$2^{(1)}$	541	$3^{(3)}$	384	$2^{(2)}$
electric fence										
equipment use	434	$3^{(4)}$	357	$3^{(2)}$	2477	$5^{(4)}$	156	$5^{(5)}$	510	$1^{(1)}$
escaped prescribed burn										
false alarm							115	$6^{(6)}$		
fire bug										
fireworks										
incendiary			77	$13^{(8)}$	11267	$1^{(2)}$	61	$9^{(9)}$	47	$13^{(11)}$
lightning	96	$8^{(7)}$	201	$6^{(5)}$	719	$13^{(9)}$	1868	$1^{(1)}$	261	$3^{(3)}$
logging										
machine use										
miscellaneous	152	$6^{(3)}$	347	$4^{(3)}$	2741	$4^{(3)}$	638	$2^{(2)}$	27	$15^{(9)}$
miscellaneous unknown			39	$16^{(11)}$						
misuse of fire										
natural source									11	$20^{(15)}$
none									25	$16^{(12)}$
open/outdoor fire									39	$14^{(6)}$
other									230	$4^{(4)}$
power line							9	$15^{(11)}$		
railroad	33	$12^{(9)}$	81	$12^{(9)}$	1819	$6^{(5)}$	91	$7^{(7)}$	13	$19^{(14)}$
recreation										
re-ignition									74	$11^{(10)}$
smoking	161	$5^{(6)}$	56	$15^{(10)}$	1254	$9^{(6)}$	6	$16^{(10)}$	136	$7^{(8)}$
smoking (adult)										
structure fire									15	$18^{(13)}$
under invest										
undetermined									22	$17^{(5)}$
unknown			139	$8^{(6)}$						
agriculture			83	11					76	10
arson	699	2								
ashes	93	9								
auth yard trash										
breakover										
brush/leaves										
burner					1126	11				
burning										
burning vehicle										
camp fire							431	4		
construction land clearing										
control burn										
escape										
escaped prescribed burn										
excitement										
exhaust			89	10						
fireworks	43	11					22	13	78	9
flame/torch used for lighting										
incinerator, burning barrel										
lightning										
miscellaneous									72	12
mischief										
none										
open/outdoor fire (fine cause)									130	8
other			387	2	1373	8				
piled					4665	3				
playing with fire										
power line	132	7								
pyromania										
recreationist			67	14						
residential							23	12		
running					1676	7				
slash disposal										
smoking							55	10		
spontaneous	21	13								
structure										
trash			270	5						
uncontrolled unattended										
undetermined									194	5
unknown							26	11		
vehicle					714	14				
warming fire										
welding equipment use										

Table 12 Continued

	NE		NJ		OR		TN		TX_FS	
Cause	count	rank	count	rank	count	rank	count	rank	count	rank
arson					268	$7^{(7)}$				
camp fire	97	$13^{(8)}$	857	$9^{(7)}$			71	$14^{(10)}$	56	$13^{(8)}$
children	74	$14^{(9)}$	3254	$3^{(3)}$	260	$8^{(8)}$	16	$20^{(15)}$	38	$14^{(9)}$
children (<12 yrs)							80	$13^{(9)}$		
debris burning	1132	$6^{(1)}$	1024	$8^{(8)}$	1634	$2^{(2)}$	682	$4^{(1)}$	1008	$1^{(1)}$
electric fence	70	$15^{(10)}$					3	$22^{(17)}$		
equipment use	1171	$4^{(3)}$	1662	$4^{(5)}$	1279	$3^{(3)}$	200	$9^{(5)}$	404	$5^{(5)}$
escaped prescribed burn										
false alarm			1375	$7^{(6)}$						
fire bug							447	$6^{(3)}$		
fireworks							11	$21^{(16)}$		
incendiary	453	$12^{(7)}$	7763	$1^{(1)}$			54	$16^{(2)}$	377	$6^{(4)}$
lightning	1516	$2^{(4)}$	186	$15^{(10)}$	2570	$1^{(1)}$	56	$15^{(11)}$	483	$3^{(3)}$
logging										
machine use							100	$12^{(8)}$		
miscellaneous	1278	$3^{(2)}$	3646	$2^{(2)}$	750	$4^{(4)}$	293	$8^{(4)}$	665	$2^{(2)}$
miscellaneous unknown										
misuse of fire										
natural source										
none										
open/outdoor fire										
other										
power line							49	$17^{(12)}$		
railroad	635	$9^{(5)}$	793	$10^{(9)}$	80	$14^{(9)}$	113	$11^{(7)}$	75	$11^{(6)}$
recreation					662	$5^{(5)}$				
re-ignition										
smoking	474	$11^{(6)}$	1657	$5^{(4)}$	399	$6^{(6)}$	30	$19^{(14)}$	61	$12^{(7)}$
smoking (adult)							119	$10^{(6)}$		
structure fire							37	$18^{(13)}$		
under invest					7	$15^{(10)}$				
undetermined										
unknown										
agriculture	675	8					294	7		
arson										
ashes										
auth yard trash										
breakover										
brush/leaves							1090	3	452	4
burner										
burning										
burning vehicle					160	13				
camp fire			304	14	171	10				
construction land clearing										
control burn	1170	5								
escape										
escaped prescribed burn										
excitement										
exhaust										
fireworks										
flame/torch used for lighting										
incinerator, burning barrel										
lightning									186	8
miscellaneous										
mischief			401	13						
none										
open/outdoor fire (fine cause)										
other			1561	6	226	9	559	5	344	7
piled										
playing with fire										
power line					167	12			139	10
pyromania			411	12			1852	1		
recreationist										
residential										
running										
slash disposal										
smoking										
spontaneous										
structure										
trash	726	7					1146	2	185	9
uncontrolled unattended										
undetermined										
unknown	2261	1	514	11						
vehicle	560	10								
warming fire					170	11				
welding equipment use										

Table 12 Continued

Cause	TX_VFD count	TX_VFD rank	UT count	UT rank	VA count	VA rank	VT count	VT rank	WA count	WA rank	WI count	WI rank
arson									128	$8^{(7)}$		
camp fire	445	$12^{(8)}$	96	$12^{(6)}$	325	$11^{(9)}$	93	$10^{(6)}$			960	$4^{(5)}$
children	258	$14^{(7)}$	69	$13^{(8)}$	1581	$6^{(6)}$	123	$6^{(4)}$	112	$9^{(6)}$	68	$14^{(9)}$
children (<12 yrs)												
debris burning	116	$2^{(1)}$	444	$4^{(4)}$	8671	$1^{(1)}$	313	$2^{(1)}$	586	$5^{(4)}$	1093	$3^{(2)}$
electric fence												
equipment use	387	$4^{(3)}$	593	$3^{(5)}$	1975	$4^{(4)}$	100	$8^{(3)}$			943	$5^{(4)}$
escaped prescribed burn												
false alarm			826	$2^{(3)}$								
fire bug												
fireworks												
incendiary	560	$11^{(6)}$	196	$8^{(7)}$	3280	$3^{(3)}$	95	$9^{(5)}$			1100	$2^{(3)}$
lightning	136	$8^{(4)}$	2638	$1^{(1)}$	852	$7^{(7)}$	45	$14^{(9)}$	103	$2^{(3)}$	307	$12^{(7)}$
logging									22	$14^{(1}$		
machine use												
miscellaneous	129	$10^{(2)}$	220	$6^{(2)}$	3414	$2^{(2)}$	260	$4^{(2)}$	867	$4^{(2)}$	2227	$1^{(1)}$
miscellaneous unknown												
misuse of fire												
natural source												
none									103	$3^{(1)}$		
open/outdoor fire												
other												
power line												
railroad	274	$13^{(9)}$	68	$14^{(9)}$	490	$10^{(8)}$	80	$13^{(8)}$	23	$13^{(9}$	491	$8^{(6)}$
recreation									489	$6^{(5)}$		
re-ignition												
smoking	133	$9^{(5)}$	16	$15^{(10}$	1769	$5^{(5)}$	83	$12^{(7)}$	64	$11^{(8}$	167	$13^{(8)}$
smoking (adult)												
structure fire												
under invest												
undetermined												
unknown												
agriculture	179	6	174	9								
arson					668	9						
ashes												
auth yard trash												
breakover												
brush/leaves							232	5			654	7
burner												
burning							594	1				
burning vehicle												
camp fire									437	7		
construction land clearing												
control burn												
escape												
escaped prescribed burn												
excitement											381	10
exhaust												
fireworks									43	12		
flame/torch used for lighting												
incinerator, burning barrel							120	7			465	9
lightning												
miscellaneous												
mischief												
none									407	1		
open/outdoor fire (fine cause)												
other	137	1	198	7					69	10	904	6
piled												
playing with fire									22	14		
power line	197	5	117	11	281	12	92	11			378	11
pyromania												
recreationist												
residential												
running												
slash disposal												
smoking												
spontaneous												
structure					144	14						
trash	399	3										
uncontrolled unattended			121	10								
undetermined												
unknown			441	5	685	8	313	2				
vehicle					179	13						
warming fire												
welding equipment use	162	7										

In Utah, miscellaneous fell from 2nd to 6th with the dominant fine cause unknown. Maryland had a more interesting shift of fine cause from 3rd to 6th. The dominant fine cause in Maryland was arson, however; arson mapped up directly to the coarse cause arson. This left only power line to be a dominant fine cause that would cause such a shift in rank. In North Dakota, miscellaneous fell from 9th to 15th. The dominant fine causes were fireworks, miscellaneous, open/outdoor fire. Undetermined, and agriculture. Miscellaneous in Arizona shifted from 2nd to 5th, however the two greatest fine causes were other and undetermined. Burning vehicle was a very far off 3rd contributing fine cause. Three out of five of these states had power line as a fine cause that accounted for greater than 100 fires.

Lightning was another coarse that that shifted in rank with the addition of top five fine causes. Four states exhibited noteworthy changes in the rank of lightning fires. New Jersey had lightning fall from a rank of 10th to 15th with a very dominant fine cause of other. In Vermont lightning fell from a rank of 9th to 14th. The top fine cause that was added to Vermont was burning. Wisconsin had lightning fall from 7th to 12th. The dominant fine cause in this state was also other. In Minnesota, lightning fell from 9th to 13th. The top three fine causes were piled, running, and other. In three out of the four states other was the dominant fine cause that contributed to the falling in rank of lightning.

Washington, Michigan, Texas Forest Service (TX_FS) and Virginia all had changes in the rank of the coarse cause rail road. In Virginia, railroad fell from 8th to 10th. The greatest fine cause was unknown. Washington had railroad ranked at 9th and with the addition of the fine causes the rank fell to 13th. The predominant fine causes camp fire and none. In Michigan, the railroad fell from 9th to 12th. The largest fine cause was other. The Texas Forest Service also had rail road fall from 6th to 11th. The dominant fine causes were brush/leaves and other. In three out of the four cases either unknown or none fine cause was specified.

In Colorado and Montana the smoking coarse cause fell several ranks when the fine causes were added in. Montana had smoking fall from 10th to 16th. The largest fine causes where camp fire, smoking, and unknown. In Colorado smoking fell from 9th to 12th. The largest fine causes added were lightning, undetermined and incinerator burning barrel. Both of these states had the addition of either undetermined or unknown.

Discussion

The results of the analysis of wildland fire cause in the United States indicated that there is room for some change to the USFS standard nine statistical cause classifications. The standard nine classifications have been in use for decades and little change has been made to them throughout their existence. The results indicated that debris burning could be split into trash, agricultural burning, industrial (forestry) burning and brush burning which would be similar to what had historically been recorded by the USFS (Donoghue 1982a). This was indicated by both the coarse and fine cause results. The coarse cause results showed that the overall rank of debris burning was 1st, but the when the other classification system was utilized it fell to 11th. Arkansas, Florida, Georgia, Louisiana, and Tennessee all had debris burning fall greater than or equal to 2 ranks when the fine causes were evaluated.

Debris burning was one of the causes that many researchers have not mentioned in their research of other datasets. Our research indicated that if a cause is classified as debris burning the underlying fine cause could be one of many different causes. Our results indicated that debris burning should be split into several categories. Georgia is a state that solely utilized fine causes to further explain debris burning. In the current state debris burning by itself does not clearly define what type of debris was burning. The debris could be a residential person or an industry burning slash. The first major split that the results suggest is separating residential and industrial debris burning. Furthermore both of these classifications can be performing a prescribed burn. This type of action appeared to be more common than expected in the research. Even though prescribed burning could be a fire department assisting with the action of performing such an act. If debris burning were to be re-categorized into only three groups we would suggest agricultural burning, industrial (forestry) burning and brush burning with prescribed burn being its own cause.

Miscellaneous fires were found to contain many references to vehicles and power lines which would be going back to a classification that existed many decades ago (Donoghue 1982a). The Texas Volunteer Fire Department was an example of power lines shifting miscellaneous from 2nd to 10th when power lines were added. Arizona was an example of miscellaneous falling from 2nd to 5th when burning vehicle was added.

As a point of comparison, the research done by Donoghue (1982a) and Chandler (1960) suggested that there was some lumping of unknown fire causes occurring within miscellaneous, incendiary, and smoking wildland fire causes in the USFS data. The results of our analysis of fine cause indicated that there did exist some lumping of wildland fire causes in the miscellaneous and incendiary wildland fire causes, but the smoking wildland fire cause tended to be fairly mutually exclusive from the rest of the wildland fire causes. Even in the coarse cause analysis there appeared to be something occurring with the miscellaneous and smoking fire cause categories just by comparing the differences between rankings of the overall results with that of the other classification system. However, miscellaneous was destination that held many different fine causes. North Dakota had fine causes that included fireworks, miscellaneous, and open/outdoor.

The results showed that unknown should be a fire cause all by itself because during the coarse and fine cause analysis of the wildland fire causes it was observed that unknown fires were appearing in all of the wildland fire causes except that of the lightning fires. The coarse cause analysis results indicated that unknown fires were a dominate factor because the overall rank of was 4^{th} and when the other classification system had these fires ranked 1^{st}. Nebraska was the best example of unknown fires for the fine cause because unknown fine cause resulted in a rank of 1^{st} by dropping the previously 1^{st} rank of debris burning to 6^{th}. Even though Lovreglio et. al. (2010) stated that an unknown fire does not provide the researcher with any useful information. However Lovreglio et. al. (2010) do state that the USFS does have a problem with the miscellaneous, incendiary, and smokers categories representing unknown fires. By adding unknown category, this would remove the problems associated with these particular cause categories and allow the miscellaneous cause category to act as a category that that represents fires that the other potential causes would not represent as the way that Cemegref (2012) has utilized miscellaneous.

Another interesting comparison of our results with what others that have analyzed is the apparent need for lightning to be mutually exclusive. This means that if a fire were caused by lightning then there should not be another cause needed to further describe what caused the fire. Brown et. al. (2002) had noticed dramatic differences between the Department of Interior (DOI) and the USFS in the number of lightning fires. Their hypothesis for the reason for this was that if a fire was not able to be determined in the USFS then a USFS fire manager would categorize the fire as caused by lightning. This trend appeared in the overall results of this study as compared to the states that utilized another classification system when the overall rank of lightning fell from 6th to 16th in the other ranking. This indicated that our results of the wildland fire analysis had a similar trend. During the fine cause analysis of New Jersey, Vermont, and Minnesota utilized the other fine cause in conjunction with the lightning coarse cause. Other states did not have any significantly apparent fine causes associated with the lightning coarse cause. So at this point there does not exist significant evidence in the analysis to suggest any lumping of wildland fire causes into the lightning category. However, another item that Brown et. al. (2002) does suggest is that wildfires have a tendency to occur where people are located and more specifically where people are traveling (either recreationally or using a source of infrastructure).

Our results do show that a large amount of wildland fires do occur by people who are utilizing vehicles. Whether these vehicles are being used on road ways or recreationally is inconclusive. In the coarse cause evaluation alone the other classification had a rank of 4th and the overall had a rank of 11th. Vehicles were a fine cause that was apparent under either miscellaneous or equipment use coarse causes. Vehicles when removed from these two categories and represented on their own tended to fall into either the top ten or close to the top ten fire causes after all fine causes were evaluated. This cause is one of the causes that the results suggested should also be an addition to the standard nine cause classifications.

Power lines appeared under the miscellaneous cause category and when extracted represented fires close to the top ten causes in many states. The coarse cause analysis results showed power lines shifting from 16th in the overall to 12th in the other classification system. In the fine cause analysis they were the one of two dominant causes that changed the rank of miscellaneous in the Texas Volunteer Fire Department fine cause analysis. Power lines would be another suggestion from the research to remove from miscellaneous and add to the standard nine causes for the same reason that we suggest vehicles as their own cause.

The main reason that we agree with what the results are suggesting is that these additions to the standard nine wildland fire causes are the same as what many researchers have documented about the USFS data. There are problems with the current system of wildland fire cause classification in the United States and many have suggested that expanding the wildland fire causes would aide in reducing the problems with the current wildland fire cause classification system (Donoghue 1982a, Chandler 1960, Brown et. al. 2002).

Jackson (2010) suggests that a wildland fire cause should reflect the situation that caused the wildland fire. We agree with this idea in that by adding these causes the situation will be more readily definable to future researchers. Our results could have had different results if the data had not been skewed towards the standard nine causes, but we believe if that had not been the case the conclusions to add more wildland fire causes would still be the same. Also a good portion of our data had been removed due to suspected duplication and lack of being able to definitively translate it to a useable format. Even with all of these limitations to our research, we believe our results to be representative of the current wildland fire cause situation in the United States. However, the state of the current situation in the United States did not differ from the situation that was exemplified by Cemagref in Europe.

Cemagref (2010) states that there did exist situations where the wildland fire cause of a particular fire could not be found. During this investigation Cemagref determined a method for fitting causes into a dichotomous key in order to sort through the wildland fire causes from various countries. This dichotomous key determined how a wildland fire cause would fit into the new hierarchical key. This method of classifying wildland fires is similar to the alternative building block system that Donoghue (1982a) mentions. This particular method of classification does provide a key break in the wildland fire causes. This break is a fire caused by a human and a natural fire (Cemagref 2012). This distinction is also present in the USFS fire cause classification system except that the fire cause is not broken down as much as the European system. The European Commission Joint Research Centre (2012) does conclude that the final product of EFFIS will not provide a one to one correspondence between that of the countries' original coding classification and that of EFFIS, but the system is designed to be expandable over time. With this stated the USFS system could be improved by adding additional cause codes to the existing system without having to adopt a completely new system that could cause the loss of historical wildland fire data as indicated by our results.

Conclusion

The overall results of this study indicate that the major outliers of the causes of wildland fires are debris burning, miscellaneous, and incendiary. The fine cause classification can provide a method for determining any additions to the existing standard nine causes. Debris burning appears to be a very broadly defined cause and should be split into several categories in order for a better understanding of what exactly has caused a particular wildland fire. Two major distinctions for debris burning are agricultural (or job) related debris and the residential debris burning. Miscellaneous wildfires seem to contain many different causes of wildland fire. Two causes that can easily be developed into their own categories are power lines and vehicles. Both of these causes appear in abundance under the miscellaneous coarse cause category. Vehicles are a primary form of transportation and do cause many of the wildland fires, whether that be from a vehicle on fire or the exhaust of a vehicle. Incendiary is one cause that could be split up into many different categories, but there does not exist a clear concise definition as to what an incendiary fire is. This makes dividing up the incendiary fire cause very difficult. Overall that would be an addition of at least five or more cause categories to the existing USFS nine statistical causes.

The underlying problem with wildland fire causes is a lack in consistency in the definition of a particular wildland fire cause. One example of this is incendiary. Some states use incendiary as a category for arson fires while others use it to place fires that were simply set by humans. With the addition of any new causes to the standard nine there needs to be a clear and concise set of definitions for each cause.

As for the USFS system of wildland fire cause categorization into three separate cause classes, there appears to be no problem with this as long as the definitions are clear. The European system does have one major benefit in that if a wildland fire cause is not known there is an option to simply categorize a fire as unknown. The NFIRS database does allow for this selection but having too many finer causes with that of a statistical or major or primary cause does lead to problems with analysis of the data as seen in Wisconsin when fine causes have only been used twice in over ten thousand fires. This being said the cause system or categories themselves must be dynamic and able to grow or shrink over time with the needs of the wildland fire manager.

CHAPTER III

A COMPARISON OF LOCATION SYSTEMS: UNITED STATES PUBLIC LAND SURVEY AND GEOGRAPHIC COORDINATE SYSTEMS

Introduction

The location of a particular point is important when performing any spatial analysis. The accuracy of location information will affect the results of such analysis. Location information can come in many formats. One such example of location information is the street address of a location. Street address information is widely used in conjunction with modern Global Positioning System (GPS) aided navigation systems to provide directions from one location to another (Hong and Vonderoche 2011). Hong and Vonderoche (2011) determined that positional accuracy had a negligible effect on overall travel time between locations given uncertainty of the input of Geographical Information Systems (GIS) street information. Another application of address information is when census data is overlaid with street data address data to determine the general socioeconomic information for a given address (Ratcliffe 2001). Ratcliffe compared the accuracy of census data against various geocoding address algorithms. His results showed that accuracy can vary based on which algorithm is used to geocode the address. As a final example of a situation where accuracy is important, is when modeling wildland fire behavior (Alexander and Cruz 2013). Inaccurate location information among any other inaccurate fire information can affect the results of a wildland fire model.

The analysis presented in this chapter utilizes wildland fire data in the United States as an example of an application in which more than one location method is utilized to describe a single spatial event. Wildland fire data utilizes a system of location known as the United States Public Land Survey System (USPLSS) in the United States in addition to other methods of location description. The USPLSS system is a very old non-coordinate based system. However, this system is still in wide use today in many applications other than that of wildland fires.

Data for this study was obtained during a 2004-2009 National Association of State Foresters wildland fire database project of the Spatial Sciences Laboratory at Texas A&M University. During the project some individual states submitted wildland fire data that contained both USPLSS and another geographic coordinate system as a way to define the location of a particular wildland fire. The overall purpose of this chapter is to determine if there exist a significant difference between USPLSS and another geographic coordinate system at the county level. By doing this it was assumed that the county was the most accurate known location provided by an individual state. To begin the analysis, fire locations were analyzed if a pair of points lies inside or outside of a county with respect to each location system present and the significance of these differences were determined by utilizing McNemar's χ^2 test. As a second level of analysis the pairs of points were analyzed as to their distance relative to the county border utilizing the Stuart-Maxwell test. As a final analysis the distributions of each set of points distance relative to a given county was utilized to determine if there exist any anomalies in the data.

Coordinate Systems

Coordinate systems are a way of locating or referencing a point on the earths surface in xy (USGS 2010). These systems have been used throughout history to describe locations on earth. Examples of these systems include latitude/longitude (xy), UTM (xy), state plane (xy), and USPLSS (xy) systems.

A key aspect of many coordinate system is that of its projection. Since the earth is approximately an oblate spheroid (also called an oblate ellipsoid), there has to be a defined way of flattening it into a map. Methods of flattening the earth or portions of the earth are called projections. They describe a mathematical projection as a part of the three-dimensional earth onto a plane (as a sheet of paper). Some common methods are Transverse Mercator and Lambert Conformal (USGS 2010).

All coordinate systems are based on a datum. A datum describes the origin of the coordinate system or rather the shape and position of the ellipsoid that defines how the earth is centered. For example, longitude is the angle of a point relative to the Prime Meridian, Latitude is an angle relative to the Equator and the center of the earth to form a single point based on a particular datum that has been pre-established in conjunction with the stated coordinate system. Two examples of datums include North American Datum (NAD) 27 or NAD 83. NAD 27 was developed in 1927 and has a starting point in Meades Ranch, Kansas with a projection based on the Clark Ellipsoid (USGS 2010). NAD 83 was an improvement to the NAD 27 system by implementing satellites and the same origin but using a different newer spheroid that was based on distance from the center of the earth (USGS 2010). This made NAD 83 a more accurate datum than that of NAD 27.

The UTM coordinate system is based on a system dividing the earth into sixty north-south zones with each equaling six degrees in longitude wide (USGS 2010). This system, unlike that of latitude/longitude, has a standard unit of meter. This means that the distance between points on a map will be in units of meters instead of degrees and can be for any chosen ellipsoid. The UTM coordinate system can be used to describe a point anywhere in the United States between 80˚N to 84◦N longitude. All USGS topographic maps utilize the UTM coordinate system with the NAD 27 projection, but some newer maps using the NAD 83 projection (USGS 2010).

Another common system used in the United States is the State Plane System. This is actually a set of 120 zone based systems where each zone is state specific and either covers a whole state or a portion of a state (USGS 2010). Many local municipalities utilize this system due to this high level of precision that is achieved by its use of small zones. The system utilizes the same Transverse Mercator projection as the UTM system in cases where the state runs with a long north-south boundary, while states that are wider than long utilize the Lambert Conformal projection. Unlike the UTM system, the linear unit of the State Plane System is feet in most cases.

Some systems only describe parcels of land and their location relative to monuments instead of utilizing a projection. Two such systems are the metes and bounds system and the United States Public Land Survey. The metes and bounds system was created in the original thirteen colonies, while the USPLSS began in 1785, and covers most of the modern United States. They do not have (x,y)-type coordinates associated with them, but they have been tied to a coordinate system using a variety of methods.

USPLSS

The United States Public Land Survey was created in accordance with the Land Ordinance of 1785. The original survey of Ohio, the first state to be surveyed, began in 1785. The purpose of the land survey was to divide the United States public lands in the Northwest Territory into a system of approximately rectangular parcels of land to facilitate transferal of public lands into the private domain (Avery and Burkhart 1994). The original survey divided the territory into townships (northing) and ranges (easting) nominally six miles square, then to further subdivide most townships into 36 sections that would be nominally one mile square. Most sections were divided into quarters that are nominally 1/4 mile square, then many quarters were further divided into quarter-quarters that are nominally 1/16 of a mile square. Figure 3 provides a simple illustration of this.

The locations of USPLSS townships are based on a system of baselines and meridians (Avery and Burkhart 1994). Baselines and meridians are nominally lines of longitude and latitude, respectively. The intersection of any given baseline and meridian is a point called the initial point. There are a total of 46 sets of meridians and baselines in the public land survey, each of which has its own unique name. In addition, three meridians in Ohio were the result of private land surveys that used a similar system (as indicated by Figure 3). Townships to the east of the initial point are given sequential numbers as are those to the west. The ranges are to the north or south. While both township and range numbers define the area location, that area is usually referred to simply as township. For example, T2NR3W represents a township with its southeastern corner nominally two miles north and three miles west of the initial point. The earliest surveys suffered because the curvature of the earth was not taken into account. In later surveys this was taken into account and guidelines were added to ensure that the curvature of the earth was represented (Avery and Burkhart 1994). The guidelines (the heavier lines in Figure 3) were 24 miles in length, nominally due north (south) and east (west).

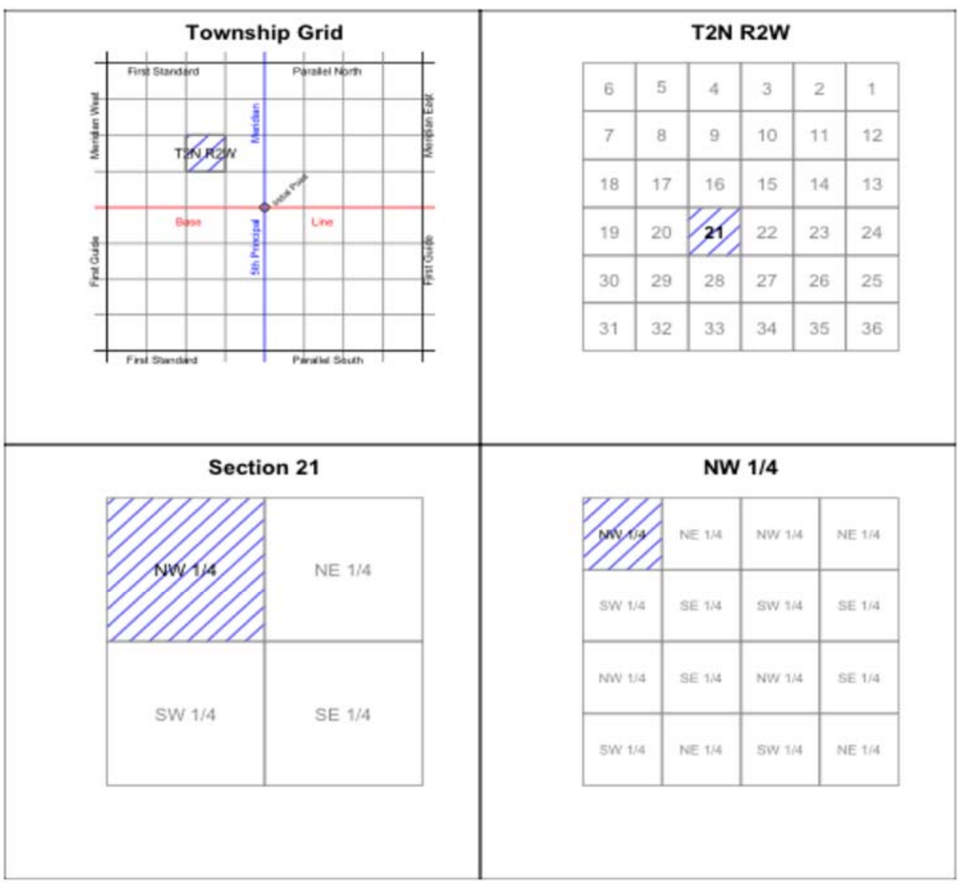

Figure 3 An illustration of the USPLS depicting the derivation o f the NW 1/4 NW 1/4 S. 21, T2N, R2W, 5th P.M.

A person can find a corner on the survey that is physically located on the ground using the system of monuments that were left in place by original surveyors (Dahlberg 1984). The most common system, in a forested area, of marking was conducted using a method of bark blazing on specific trees (Avery and Burkhart 1994). One major problem with this system of monuments is that the physical monuments may no longer exist due, for example, to landslides or land use changes (Dahlberg 1984). A possible solution as Dahlberg suggests is to reestablish these monuments and maintain the monuments after they have been reestablished. A major issue with the United States Public Land Survey data is that there is known error. The surveyors themselves may have made an error, and this error may not have a definite solution for correction (Figure 4) (Bourdo 1956; Dahlberg 1984). Figure 4 provides an example where ranges 13 and 14 east do not line up as prescribed by the design of the USPLSS. Also sections 1-6 of range 13 are close to one square mile as compared to those of range 14 section 5 of township 24 north. On a final note about Figure 4, there are clear lines of correction for the curvature of the earth represented by a solid bold line.

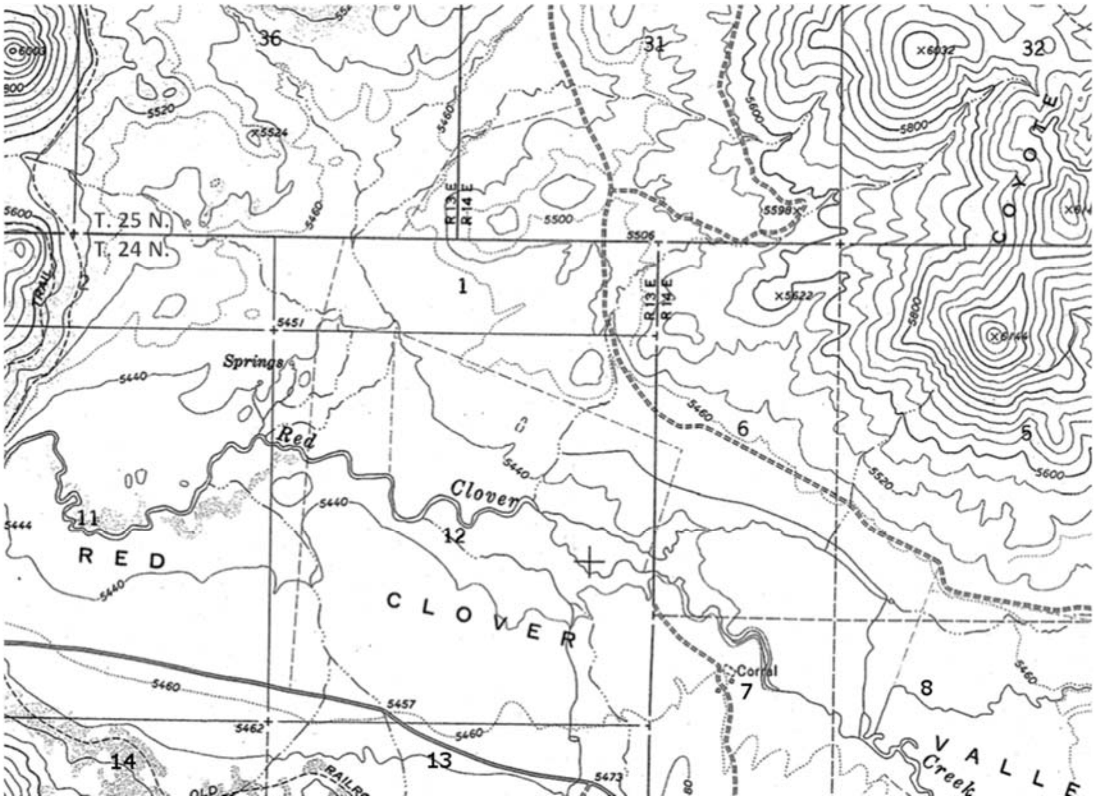

Figure 4 Portion of the Crocker Mountain Quadrangle USGS 7 1/2 - minute quadrangle map (USGS 1972) illustrating corrections due to the earth's curvature and measurement error in the USPLS. Shown are townships (sections) T25NR13E, T25NR14E, T24NR13E, T24NR14E, T25NR13E(35, 36).

Existing Conversion Processes: USPLSS to Latitude Longitude

The USPLSS is not a modern coordinate system as mentioned above; however, there have been efforts to link this land survey to a modern coordinate system. These efforts have been done by corporations, federal/state/local government, and educational institutions. Montana State University (trs2ll), Bureau of Land Management (Geographic Measurement Management for Windows or WinGMM), and Cadastral National Spatial

Data Infrastructure Project (CadNSDI) are three examples of this effort to link the USPLSS to a modern coordinate system.

Trs2ll is a software program that converts USPLSS section level data to point of latitude and longitude for only seventeen states (D. Gustafson pers. comm. 7 September 2011; Wefald 2011). However, the process behind the code to convert this information was developed by Martin Wefald, who has retired from the USGS, and is presented by Daniel Gustafson. Gustafson (2011) stated that the system is based on regression of uniform blocks placed over uniform public land survey territories. In addition he states that most of the code behind the program is data to deal with the irregularities of the USPLSS system. The system itself is tied to either NAD 27 or NAD 83 based on what the user defines. The accuracy of the system itself varies depending on the location of interest due to the irregularities on the survey itself (Gustafson 2011).

WinGMM is software developed much like that of trs2ll except that it covers all United States Public Land Survey states and generates shape files for use with in GIS. The WinGMM utilizes a least squares analysis to determine how the townships will map out in either NAD 27 or NAD 83 datums (Bureau of Land Management 2001). There are levels of data that the system utilizes. The first level is the monuments, and they are used as control points for the overall projection of the USPLSS (Bureau of Land Management 2001). The next level of the software utilizes plat data which defines the lines between the monuments. The final level assigns points to the corners of the township, section, quarter, quarter quarters based on the results of the least squares calculations of the above two levels. The major advantage of this system is that the software records accuracy of the prediction error, based on the least squares calculations, to each of the USPLSS corner points.

Cadastral National Spatial Data Infrastructure (CadNSDI) is a current federal project to map the USPLSS data in an electronic format. This project utilizes three levels of data to link the USPLSS with a modern coordinate system. The three levels of CadNSDI data sources are Authoritative, Trusted, and Cadastral (Federal Geographic Data Committee Subcommittee for Cadastral Data 2009). Authoritative data comes from legal authorities like that of a local tax collector's office or a county/state government. Trusted data comes from sources that have a documented method of developing the data like that of the Bureau of Land Management. Cadastral data comes from sources that only contain information that is tied to monuments that can be tied to a modern coordinate system. The CadNSDI projects process is not based directly on regression, but rather that of merging all of this information into one contiguous dataset (Federal Geographic Data Committee Subcommittee for Cadastral Data 2011). The data that is submitted to the project is prepared to merge into the USPLSS system data using a set of validation rules that prevent duplication in or degradation of the overall data (Federal Geographic Data Committee Subcommittee for Cadastral Data 2011). Like the WinGMM software system, CadNSDI records the relative accuracy of the data for each piece of data; however, CadNSDI categorizes all of their data as to its accuracy in addition to providing the numerical accuracy of the data.

Global Positioning Systems

In recent years many firefighting agencies have adopted the use of global positioning systems (GPS) for recording the location of fires. These systems receive geographical units (latitude and longitude), but some may be programmed to output UTMs.

In 1963, the Space Division of the United States Air Force developed the first GPS (McNeff 2002). GPS coordinates are based on the triangulation of at least three satellites and a ground based unit. GPS is a system of location based on time (McNeff 2002). The speed of light allows the calculation of the distance that the pulse from the satellite travels. The use of atomic clocks both within the GPS unit and on each satellite permits, at least in theory, very accurate determination of location.

A GPS device can retrieve the time from as little as three satellites to calculate the user's relative location on the ground (McNeff 2002). The accuracy of the location given by the users unit is increased by linking the information with that of a stationary ground based unit in the particular area that the person is located in and the number of satellites from which the unit receives information (Jiung-yao and Chung-Hsien 2008). However, a number of factors can interact to degrade the quality of GPS data. For example, the atmospheric conditions can affect the receiving power of a GPS unit that would inhibit the unit from receiving an accurate time from satellites (Bajaj et al. 2002). Also terrain and vegetative canopy can cause distortion of the signal receiving time for the unit (Jiung-yao and Chung-Hsien 2008). Another factor that may inhibit the dependability of the unit is that of the unit and user (McNeff 2002). The user may adjust settings on the unit that will cause the unit to inaccurately calculate a position (Jiung-yao and Chung-Hsien 2008). Also the user may not be aware of how many satellites have been received for a particular point of interest, which will cause irregularities in information analysis (McNeff 2002). The unit itself may have internal software calculation errors that the user is unaware of (McNeff 2002). A miscalculation in signal time in the magnitude of only milliseconds can cause the inaccuracy of a GPS location to be off by 200 miles depending on the altitude of the satellites (Bajaj et al. 2002). As with most modern technology, the quality of GPS reading is improving on a daily basis, but there still will exist issues with its accuracy.

Hypothesis and Assumptions

1) People who know USPLSS are able to locate themselves fairly accurately on a map to at least the Quarter Quarter section unless they are near a boundary.
2) While even recreational grade GPS may be quite accurate, reported coordinates may be considerably off.

The analysis portrayed in this chapter was based on two basic assumptions of the data. The principal assumption of the analysis was that the reported county was the most accurate location that was submitted to the project. In addition it was assumed that some of the states were converting from one location system to another location system. This idea that a state was converting from one system to another would cancel itself out in the analysis because if they were accurately converting from one system to another then both points would be relatively close to each other. With both points occurring relatively close to each other then the points would be relatively equal in their position in or out of a county. These two assumptions are what enabled the analysis that is portrayed in this chapter.

Methods

The data were analyzed on a state by state basis because different states submitted different types of location information, latitude and longitude, USPLSS, etc., and the data for each state were for different temporal periods. Each state's set of data was merged and cleaned. The cleansing process ensured that USPLSS data had all elements necessary to translate them to latitude and longitude. The primary element that had to be added to the data was the meridian. The meridians were obtained using ESRI ArcGIS® to determine what counties were on a particular meridian. In addition, in many cases township direction (N,S) and range direction (E,W) were swapped and many states submitted section data that was greater than 36. While the USPLSS allows for section numbers greater than 36 in resurveys, for example, California Township 13 North Range 1 East, Humboldt Meridian, townships having such sections are extremely rare and the information is difficult to verify. For the instances where USPLSS information was not completely decipherable the entire piece of data was omitted from analysis. The geographic coordinate system data was submitted most commonly as latitude and longitude but a couple of states submitted UTM data. The latitude and longitude information primarily had a problem of being flipped and the longitude had to be converted to a negative number. The UTM information more often than not required the assignment of zones.

Once the data was clean, the USPLSS data had to be translated into a geographic coordinate system in order to compare the location information to that of the corresponding geographic coordinate. Data was uploaded to the Bureau of Land Management's TownshipGeocoder web service (http://www.geocommunicator. gov/GeoComm/lsis home/townshipdecoder/index.htm [Verified 08 May 2013]). This service provided latitude and longitude of the center of the USPLSS location. This center was determined by the grain of the USPLSS information that was submitted. For example, if only township information was submitted, then the center of the township was produced; if the section was submitted to the web service, then the center of the section was produced. Not all data was translatable by the web service because some of the USPLSS data is not available via GeoCommunicator and in this instance the data was removed from the data set.

The two points (translated USPLSS and geographic coordinate) were uploaded into ESRI ArcGIS®, and the counties of a particular state were overlaid with the points. All points and counties were mapped using the coordinate system GCS North American 1983 and NAD 1983 datum. These datum and projection were chosen because it is consistent with historical USGS topo maps from which all or most USPLSS coordinates were determined and GeoCommunicator uses these as well. Then the points and counties were projected to the coordinate system North America Albers Equal Distance Conic and NAD 1983 datum in order to have an equal distance linear measurement (in meters).

A spatial join between the points and their corresponding county was performed to determine if a particular point was located in its county. If a point was not located in the declared county, then the euclidean distance to the edge of the county was calculated. These distances were then parsed into five categories (.5 km, 1 km, 5km, 10km, >10km) and counted, similar to that of Ratcliffe (2001). Also the maximum, average, and median distances were taken on a state-by-state basis omitting the points which fell inside of the declared county as they were valued at 0km. The points correctly falling within a declared county and those falling outside the county were quantified. After all states were analyzed, the data was merged together to form a holistic analysis of the United States.

In order to evaluate the findings all data was transformed into individual contingency tables by state and holistically as one contingency table based on the paired location data. The first sets of contingency tables were for the analysis of points that reside in or out of the county for a given pairing of location methods. To analyze these results McNemar's χ^2 test was utilized. McNemar's χ^2 test evaluates the equality of the probability (p) along the diagonal (p_{21}-p_{12}) of a 2x2 contingency table as seen in Table 13 (McNemar 1947).

Table 13 Example of McNemar χ^2 contingency table. Where p represents probability and a represents the count of wildland fire events that occur in a given category.

		USPLS		
		In County	Out County	Row Total
Other	In County	a_{11} (p_{11})	a_{12} (p_{12})	$a_{1.}$ ($p_{1.}$)
	Out County	a_{21} (p_{21})	a_{22} (p_{22})	$a_{2.}$ ($p_{2.}$)
	Column Total	$a_{.1}$ ($p_{.1}$)	$a_{.2}$ ($p_{.2}$)	$a_{..}$

The null hypothesis states that p_{21} is equal to p_{12} (Equation 1). The probability that a count of events were in the declared county for USPLS and out of the declared county for the other system of location was calculated by dividing the total number of events that met this criteria (a_{21}) by the total number of events ($a_{..}$) in the matrix. By rejecting the null hypothesis we are accepting that these two probabilities are not equal and there does exist some difference between the two location systems (Equation 2). p_{21} is the probability that the count of events where USPLSS occurred in the declared county, but the Other coordinate indicates that it did not. p_{21} should be equal to p_{12} given that the two location systems are assumed to describe the same location. The significance of the difference between these probabilities was calculated via McNemar's χ^2 as represented in equation 3. So in other words if a point is out of the county for USPLSS then that same point should be outside of the county for the other system of location.

$$H_O: p_{21} = p_{12} \qquad \textbf{Equation 1}$$

$$H_1: p_{21} \neq p_{12} \qquad \textbf{Equation 2}$$

$$\chi^2 = \frac{(p_{12} - p_{21})^2}{p_{12} + p_{21}} \qquad \textbf{Equation 3}$$

The second set of contingency tables were set up to describe the distance to county. The points that resided in the county were given a value of 0 km. The Stuart-Maxwell test was utilized to analyze the interaction or lack of interaction between the two location systems and how far off each system was with respect to the county. The contingency table was set up similar to that of the McNemar's test, but the data was placed in the table based on the five categories (Table 14).

Table 14 Example of Stuart-Maxwell χ^2. Where *p* represent probability and *a* represents the count of wildland fire events that occur in a given category.

		USPLS						
		0.0km	0.5km	1.0km	5.0km	10.0km	>10.0km	Row Total
Other	0.0km	a_{11} (p_{11})	a_{11} (p_{12})	...	...	...	...	$a_{1.}$ ($p_{1.}$)
	0.5km	a_{21} (p_{21})	a_{22} (p_{22})	...	...	...	...	$a_{2.}$ ($p_{2.}$)
	1.0km	a_{31} (p_{31})	a_{32} (p_{32})	...	...	...	...	$a_{3.}$ ($p_{3.}$)
	5.0km	a_{41} (p_{41})	a_{42} (p_{42})	...	...	...	...	$a_{4.}$ ($p_{4.}$)
	10.0km	a_{51} (p_{51})	a_{52} (p_{52})	...	...	...	...	$a_{5.}$ ($p_{5.}$)
	>10.0km	a_{61} (p_{61})	a_{62} (p_{62})	...	...	...	...	$a_{6.}$ ($p_{6.}$)
	Column Total	$a_{.1}$ ($p_{.1}$)	$a_{.2}$ ($p_{.2}$)	...	...	...	...	$a_{..}$

McNemar's test could not be utilized in this case because it is only valid or 2x2 tables and this table is 6x6. The Stuart-Maxwell test null hypothesis states that all probability pairs are equal for each set of rows and columns (Equation 5) (Chow 2010). If is one set for which the pair is statistically different then the null hypothesis is rejected (Equation 5). This test was utilized to support the purpose of this paper which is to determine if there is a significant difference between two location systems. The purpose of this test was to determine if there existed a significant distance variation among the two different location systems. As an example the overall probability for a location to be 0 km for USPLS and Other, the probability of a set of points to be 0 km is represented by $p_{.1}$ and the probability of for a set of points to be 0 km is represented by $p_{1.}$. What can make these sets of points different from what was calculated in the McNemar test above is that they are not only comprised of points that resided in the county but they also have groups of points that resided at five other locations categories outside of the county. One would expect each of the probabilities to be equal if both of these location systems were the same. However this test can indicate if there exist a difference between not only the location systems residing inside or outside of the county but whether or not there exist a difference with in the various distance measurements as represented by the interpretation of χ^2 test statistic (Equation 6). If the above $p_{.1}$ and $p_{1.}$ are not equal, this is due to an internal difference of points residing outside of the county as some distance. Therefore, if we fail to accept the null hypothesis of the Stuart- Maxwell test there does exist some difference between the two location systems with in the given categories of distance between the counties.

$H_O: p_{1.} = p_{.1}, p_{2.} = p_{.2}, \ldots, p_{r.} = p_{.r.}$ $r = 2,3,4,5,\ldots$ **Equation 4**

$H_1: p_{i.} \neq p_{.i}$ for at least one $i = 1,2,3,\ldots.$ **Equation 5**

d contains each k-1 amount from the amounts of $d_1, d_2, \ldots, d_{k-1}$ in which:

$d_i = n_{i.} - n_{.i}, \ldots \quad i = 1,2,\ldots,k.$

Also, the matrix $S = [s_{ij}]$ with the dimension of (k-1) x (k-1) which is the covariance matrix of d can be defined as follows:

$s_{ii} = n_{i.} + n_{.i} - 2n_{ii},$

$s_{ij} = -(n_{ij} + n_{ji})$

The Stuart-Maxwell statistic is calculated from the following formula:

$X^2 = d'S^{-1}d$ **Equation 6**

As a final level of analysis the mean, median, and maximum distances were calculated for each state and holistically for all states combined excluding the points which resided in the declared county as they were at 0 km. This was done to provide some insight as to the distribution of the distances to county. If a maximum distance to county was much larger than the mean and median then there exist at least one outlier point causing this maximum distance to be extremely high. However if the maximum distance was close to the mean of the distances to county and the median distance to county was lower than the mean the distribution of the distances to county had many smaller distances that would lie to the left of the mean. These measurements were done to give an idea how the distances to county were distributed.

Results

Out of the 30 states which are included on the USPLSS and were a part of the NASF project, 12 states submitted data that contained both USPLSS and some other location system. Most of the other 18 states submitted only USPLSS information or another location system in each submission. Of the 12 states only 2 states submitted data that utilized UTM instead of LL. Some submissions later in the process only submitted LL. We speculated that these states were still collecting USPLSS but they were translating their data before submitting to the NASF project as verified by Oregon (T. Vonn, pers. comm., 2 March 2012). The results of each state are presented in alphabetical order and the counts of points represent an individual fire incident.

Alabama, Idaho, Michigan, Mississippi, Minnesota, and South Dakota are states which did not have a significant difference ($p\text{-value} > 0.05$) in the number of points inside and outside of the county. Arkansas and Oregon were states that for the USPLS points inside of the county there were over 10% of the LL points that were outside of the county within the group of USPLS points inside of the county where both had p-values<

$2.2x10^{-16}$ (Table 15). Both of these states had more USPLSS points in the county than LL points. Oklahoma and Washington had very close percentages of points inside and outside of the county, but overall both states had more USPLSS points inside of the county. Oklahoma was the only of the two states that was significantly different with a p-value = $6.904x10^{-13}$.

Table 15 In and out of county location contingency tables, excluding insignificant individual results from Alabama, Idaho, Michigan, Mississippi, Minnesota, and South Dakota, where p-value > 0.05.

	USPLS					
Other	In		Out		Total	
Arkansas						
In	8405	(79.41%)	448	(4.19%)	8753	(82.86%)
Out	1502	(14.19%)	329	(3.08%)	1831	(17.14%)
Total	9907	(93.60%)	777	(7.27%)	10584	
McNemar $\chi 2$ =569.7005,$P< 2.2x10^{-16}$						
Oklahoma						
In	5982	(96.20%)	40	(0.64%)	6022	(96.85%)
Out	135	(2.17%)	61	(0.98%)	196	(3.15%)
Total	6117	(98.38%)	101	(1.62%)	6218	
McNemar $\chi 2$ =51.5714, P=$6.904x10^{-13}$						
Oregon						
In	1475	(21.98%)	29	(0.43%)	1636	(22.41%)
Out	5047	(75.19%)	161	(2.40%)	5047	(75.19%)
Total	6522	(97.17%)	190	(2.83%)	6712	
McNemar $\chi 2$ =4583.909, P< $2.2x10^{-16}$						
Utah						
In	5469	(91.65%)	235	(3.94%)	5704	(95.59%)
Out	137	(2.30%)	126	(2.11%)	263	(4.41%)
Total	5606	(93.95%)	361	(6.05%)	5967	
McNemar $\chi 2$ =25.172, P= $3.753x10^{-07}$						
Washington						
In	3212	(95.51%)	34	(1.01%)	3246	(96.52%)
Out	52	(1.55%)	65	(1.93%)	117	(3.48%)
Total	3264	(97.06%)	99	(2.94%)	3363	
McNemar $\chi 2$ =3.7674, P= 0.05226						
Wisconsin						
In	668	(96.53%)	3	(0.43%)	671	(96.97%)
Out	18	(2.60%)	3	(0.43%)	21	(3.03%)
Total	686	(99.13%)	6	(0.87%)	692	
McNemar $\chi 2$ =10.7143, P= 0.001063						
All States						
In	61642	(82.37%)	794	(1.06%)	62436	(83.43%)
Out	6893	(9.21%)	5503	(7.35%)	12296	(16.35%)
Total	68535	(91.59%)	6297	(8.41%)	7432	
McNemar $\chi 2$ =5064.927, $P< 2.2x10^{-16}$						

Wisconsin only had 2.60% of the LL points within the group of USPLSS points inside the county that were outside of the county. Utah was the only state that had significantly more USPLSS points out side of the county (p-value= 3.753×10^{-07}). Overall there was a 14.3% difference in the between USPLSS points inside the county verses LL points inside of the county (p-value < 2.2×10^{-16}).

To further analyze the points inside and out of the county the individual points were categorized at six different distances (km) to county (0.0,0.5,1.0,5.0,10.0,>10.0). Like the results above the Stuart-Maxwell test for Idaho, Michigan, Minnesota, and Mississippi null hypothesizes were not rejected with a p-value > 0.05 indicating that there did not exist a significant difference in the distances of point to the declared county. However, Alabama did have significant results (p-value = 1.379×10^{-10}) in that were less LL points that were 5.0km away from the county than USPLSS points and more LL points that were10km from the county than USPLSS points (Table 16).

Table 16 Distance to county Stuart-Maxwell test contingency table for significant states, excluding insignificant individual results from Idaho, Michigan, Mississippi, Minnesota, and South Dakota, where p-value > 0.05.

	USPLS													
Other	0.0km		0.5km		1.0km		5.0km		10.0km		>10.0km		Total	
Alabama														
0.0km	3698	(44.66%)	1	(0.01%)	0	(0.00%)	2	(0.02%)	0	(0.00%)	0	(0.00%)	3701	(44.69%)
0.5km	0	(0.00%)	5	(0.06%)	25	(0.30%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	30	(0.36%)
1.0km	0	(0.00%)	0	(0.00%)	5	(0.06%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	5	(0.06%)
5.0km	0	(0.00%)	0	(0.00%)	0	(0.06%)	220	(2.66%)	0	(0.00%)	0	(0.00%)	220	(2.66%)
10.0km	0	(0.00%)	0	(0.00%)	0	(0.06%)	24	(0.29%)	222	(2.68%)	0	(0.00%)	246	(2.97%)
>10.0km	0	(0.00%)	0	(0.00%)	0	(0.06%)	0	(0.00%)	0	(0.00%)	4079	(49.26%)	4079	(49.26%)
Total	3698	(44.66%)	6	(0.07%)	30	(0.36%)	246	(2.97%)	222	(2.68%)	4079	(49.26%)	8281	

Stuart-Maxwell $\chi 2=52$, $P = 1.379 \times 10^{-10}$

Table 16 Continued

	USPLS													
Other	0.0km		0.5km		1.0km		5.0km		10.0km		>10.0km		Total	
Arkansas														
0.0km	8405	(79.67%)	15	(0.14%)	31	(0.29%)	30	(0.28%)	16	(0.15%)	356	(3.33%)	8853	(82.86%)
0.5km	68	(0.64%)	6	(0.06%)	14	(0.13%)	0	(0.00%)	0	(0.00%)	4	(0.04%)	92	(0.86%)
1.0km	29	(0.27%)	3	(0.03%)	7	(0.07%)	1	(0.01%)	1	(0.01%)	1	(0.01%)	42	(0.39%)
5.0km	132	(1.24%)	1	(0.01%)	5	(0.05%)	29	(0.27%)	2	(0.02%)	6	(0.06%)	175	(1.64%)
10.0km	129	(1.21%)	0	(0.00%)	1	(0.01%)	1	(0.01%)	22	(0.21%)	10	(0.09%)	163	(1.53%)
>10.0km	1144	(10.71%)	4	(0.04%)	13	(0.12%)	20	(0.19%)	12	(0.11%)	166	(1.55%)	1359	(12.72%)
Total	10684	(92.73%)	29	(0.27%)	71	(0.66%)	81	(0.76%)	53	(0.50%)	443	(5.08%)	10584	
Stuart-Maxwell $\chi 2$=613.8003, $P< 2.2x10^{-16}$														
Oklahoma														
0.0km	5982	(96.20%)	2	(0.03%)	8	(0.13%)	3	(0.05%)	6	(0.10%)	21	(0.34%)	6022	(96.85%)
0.5km	36	(0.58%)	0	(0.00%)	7	(0.11%)	0	(0.00%)	1	(0.02%)	0	(0.00%)	44	(0.71%)
1.0km	6	(0.10%)	0	(0.00%)	5	(0.08%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	11	(0.18%)
5.0km	12	(0.19%)	0	(0.00%)	1	(0.02%)	14	(0.23%)	2	(0.03%)	0	(0.00%)	29	(0.47%)
10.0km	18	(0.29%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	11	(0.18%)	1	(0.02%)	30	(0.48%)
>10.0km	63	(1.01%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	2	(0.03%)	17	(0.27%)	82	(1.32%)
Total	6117	(98.38%)	2	(0.03%)	21	(0.34%)	17	(0.27%)	22	(0.32%)	39	(0.63%)	6218	
Stuart-Maxwell $\chi 2$ =65.4521, P=9.03times10^{-13}														
Oregon														
0.0km	1475	(21.98%)	9	(0.13%)	5	(0.09%)	6	(0.09%)	5	(0.07%)	4	(0.06%)	1504	(22.41%)
0.5km	32	(0.48%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	32	(0.48%)
1.0km	32	(0.48%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	32	(0.48%)
5.0km	212	(3.16%)	0	(0.00%)	1	(0.04%)	3	(0.04%)	0	(0.00%)	4	(0.06%)	220	(3.28%)
10.0km	282	(4.20%)	1	(0.01%)	2	(0.03%)	2	(0.03%)	1	(0.01%)	3	(0.04%)	291	(4.34%)
>10.0km	4489	(66.88%)	25	(0.37%)	25	(0.37%)	36	(0.54%)	28	(0.42%)	30	(0.45%)	4633	(69.03%)
Total	6522	(97.17%)	35	(0.52%)	33	(0.49%)	47	(0.70%)	34	(0.51%)	41	(0.61%)	6712	
Stuart-Maxwell $\chi 2$ =5023.006, $P<2.2x10^{-16}$														
Utah														
0.0km	5469	(91.65%)	23	(0.39%)	16	(0.27%)	38	(0.64%)	20	(0.34%)	138	(2.31%)	5704	(95.59%)
0.5km	31	(0.52%)	5	(0.08%)	10	(0.17%)	1	(0.02%)	0	(0.00%)	1	(0.02%)	48	(0.80%)
1.0km	6	(0.10%)	0	(0.00%)	7	(0.12%)	6	(0.10%)	2	(0.03%)	1	(0.02%)	22	(0.37%)
5.0km	17	(0.28%)	0	(0.00%)	7	(0.12%)	23	(0.39%)	3	(0.05%)	3	(0.05%)	53	(0.89%)
10.0km	6	(0.10%)	0	(0.00%)	0	(0.00%)	0	(0.00%)	19	(0.32%)	0	(0.00%)	25	(0.42%)
>10.0km	77	(1.29%)	1	(0.02%)	0	(0.00%)	2	(0.03%)	2	(0.03%)	33	(0.55%)	115	(1.93%)
Total	5606	(93.95%)	29	(0.49%)	40	(0.67%)	70	(1.17%)	46	(0.77%)	176	(2.95%)	5967	
Stuart-Maxwell $\chi 2$ =50.3196, P=$1.192x10^{-09}$														

Table 16 Continued.

	USPLS						
Other	0.0km	0.5km	1.0km	5.0km	10.0km	>10.0km	Total
			Washington				
0.0km	3212 (95.51%)	23 (0.68%)	1 (0.03%)	2 (0.06%)	3 (0.09%)	5 (0.15%)	3246 (96.52%)
0.5km	22 (0.65%)	8 (0.24%)	2 (0.06%)	1 (0.03%)	0 (0.00%)	1 (0.03%)	34 (1.01%)
1.0km	3 (0.09%)	2 (0.06%)	3 (0.09%)	0 (0.00%)	0 (0.00%)	1 (0.03%)	9 (0.27%)
5.0km	4 (0.12%)	1 (0.03%)	2 (0.06%)	12 (0.36%)	0 (0.00%)	0 (0.00%)	19 (0.56%)
10.0km	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.03%)	7 (0.21%)	0 (0.00%)	8 (0.24%)
>10.0km	23 (0.68%)	0 (0.00%)	1 (0.03%)	1 (0.03%)	0 (0.00%)	22 (0.65%)	47 (1.40%)
Total	3264 (97.06%)	34 (1.01%)	9 (0.27%)	17 (0.51%)	10 (0.30%)	29 (0.86%)	3363
Stuart-Maxwell χ2 =11.7249, *P*=0.03876							
			Wisconsin				
0.0km	668 (96.53%)	0 (0.00%)	0 (0.00%)	1 (0.14%)	1 (0.14%)	1 (0.14%)	671 (96.97%)
0.5km	1 (0.14%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.14%)
1.0km	2 (0.29%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (0.29%)
5.0km	2 (0.29%)	0 (0.00%)	0 (0.00%)	1 (0.14%)	0 (0.00%)	0 (0.00%)	3 (0.43%)
10.0km	1 (0.14%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	1 (0.14%)
>10.0km	12 (1.73%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	0 (0.00%)	2 (0.29%)	14 (2.02%)
Total	686 (99.13%)	0 (0.00%)	0 (0.00%)	2 (0.29%)	1 (0.14%)	3 (0.43%)	692
Stuart-Maxwell χ2 =12.641, *P*=0.02699							
			All States				
0.0km	61642 (82.48%)	73 (0.10%)	63 (0.08%)	82 (0.11%)	51 (0.07%)	425 (0.57%)	62336 (83.41%)
0.5km	192 (0.26%)	66 (0.09%)	58 (0.08%)	2 (0.00%)	1 (0.00%)	6 (0.01%)	325 (0.43%)
1.0km	78 (0.10%)	5 (0.01%)	51 (0.07%)	7 (0.01%)	3 (0.00%)	3 (0.00%)	147 (0.20%)
5.0km	379 (0.51%)	2 (0.00%)	16 (0.02%)	352 (0.47%)	7 (0.01%)	13 (0.02%)	769 (1.03%)
10.0km	436 (0.58%)	1 (0.00%)	3 (0.00%)	29 (0.04%)	309 (0.41%)	14 (0.02%)	491 (1.06%)
>10.0km	5808 (7.77%)	30 (0.04%)	39 (0.05%)	59 (0.08%)	44 (0.06%)	4384 (5.87%)	10364 (13.87%)
Total	68535 (91.71%)	177 (0.24%)	530 (0.31%)	530 (0.71%)	415 (0.56%)	4845 (6.48%)	74732
Stuart-Maxwell χ2 =50308.163, *P*=$2.2x10^{-16}$							

Arkansas and Oregon had a large number of LL points that were >10.0km from the county when USPLSS measured them inside of the county (p-value< $2.2x10^{-16}$). Oklahoma and Wisconsin exhibited the same phenomena but they only had less than 2%. Washington had a 0.68% of LL points that were >10.0km when USPLSS was inside of the county and 0.68% of USPLSS points were 0.5km from the county when LL points were inside of the county (p-value=0.03876). Utah had 2.31% of USPLSS points that were >10.0km from the county when LL points were inside of the county. Overall, all states combined had 7.77% of LL points were >10.0km outside of the county when USPLSS was inside of the county.

To aid in the understanding of the distribution of the distance measurements the mean, median, and maximum distances were calculated for the states which had significant differences in Table 16. Even though Alabama had significance in table 16 there was not a large difference in these measurements between the LL and USPLSS. Arkansas and Washington had a larger maximum distance for LL than USPLSS meaning that LL was further away from the derived county (Table 17).

Table 17 Summary of distance (km) excluding insignificant individual results from Idaho, Michigan, Mississippi, Minnesota, and South Dakota.

	Other	USPLSS
	Alabama	
Mean	60.910	60.907
Median	72.881	72.626
Max	416.197	416.198
	Arkansas	
Mean	29.234	35.150
Median	47.770	68.703
Max	500.193	342.076
	Oklahoma	
Mean	7.657	6.841
Median	28.306	47.490
Max	327.113	442.648
	Oregon	
Mean	47.822	3.645
Median	50.358	24.604
Max	487.772	534.196
	Utah	
Mean	6.290	8.803
Median	51.038	49.623
Max	409.886	753.488
	Washington	
Mean	3.355	2.667
Median	39.772	21.313
Max	797.259	194.241

Table 17 Continued.

	Other	USPLSS
	Wisconsin	
Mean	45.619	11.125
Median	78.233	38.316
Max	435.421	188.263
	All States	
Mean	46.302	46.027
Median	57.577	66.808
Max	797.259	753.488

Oregon and Wisconsin had a smaller mean and median USPLSS distance than LL, but Oregon had a larger maximum USPLSS distance than LL. The median Oklahoma LL distance was half of what the median USPLSS distance was and the maximum LL distance was less than maximum USPLSS distance. Utah had a greater UPLSS maximum distance and a greater mean USPLSS. The distribution of all states combine for both location systems were very similar to each other except the maximum USPLSS distance was less than the maximum other coordinate systems distance. Also the median USPLSS distance was less than the median other coordinate systems distance. The exception to this trend was in Oregon and Oklahoma.

Discussion

The results of individual states indicated that when a fire location did not occur in the given county that most of these points were outside of the county by greater than 10km. There did not exist a single state in this study where most of the points were close to the county. When all points were analyzed as a whole (regardless of state) the results indicated that USPLSS points occurred within the given county boundary more often than another system of location. Even when the points were analyzed as a whole the results indicated that if a given point did occur outside the county that the point would most likely occur greater than 10km.

Many states could not be contacted during this study to determine if they had translated data from one system to another. However, Michigan, Minnesota, and Arkansas did confirm that they were translating data from one system to another. Michigan and Minnesota both were translating data from USPLSS to another system and the results did support this. Arkansas was a more complex situation in that the fire data is recorded in and translated from either USPLSS or LL. The results of Arkansas are then depicting either an inaccurate translation or transcription error from one system to another or an in accuracy that cannot be accounted for. This inaccuracy could be from the GPS as mentioned above or the user could simply not know where they are located on the plat map when recording the USPLSS location. The results could not explain either phenomena, but did indicate that USPLSS points occurred in the county more often.

Conclusion

USPLSS and other location systems have been around for many years. Both systems provide a way of locating something or someone on the earth. This study has conclusively determined that in the case of wildland fire data, USPLSS tended to be more in the derived county than the latitude and longitude when USPLSS location description were provided. So if a decision were made to abandon USPLSS, that decision would not be well founded.

Other location systems differ from USPLSS in that they are currently being recorded electronically and they are widely available for consumers as well as professionals. The only problem with these other systems is that there are inherent technological issues as to their accuracy. The USPLSS system does not currently have a standardized electronic means of recording data in the digital age. However the USPLSS system does utilize visual landmarks that can aide in the accuracy of the user that is recording information.

Overall location data will likely always have some inaccuracy associated with it. These inaccuracies must be accounted for before any of the data is utilized in any analysis. If these inaccuracies are accounted for, results of any study having to do with spatial information can be better utilized.

CHAPTER IV

DATA STORAGE, PROCESSING AND QUALITY CONTROL STRATEGIES FOR WILDFIRE DATA

Introduction

In October 2002, the National Association of State Foresters (NASF) directed its Fire Protection Committee to investigate alternative strategies to cost-effectively collect a minimum set of data from all members. In January 2003 the NASF Fire Committee and the State Fire Chiefs, Managers, and Supervisors Group agreed upon the use of 13 core variables, listed previously, that would be collected and reported by each state on a quarterly basis. In January 2003, the Texas A&M Spatial Sciences Lab, working through the Texas Forest Service, developed a web-based submission and data warehousing strategy to accomplish this task.

The first attempt that was made to process this data consisted of some of the 13 subroutines that called other common routines, such as for the processing of data for the U. S. Public Land Survey System (USPLSS), but there was also a large amount of state-specific code. Other complications emerged, such as not just field names but sometimes the actual suite of included fields changing from year to year, even for a given state.

This attempt was ultimately abandoned with the realization that, even with the proof of concept subset of states, maintenance of the code would become unmanageable. Issues of maintenance of the submittal system then multiplied as more states submitted their data. The main issue was that there did not exist a standard submittal format for every state to use in their submission process. In addition to not having a standard format for data, the individual states had their own set of information that they would submit to the data warehouse. To solve these problems, the submittal system was restructured into a generic code that would process each individual state into the data warehouse. This generic code would be fed state specific code from the database itself to insert data in the correct format and without errors to the main wildfire data warehouse. This method of storing code in a database made the process of submitting data into the database very manageable.

Three major issues emerge from building a uniform wildfire database based on non-uniform data: identification of causes of wildfire, lack of error checking, and the use of multiple submission formats of location information. Concerning wildfire causes, many states use a nationally accepted set of nine wildfire causes while others use their own classification systems (NWCG 1998). Lack of naming standards creates data retrieval problems and can produce miscounts and mismatches. The lack of error checking in datasets posed a major problem when trying to maintain acceptable wildfire data. Some of the errors were simple to correct after the fact.

These simple errors included misspelling a county name, lack of consistent nomenclature within a particular field in a dataset, and latitude and longitude that were in reverse order. Other errors were more complex, such as coordinates that were not even in the state in which the fire was supposed to have started, fires that were posted as out before they even were started, etc.

The use of multiple submission formats for wildfire locations was a third major issue for building the uniform database. Although there existed an agreed upon criteria for submission of latitude and longitude, many states used United States Public Land Survey (USPLS), Universal Transverse Mercator (UTM), or block grid location information instead. The different submission formats made uniformity of pinpointing wildfire locations difficult if not impossible in some instances. To cite one rather egregious example, one state submitted USPLS data at the quarter-quarter level, but they failed to submit the meridian in which the fire occurred. For almost all fires we were able to deduce the meridian from the combination of ranger district and the duplication magnitudes of the township and range values. Worse than that though was the fact that they also failed to submit section numbers. So even though the fire locations were often recorded to the nearest 0.635 km (1/4 mile), we could only place the fires to with in the nearest 15 km (6 mi).

In an effort to improve the data submittal system that was utilized for the NASF project, this chapter will illustrate a new proof of concept web based data submittal system. The three data integrity issues above are handled autonomously by the web application or the database. The main portion of this paper will describe the design of the database system and the methods of both the web application and the database that were utilized to test three main concepts. The first of these concepts was to design a system that could autonomously solve data integrity issues on the front of a data entry when not standard entry format was utilized. Secondly, the focus of the design was to ensure that all aspects were designed in a modular format so that maintenance of the system could be done relatively easily as well as any additions to the system could be done without the system failing. The third and final conceptual test was to determine is ESRI ArcServer and Microsoft SQL Server were an ideal platform for which to host such an application.

Review of Existing Systems

Wildfire Databases

A wildfire database, also referred to as a data warehouse, provides a platform for collaborative analysis of various wildfire related interest (Lee et al. 2002). The topic on which historical wildfire information has had a major effect worldwide is wildfire and forest management policies (Dimitrakopoulos 2001; Lee et al. 2002; Short 2014, United States Fire Administration 1997). These policies give rise to programs that result in public wildland fire awareness and influence national policy as to how particular types of wildfires may be prevented (Dimitrakopoulos 2001). The legal system also relies upon wildfire databases (United States Fire Administration 1997). Courts may use wildfire data to estimate the total cost of the damages associated with a wildfire as well as the location where a given wildfire has occurred (United States Fire Administration 1997). Additionally, these databases are used in the development of wildland fire behavior models (Lee et al. 2000; Dimitrakopoulos 2001; Lee et al. 2002). This information can be used to help firefighters combat wildfires. A historical database provides information on fires that have already occurred to help researchers create a place for testing models before utilizing them in predicting the behavior of an actual wildfire (United States Fire Administration 1997).

International Wildfire Database Systems: European Forest Fire Information System

European Forest Fire Information System (EFFIS) serves as both the housing for the European Union (EU) wildfire data and the software that may be used to extract wildland fire information for a potential user (Camia et al. 2006; European Union 2009). EFFIS became operational in 2000 as a result of the Joint Research Centre of the European Commission appointing a committee to develop the database system. The information available to the public consists of the eight fields summarized in Table 18.

Table 18 EFFIS data available for download by the public.

EFFIS Data		
Commune	Area(HA)	Fire Date
Latitude/Longitude	Province	Country
Last Update		

The database houses historical data as well as current fire information (San-Miguel-Ayanz et al. 2003; Illiadis 2005). The current information is set up in such a way that when a fire occurs the information is already being created within EFFIS on that particular fire via that was detected via MODIS satellite detection (San-Miguel-Ayanz et al. 2003). This is important because the data is then portrayed on an interactive web site that anyone may use to see current information on a particular wildfire. The same web display system may be used to query information about an existing or a historical fire (San-Miguel-Ayanz et al. 2003). One limitation to EFFIS is that only members of the European Union submit data to the database (San Miguel-Ayanz et al. 2003).

International Wildfire Database Systems: Canadian Wildland Fire Information System & Fire Monitoring, Mapping and Modeling System

The Canadian National Fire Database is built in two parts. The Canadian Wildland Fire Information System (CWFIS) and Fire Monitoring, Mapping and Modeling System (FIRE M3) data systems come together to form a national dataset (Lee et al. 2002). The CWFIS was fully operational in 2000. CWFIS continuously keeps track of weather data from various weather stations throughout Canada to provide fire weather information and allow input of fire data (cause, location, property ownership, etc.) from various national agencies. FIRE M3 is a satellite based information gathering system that was fully integrated with CWFIS in 2003 (Natural Resources Canada 2008). FIRE M3 serves as a way to track a fire that is already occurring or detect a new fire. The satellite information from FIRE M3 is then input and stored in CWFIS for later extraction and data analysis. The public may access data in multiple formats containing the information in Table 19.

Table 19 CWIFS data that is made publicly available.

	CWIFS Data	
Year	Month	Day
Province	Latitude	Longitude
Start Date	Dectect Date	Cause
Size	Fire Region	Fire Zone
Ecoregion	Ecodistrict	Ecozone

CWFIS and FIRE M3 come together to form a data system that is rather unique in that there is a combination of ground based fire data and remotely sensed fire data (Natural

Resources Canada 2008). CWFIS also has a web component that is queryable by any outside user. With the addition of satellite tracking of fires and real time fire weather data, CWFIS provides a vast amount of data that may be used to create models to predict fire behavior and current fire information (Lee et al. 2002).

United States Wildfire Database Systems: National Fire Incident Reporting System

The U. S. Fire Administration established the National Fire Incident Reporting System (NFIRS) in 1976 with the authority given by the Federal Fire Prevention and Control Act of 1974 (United States Fire Administration 2012). The Federal Fire Prevention and Control Act of 1974 stated the need for a federal integrated data center to house and analyze national fire data. This data center would not only contain information on wildland fires but was to contain information about all incidents to which fire agencies respond in the United States (U. S. Senate 1974). Under the provisions of this act NFIRS now collects data from over 42 states nationwide (United States Fire Administration 2004).

Participants in NFIRS voluntarily submit their data to the national database via NFIRS specific forms (United States Fire Administration 1997). However the actual form fields may be modified by individual states for their own data needs (United States Fire Administration 2012). In an effort to facilitate better wildland fire reporting NFIRS created a Wildland Module that directly targets the wildland fire problem in the United States (FEMA 2013). Wildland fires may be reported using either the Standard Module or the Wildland Module at the user's discretion. However, this can be a major issue at the data extraction phase where users are not properly trained in creating the necessary queries. One drawback to NFIRS is that there does not currently exist any way that the NFIRS fire information is available for public use except via direct request.

The Wildland Fire Module consists of twelve fields (Table 20). These twelve fields are not necessarily separate from the rest of the database system in that they are incorporated in other parts of the system. All wildland fire incidents must include information in the Basic Incident Module and must also have a corresponding record in the Fire Module (FEMA 2013).

The use of the Wildland Fire Module allows the fire data to be expanded to include information specific to a wildland fire. This includes a special set of wildland fire causes that are separate from those used, for example, for structure fires. Also the location information is more suitable to that of a wildland fire as compared to a conventional structural fire. However, this module is not a standard requirement for the NFIRS database system to operate (FEMA 2013). So only limited data validation exists inside of the Wildland Fire Module to that of the rest of the database system with respect to such fields as fire cause. NFIRS does allow the ability to submit weather information from the National Fire Danger Rating System Weather Station that monitors weather conditions at the location of fire origin (FEMA 2013).

Table 20 Information contained in the NFIRS Wildland Fire Module.

NFIRS Wildland Fire Module Data		
Property Details	Fire cause	Ignition information
Fire suppression and management	Mobile property type	Equipment involved in ignition
Weather data	Fuel model at origin	Total acres burned
Property management	Person responsible	Fire behavior

United States Wildfire Database Systems: National Interagency Fire Management Integrated Database

The USDA Forest Service developed the National Interagency Fire Management Integrated Database (NIFMID) in 1992 to house and support the data from the Administrative Forest Fire Information Retrieval and Management System (AFFIRMS), a legacy database system (Bunton 1997). NFIMID is an improvement to AFFIRMS in that the database supports the integration of live weather information for fires that occur and the data is not held on tapes (Bunton 1997; USDA Forest Service 1998). However, NIFMID still supports data via the legacy FIRESTAT system of reporting wildfire information (Bunton 1997). The main reason for the creation of NIFMID was that of necessity. The management and retrieval of information from AFFIRMS had become a cumbersome task (Bunton 1997). NIFMID changed data retrieval by supporting a simplified data retrieval system known as Kansas City Fire Access Software (KCFAST), which is still in use today. NIFMID like the systems prior to it was intended to serve as a storage place for wildland fire data on national lands, include land holdings of the Bureau of Land Management, National Forest Service, and National Parks, but has not yet been used for this (K. Short, pers. comm., 28 May 2014).

Methods

The data submittal system that was utilized during the NASF project provided a baseline data system that could be modified to function similar to the design of the PYROSTAT data submittal system (Dimitrakopoulos 2001). The process of redesigning the NASF database was done in a two-step process. First the original NASF database that housed the fire data had to be redesigned to accommodate both existing and any new data that might be added over time. Secondly a web based submittal system had to be developed to interact with the new database in addition to performing any processes that were needed to maintain data integrity.

Database Structure

The new database was composed of four major components. Each of these components interacted with each other to form a uniform dataset. Data entered into the system in two ways. The first of these components was the user information and it contained information about the user submitting data (Figure 5). The user information tables provided the contact information related to the person submitting data to the data system. This information could later be used to contact the user if any question about the data submitted arises.

The user either uploaded a data file or entered wildfire information into a user form one fire at a time. Upon submitting fire data, the second portion of the data system, file definition data, provided access to either the actual dataset submitted or indicated if single fire was inserted using the a user form. In either instance, when data was submitted to the system a primary key was generated for both the SUBMISSION_DATA_FILE and SUBMISSION_DATA_TABLE tables. These tables contained either user form data or an actual data file that was linked back to the user information via the foreign key, SubmissionID. This database utilized the primary and foreign key method for linking tables together.

For the purposes of this paper primary keys are bold and foreign keys are italic in figure 5. In a relational database a primary key is a unique identifier of data in a specific data table. A foreign key is a key that is may be not unique enough to identify items in a specific table but rather is used to link data from one table to another, as it is a primary key in another table.

The third component of the database was fully populated only if the user submitted a data file (Figure 5). If data had been submitted via the web form all data translation and integrity checks were performed by the web application and data in the field definitions portion of the data system were not necessary. With the submission of a data file the user was allowed to select either a stored set of field definitions or create a new set of field definitions. A basic example of a field definition was composed of a VariableID as the primary key and the sqlFieldTranslation. The VariableDescription described which field the VariableID was presentative of. As a simple example we will use FireID as the field that is being created. FireID would be the value in the VariableDescription and VariableID would be generated by the database. The second part of a field definition contained the sqlFieldTranslation tuple. This tuple was comprised of the sql statement that defined the field and a short description if the user desired to enter one. In this example a sql statement could simply be "[Fire Number]". All standard sql function were supported by the data submittal system and a sql statement could be as long as a user desired to enter. The creation of a whole set of field definitions was a multi-step process.

This process began by mapping fields in the data file to the available variables in the database. A variable, represented by the VariableDescription, was a predefined data field (fire cause, USPLS location, etc…) that the data submittal system and database would accept. The second part a field definition was a simple SQL statement that is used to translate the field in the uploaded file to the pre-defined format that was accepted by the data submittal system. This statement was stored in the FIELD_DEFINITIONS table.

The simple SQL statement was what actually defined the field so that the data could be translated to a uniform format for the web application to read and process. The database itself placed further constraints on the variables: county, cause, and ownership. If these variables were present then the field value must exist in the associated validation table (OWNERSHIP_CODES, CAUSE_CODES, AND COUNTY_CODES). The physical process of mapping these codes was handled by web application portion of the data submittal system. The third component of the database was the key to translating the data from multiple uploads of heterogeneous data files to the uniform product that was stored in the fourth and final component of the database. During the NASF project we preferred this mapping. The proposed system puts onus on the submitting end of the data system. As such it requires a higher level of technological thinking (basic SQL knowledge), but will hopefully result in better attention being paid to the data (Would that state have forgotten to add section numbers?).

1. User information
SUBMISSION_CONTACT
{**ContactID**,PersonLocation(stateCode,stateName,stateFIPS),Person(Name(FirstName,LastName),Email)}
SUBMISSION_DATA
{**SubmissionID**,*ContactID*,SubmissionOrigin(stateCodeS,stateName,stateFIPS)}

2. File Definition
FILE_DEFINITIONS_DATA_FILE
{**FileID**,*SubmissionID*,FileInformation(fileName,fileType,actualFile)}
FILE_DEFINITIONS_DATA_TABLE
{**DataTableID**,*FileID*,*FieldDefintionsID*,TableInformation(TableName,FireDeparmentType)}

3. Field Definitions
FIELD_DEFINITIONS
{**VariableID**, VariableDescription *FieldDefinitionsID*,
FieldDefinitionDescription,SQLFieldTranslation(FieldDefinition,FieldDescription)}
CODE_DEFINITION_CAUSE
{**CauseID**,*VariableID*,*InternalCodeCause*}
CODE_DEFINITION_OWNERSHIP
{**OwnershipID**,*VariableID*,*InternalCodeOwnership*}
CODE_DEFINITION_COUNTY
{**CountyID**,*VariableID*,InternalCode,*StateAndCountyFIPS*}
CAUSE_CODES
{**InternalCodeCause**,CauseCode(CauseCode,CauseCodeDescription)}
OWNERSHIP_CODES
{**InternalCodeOwnership**,CauseCode(OwnershipCode,OwnershipCodeDescription)}
COUNTY_CODES
{**StateAndCountyFIPS**,CountyDescription}

4.Core Fire Data
CORE_FIRE_DATA_PROCESSED_DATE
{**DataTableID**,stateCodeS,processedDate}
CORE_FIRE_INFORMATION
{**FireID**,*DataTableID*,GeneralFireInformation(StateAndCountyFIPS,totalAcres,NumberofInjuries,NumberofFatalities)}
SUBSET_LOCATION_USPLS
{**USPLSLocationID**,*FireID*,LocationInformation(LocationRank,clean,override,error),
USPLSLocation(TownshipNum,TownshipDir,TownshipFrac,RangeNum,RangeDir,RangeFrac,Section,Alliquot)}
SUBSET_LOCATION_DEGREES
{**DegreesLocationID**,*FireID*,LocationInformation(LocationRank,clean,override, error),DegreesLocation(Latitude,
Longitude,Datum)}
SUBSET_LOCATION_UTM
{**UTMLocationID**,*FireID*,LocationInformation(LocationRank,clean,override, error),
UTMLocation(Easting, Northing, Zone)}
SUBSET_OWNERSHIP
{**OwnershipID**,*FireID*,OwnershipCode,OwnershipRank}
SUBSET_CAUSE
{**CauseID**,*FireID*,CauseCode,CauseRank}
SUBSET_FIRE_DATE_TIME
{**DateTimeID**,*FireID*,DateTimeOrder,DateTime(fireDate,fireTime)}
SUBSET_WEATHER
{**WeatherID**,*FireID*,WeatherConditions(MinTemp,MaxTemp,MinHumid,MaxHumid,MinWind,MaxWind,AvgWindDir,
MinPressure,MaxPressure,PrecipTotal)}

Figure 5 Wildfire data system entity relationship model. The primary keys are denoted in bold and the foreign keys are denoted by italics. Foreign keys link data between tables and primary keys are unique to data only in a specific table.

The fourth component of the database was used to store clean data from both the web form and data files that were uploaded. The CORE_FIRE_INFORMATION data table was the key portion of data constituting the minimum amount of data required for a single wildfire incident submission (Figure 5). The CORE_FIRE_INFORMATION contained a fireID (primary key) that was specific to the state and data file that was submitted to the data submittal system. Every other data table in figure 5 under the core fire data section depended on the existence of a record in the CORE_FIRE_INFORMATION data table.

Each of these other data tables in the core fire data section acted as a fire data module, similar to the functioning of NFIRS (FEMA 2013) and PYROSTAT (Dimitrakopoulos 2001). The data in the fire cause and fire ownership tables integrity was checked during the creation of the field definitions as defined by the data constraints set in the validation tables in figure 5. The location information was constrained to the county defined in the core table. Verification of the location information will be described in the web application section of this paper. Date and time information was also verified by the web application. Weather data was added to the database if and only if a valid start time and the location data was determined to occur within the county of a wildfire incident. Once data had been submitted all core fire data was autonomously uploaded to a spatial database via a script that was external to the data submittal database nightly.

Web Application Processes

One of the main purposes of the web application was to perform data integrity checking on either a bulk data file upload or a single wildfire incident. Data integrity was checked in two different ways depending on the method of data entry. If a user was submitting data via the web form for a single fire event the integrity was checked immediately, however; if a user was submitting a data file the integrity was checked in a stepwise manner by the web application.

To perform immediate data checking for a single fire upload in the user form, simple coding structures were used to trap errors. An example of simple coding structures was the determination of temporal data being in chronological order. If a user had not entered data in chronological order the system would not let the user proceed with entering data. However, more complex methodologies were utilized to verify location data. The data system could accept three different forms of location data. Each specific form of location data must be verified to exist in the county that the user had designated as the fire origin. To accomplish this verification each piece of location data was translated to the same format and fed into the Google maps application interface. The Google maps application interface was used determine the county for which a point resides in. If a user provided a point that did not exist in the stated county then the user was notified of this error and not allowed to submit the fire incident information until the error was resolved. More complex location processing was needed to process data that was submitted in a data file as there exist potentially more records in a data file that would violate the constraints of the Google maps application interface.

When a user submitted a data file the stepwise data integrity checking process began with validating the file type. The web application determined if the file was in a readable format. Once this was established the user was prompted to define the field definitions that were associated with the file or use an existing set of definitions. If the user must define the field definitions they began the process by selecting the field names of their data that fit into the pre-defined data system fields, which they wanted to submit. The user was then prompted to translate the data using simple SQL statements to the prescribed format, which the database would accept. Once the field definitions were defined the web application verified the mapping of cause, ownership, and county against the validation tables that were stored in the database if these fields were submitted. The application accomplished this by selecting a distinct list of the existing values in the data file and cross referenced these values with the defined values in the database. If a given field value could not be referenced the user was asked to map the value to the pre-defined value provided by the database.

Once the field definitions had been selected or created the user was presented with the new data set that they have defined using the field definitions. At this point the user was given the option to cancel the submission or proceed with the submission. When the user proceeded with the submission, temporary core, cause and ownership tables were created in the database because the validation of this data that took place in the creation of the field definitions and the user had not elected to submit all data to the system.

The next step in the process was determined by the existence of either temporal data or location data. If temporal data existed, the application processed the data in the chronological order for which the data occurred in the dataset for each fire incident. The application did this process by simply ordering the temporal data in a descending order and compared that with what was in the actual data file. If the data in the file did not match the ordered data then the user was prompted to accept/reject/delete these errors for specific fire incidents. By accepting or deleting the errors presented then the individual error records would not be submitted to the database and the rest of the user's records that did not have an error would be submitted to the database. However, if the user selected to reject these errors the data would be submitted to the database but the data would be flagged as having an error according to the standards of the data system. The location information was processed in a similar way except the process was much more involved.

The location verification process began by translating the location data into a common dataset. If the location data was USPLS, the data was fed to the Bureau of Land Management’s web application interface to verify the validity of the location and get the coordinates for the center of the described location, if the location was valid. The returned coordinates were then stored in a temporary data table inside of the database itself. If the user submitted either latitude and longitude or UTM, the information was first verified as being located within the bounds of the United States. When a point did not reside in the United States of America then the location was flagged as an error. All of the points for each method of location were stored in temporary data tables inside of the database with their corresponding fireIDs for further processing.

Each temporary table of locations was then individually further processed to determine if the points of location did describe a location in the county that was described in the CORE_FIRE_INFORMATION table. This process began by creating a temporary dataset view that joined the temporary location table with the temporary CORE_FIRE_INFORMATION data table. An individual set of data was then extracted from the temporary dataset view. The set of data was the set of locations for a given county. The locations were then processed as a whole to determine which points of location did not occur inside of the county using ESRI ArcObjects. The resulting error locations were then flagged as having an error in the temporary location dataset that was stored in the database. This process repeated for each set of data corresponding to a given county and location type. If a point either did not lie in the county of origin or a county had not been determined for the location the location information was in error for a wildfire event and the user was notified of the error. The user was then given the opportunity to accept/reject/delete the specific location information. These options have been described above as to what occurs with each option.

Finally the user was presented with the data that would be submitted to the data system in a translated format with all core data and its associated subsets of various data (Figure 6). At this point the user may decide to cancel the entire submission or proceed with the submission of data. If the user decided to submit the data then the temporary tables were inserted into the relational database. If a there did exist valid temporal and location data, then the application would retrieve weather data from Weather Underground and store the fire weather data for the given fire events represented by the CORE_FIRE_INFORMATION data table.

CORE_FIRE_INFORMATION

fireID	dataTableID	StateAndCountyFIPS	totalAcres	NumberOfInjuries	NumberofFatalities
00000001	0000001	48041	55	0	0

SUBSET_LOCATION_DEGREES

fireID	DegreesLocationID	LocationRank	clean	override	error	Latitude	Longitude	Datum
00000001	934154	1	0	1	1	30.6	-96.5	NAD83

SUBSET_OWNERSHIP

fireID	OwnershipID	OwnershipCode	OwnershipRank
00000001	234447	1	1

SUBSET_CAUSE

fireID	CauseID	CauseCode	CauseRank
00000001	294451	9	1
00000001	505915	11	2

SUBSET_FIRE_DATE_TIME

fireID	DateTimeID	DateTimeOrder	fireDate	fireTime
00000001	679745	1	9/14/2006	16:34:00

Figure 6 Sample dataset that a user would submit to the data system. This sample represents a submission that did not have correct location information, but the user has selected to reject the error so that information will be submitted to the data system.

Data Submittal System as a Whole

Both of the above components came together to form the conceptual wildfire database system. The database depended on the web application and the web application depended on the database to form a whole data system. The overall process of a data submittal began with the user interacting with the web application (Figure 6).

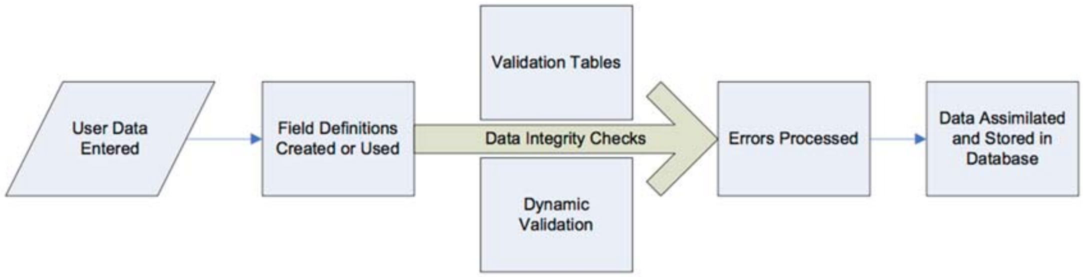

Figure 7 A broad overview of the wildfire data submittal system and its core basic processes.

The user utilized the web application to enter data into the database. The web application then in turn allowed the user to either create or use field definitions (Figure 7). The field definitions were created in the application and stored in the database for future use. The web application allowed the user to verify their field definitions prior to any data submittal to the database to ensure that all data submitted in the manor that the user was intending.

Next the web application utilized the field definitions that were stored in the database to translate data for data integrity checking purposes (Figure 6). Checking data integrity was one of the principal concepts for the creation of the proof of concept database system. The first and most simple of these checks was done using validation tables stored in the database and maintained by the database administrator. The validation tables were read by the application to ensure that the cause, ownership and county data were all acceptable by the database. The second portion of data validation that was performed by the application and did not rely on the database for processing information. The validation was a dynamic validation involving the use of code in the application to verify data. This type of validation was performed for both the temporal data and the location data. The temporal data integrity was simply checking for chronological order and only utilized simple coding structures for this. The location data integrity checking was more involved due to the incorporation of ArcServer and Microsoft SQL server or Google Maps API (for single fire submissions). The use of ArcServer in conjunction with Microsoft SQL Server were also a principal concept that was to be conceptually tested by this study.

After all validation processes errors were processed by the user of the data submittal system. The web application presented the user with data that only had errors instead of presenting them with all data including data with error flags as this could be cumbersome on the user to process. As mentioned above the user could decide at this point to reject all errors, omit errors, or cancel the entire submission. This action was enabled by the application storing temporary data tables in the database until the user decided to submit the entire dataset or only portions of the dataset to the database.

The final step in processing the user's data involved the user assimilating all of the data that had been submitted and selected for submission into a single submission of data. Conceptually this was made possible by the idea that the data system was assembled in modules. The CORE_FIRE_INFORMATION table was the only table that needed to have data inside of it and the rest of the tables could be empty if the user did desire to submit this information. The modularity allowed the application to insert data in a stepwise manner instead of having submit data into one table. In addition to assembling the user submitted data in the final step, weather data was added to the submission if the user had valid location and temporal data.

Results

The database was designed as a proof of three main concepts. The first concept was that a data system could be designed in such a way that error checking or data integrity could be performed in the front end of the data submittal process without having a standardized format for data submittal. This concept was definitively proven to be viable. The errors that were experienced during the NASF project could be prevented autonomously by building in prevention steps into the database and web application. The web application's ability to utilize the database as a cypher for such errors a misspelling county names proved conceptually viable in that these types of errors were trapped immediately and corrected by the user submitting data. In turn more complex errors like bad location information were also prevented by the web application and thus the error checking did result in a cleaner data set with little or no post data submittal interaction.

The second main concept that was proven was the idea that a database and application could be designed as a set of modules and these modules could also contain sub modules to ease the transition of newer data and error checking into a data system. The modularity was proven to be a functional design plan with the addition of weather data. Weather data was added to the database after all other components had been verified. The web application was able to successfully read and interpret data from another database using existing data in its local data system to provide the addition of weather data. The concept of reading data from another database was also utilized successfully in the verification of USPLS location data. The idea that not all data must be stored within a local system did significantly reduce the footprint of the database itself in the end. The modularity of the system enabled such functionalities to exist and be easily maintained.

As the third and final concept, it was set out to prove if ArcServer and Microsoft SQL server were a viable choice for hosting a spatial data submittal system. This concept turned out to be plausible but most likely not viable for a production size application. The primary problem with these two platforms was the time that was taken for data processing. This was most evident in the data file upload portion of the system. When a user uploaded a data file to the system, the file may have contained many records. Processing the location data with respect to the location of the fire relative to the county was very costly in terms of time. This was primarily due to the use of ArcObjects®. ArcObjects® has to translate the data into pre-defined objects that must be processed one object at a time. The processing of such objects was the primary cause of the lack of performance in the application. This was later addressed in the single fire data submittal form by avoiding the use of ArcObjects® by replacing the processing with a direct query to the Google Maps application interface. This interface was much faster but had its own limitation of use by a user if the user did not want to pay usage charges. This was why it was only used in the single fire data submittal form.

Overall the main idea that can be taken away from this data submittal and housing system was that wildfire data does have its own unique set of problems. However, many of these problems were solved in this proof of concept database and web based data submittal system. A data submittal system designed with error checking on the front end of the system not only improves the data coming out of the system but also educates the people submitting data to the system as to their own data errors that they may not be aware of. Error checking and more data can be easily added to the system as more information or error checking needs are found due to the modularity of the conceptual database system.

Discussion

Throughout the creation of the wildfire data submittal system, it became evident that the system itself had to be easily adapted to various situations. This was known in the beginning from the lessons learned in the NASF project, however; upon creation other data issues emerged that had to be dealt with. Such issues were that of duplicate data. Duplicate data was handled in this case on the assumption that users would submit data that contained a valid primary key. This key was assumed to be unique to both the state and the particular set of wildfire data being submitted. Another major assumption that had to be made was that the wildfire being described by a fire record did in fact occur within the county boundary. The county was the best location candidate to base the verification of location data. Since these assumptions were made, the data was designed in a modular aspect that would allow further customization of the application at a later date in order to account for further data validation.

The modular design that was presented by Dimitrakopoulos (2001) provided a basis for the currently proposed system. However, the system proposed by Dimitrakopoulos (2001) did not have the error checking capabilities; that was put in place with the new data submittal system. Each module or subset of the core fire data tables had its own coding class associated with it and may be modified as needed when more information is used to validate the data that is submitted to the system. Also more modules of data may be added at a later date when they become available.

The error checking that was utilized was placed on the front end of data entry. This was done because the cost of data cleansing after the fact can be enormous (Bunton 1997, Short 2014). Since the current data submittal system was designed to accept historical data, it was known that data issues experienced in the NASF project would only be small sample of potential data errors. The new system can prevent issues like that of data shift, as described by Bunton (1997), from occurring un-noticed to the user of the submittal system. An error of this magnitude, if un-noticed, could corrupt the entire database. The new submittal system provided the user with immediate feedback when an errors occur and this could help both the data submitter and end user utilize the wildfire data housed in the database system.

Conclusion

The creation of a wildfire data submittal system that prevents errors on the front end is an essential step in the right direction of wildfire database design. With the implementation of such a system data integrity is improved and the potential for the data usability is increased for the end user. A decision needs to be made for the usability of historical data based on the findings of Bunton (1997). If the data is essentially un-usable due to the cost of cleansing the data then the data should not be used at all. For the future of the data submittal system presented in this paper there still exist many additions that could be made to the database in order to enhance the richness of fire information and the speed at which validation of data takes place.

One such item that could be analyzed is the association between acres and fire duration. This could be added to the data submittal system relatively easily. Also the data system processing speed could be improved by implementing more direct spatial querying to validate location information as spatial databases continue to advance.

Data integrity will be an issue with wildfire data in the future as more data is added, but checking the validity of such data before it goes into a database can be done. With a relatively valid data set, wildfire managers can make more data informed decisions and provide more useful conclusions about wild fire occurrences.

CHAPTER V

CONCLUSIONS

Summary

Wildland fires are a continuous issue worldwide. These fires threaten both uninhabited lands as well as areas of urban fringe. Through the sharing of information more knowledge may be gained in order to aid the prevention and knowledge of this growing threat.

Many countries already have the scaffolding to accomplish the sharing of this knowledge through national wildland fire databases. The NASF data that was utilized in this study is only one of many attempts to create a uniform national dataset that can be used for data informed decision making. However, this particular dataset provided a window into the state of wildland fire reporting at both the national and state level in the United States.

Wildland fire data does inherently have errors just like that of any other dataset of its magnitude. However, the number of errors is extremely high and impeding any productive analysis. Wildland fire cause is an example of the lack of consistency in the data and location accuracy is an example of the lack of data standards that are placed on the data. The proposed wildland fire database application is a proof of concept attempt to solve some of these issues.

Conclusion

The key to creating a wildland fire database is having data that is both consistent and valid. To accomplish the consistency of wildland fire cause, the existing standard nine statistical causes that appear to be the most commonly accepted must change. On the surface these nine causes suggest that most wild fires are started by debris burning. This study proved conclusively that this cause needs to be further sub-divided in order for the resulting data to be of any use in wildland fire prevention. Also the cause of miscellaneous appears to be a dumping ground for many different causes. Two fine causes that appeared significant in the analysis were vehicles and power lines. In addition to analysis presented, there did appear to be a lack of consistent definition as to how a fire itself would be categorized in the current cause classification system. There currently does not appear to be any standard document at the national level clearly defining how to determine the correct cause category at the coarse cause level.

In terms of data validity, this study focused on the location of a wildland fire when two location systems were utilized. The primary focus was to compare the USPLSS to other systems of location. It was assumed that the location described by the location data would occur within a given county that was provided for an individual fire incident. The McNemar's and Stuart Maxwell's χ^2 test conclusively determine that fire data with USPLSS location descriptions are not necessarily more accurate and not less accurate than their associated location descriptions by other systems of location as a whole.

Overall, the proof of concept database data submittal system has proven to mitigate the two above issues. The data submittal system solved the cause problem through forcing the user to map their cause to the predefine causes provided by the database. This is not an optimal solution, but the user-assisted mapping to an accepted system is feasible. The predefined set of causes are a result of the cause analysis described above. The location information is further validated by checking if the fire location does occur within the county that is associated with a fire incident autonomously. However, the system does not restrict the format that the data is submitted, as this was an original requirement of the NASF project. Due to the lack of restriction of the data format the speed at which the data submittal system processes data is compromised, but all data going into the system does have a clearly defined standard that it must uphold in order to be accepted into the system. This does improve the usability of the final data product as it is free of any of the above errors.

Implications and Future Work

The main implication of this study is the reliability of previously collected wildland fire data. This study has proven that there has been very little done in the way of data integrity. All data that has been housed by the systems described in this study may inherently be inaccurate for any fire analysis.

The future of wildland fire management depends on having accurate wildland fire data in order to quantify and analyze the impacts of current wildland fire practices. This study has provided a means of accomplishing this. In terms of cause there will have to be a decision made as to how to clearly classify a wildland fire cause. If a cause is clearly defined then an intervention can be put in place to help reduce a particular occurrence of a wildland fire. For example, if a particular area is suffering from many wildfires due to residential debris burning then this can easily be prevented or determined if a clear cause classification system is utilized. To determine the location of the wildland fires, the information that is provided for wildland fire incidents must be verified as to its accuracy. This study only utilized the county of origin. The Canadian wildland fire system goes a step further and utilizes satellite imagery to detect and verify wildland fire occurrences. This could be added to the proof of concept data submittal system.

The currently proposed data submittal system is lacking in that the processing time is unacceptable if it were to be utilized on a large scale. There are different techniques to handle the location verification that were not utilized in this study. One such technique could be the use of spatial database tools. Spatial database are evolving in the way that they can store and the user can process spatial information in a timely manner. With the above additions to wildland fire data, more accurate analysis can be done and faster decisions about wildland fire prevention can be made.

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APPENDIX A

In the following the full results of the fine cause analysis are presented. The processing of such data can be seen in the Processing Example 1 which corresponds with the final results for Maryland. Step 0 begins by ranking the coarse causes without evaluating any of the fine causes. This step illustrates the base ranking of the coarse causes. Under each coarse cause are the potential contributions of each fine cause. In step 1 the first fine cause (arson (fine cause)) is evaluated. This process involves subtracting 690 fires from the 694 fires from coarse cause arson. Additionally 9 fine causes were subtracted from the miscellaneous coarse cause. This results in the ranking of arson changing from 2 to 10 and the initial (rank after) for arson (fine cause) to change to 2. The process continues until all fine causes have been evaluated. In the tables to follow this process is summarized without explicitly showing which coarse causes were affected by the addition of individual fine causes.

Example Process 1 Maryland processing

Fine cause Analysis Step 0

			Rank Before	1	2	3	4	5	6	7	8	9
			Rank After	0	0	0	0	0	0	0	0	0
Total	3187			965	694	443	438	289	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
**arson (fine cause)	0	-	0	0	690	9	0	0	0	0	0	0**
power line	0	-	0	0	0	128	4	0	0	0	0	0
ashes	0	-	0	0	0	93	0	0	0	0	0	0
fireworks	0	-	0	0	0	40	0	3	0	0	0	0
spontaneous	0	-	0	0	0	21	0	0	0	0	0	0
structure	0	-	0	0	0	14	0	0	0	0	0	0
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Fine cause Analysis Step 1

			Rank Before	1	2	3	4	5	6	7	8	9
			Rank After	1	10	4	3	5	6	7	8	9
Total	3187			965	4	434	438	289	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	-	2	0	0	0	0	0	0	0	0	0
**power line	0	-	0	0	0	128	4	0	0	0	0	0**
ashes	0	-	0	0	0	93	0	0	0	0	0	0
fireworks	0	-	0	0	0	40	0	3	0	0	0	0
spontaneous	0	-	0	0	0	21	0	0	0	0	0	0
structure	0	-	0	0	0	14	0	0	0	0	0	0
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Example Process 1 Continued

Fine cause Analysis Step 2

			Rank Before	1	10	4	3	5	6	7	8	9
			Rank After	1	11	4	3	5	6	8	9	10
Total	3187			965	4	306	434	289	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	-	7	0	0	0	0	0	0	0	0	0
**ashes	0	-	0	0	0	93	0	0	0	0	0	0**
fireworks	0	-	0	0	0	40	0	3	0	0	0	0
spontaneous	0	-	0	0	0	21	0	0	0	0	0	0
structure	0	-	0	0	0	14	0	0	0	0	0	0
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Fine cause Analysis Step 3

			Rank Before	1	11	4	3	5	6	8	9	10
			Rank After	1	12	5	3	4	6	8	10	11
Total	3187			965	4	213	434	289	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	7	7	0	0	0	0	0	0	0	0	0
ashes	93	-	9	0	0	0	0	0	0	0	0	0
**fireworks	0	-	0	0	0	40	0	3	0	0	0	0**
spontaneous	0	-	0	0	0	21	0	0	0	0	0	0
structure	0	-	0	0	0	14	0	0	0	0	0	0
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Example Process 1 Continued

Fine cause Analysis Step 4

			Rank Before	1	12	5	3	4	6	8	10	11
			Rank After	1	13	5	3	4	6	8	10	12
Total	3208			965	4	173	434	286	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	7	7	0	0	0	0	0	0	0	0	0
ashes	93	9	9	0	0	0	0	0	0	0	0	0
fireworks	43	-	11	0	0	0	0	0	0	0	0	0
**spontaneous	21	-	0	0	0	21	0	0	0	0	0	0**
structure	0	-	0	0	0	14	0	0	0	0	0	0
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Fine cause Analysis Step 5

			Rank Before	1	13	5	3	4	6	8	10	12
			Rank After	1	14	6	3	4	5	8	10	12
Total	3187			965	4	152	434	286	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	7	7	0	0	0	0	0	0	0	0	0
ashes	93	9	9	0	0	0	0	0	0	0	0	0
fireworks	43	11	11	0	0	0	0	0	0	0	0	0
spontaneous	21	-	13	0	0	0	0	0	0	0	0	0
**structure	0	-	0	0	0	14	0	0	0	0	0	0**
random causes	0	-	0	3	4	96	16	1	1	0	2	4

Example Process 1 Continued

Fine cause Analysis Step 6

			Rank Before	1	14	6	3	4	5	8	10	12
			Rank After	1	15	6	3	4	5	8	10	12
Total	3187			965	4	138	434	286	161	96	68	33
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	7	7	0	0	0	0	0	0	0	0	0
ashes	93	9	9	0	0	0	0	0	0	0	0	0
fireworks	43	11	11	0	0	0	0	0	0	0	0	0
spontaneous	21	13	13	0	0	0	0	0	0	0	0	0
**structure	14	-	14	0	0	0	0	0	0	0	0	0
**random causes	0	-	0	3	4	96	16	1	1	0	2	4**

Fine cause Analysis Step 7

			Rank Before	1	15	6	3	4	5	8	10	12
			Rank After	1	16	12	3	4	5	8	10	13
Total	3187			962	0	42	418	285	160	96	66	29
Fine cause	Count	Rank Before	Rank After	debris burning	arson	miscellaneous	equipment	children	smoking	lightning	camp fire	railroad
arson (fine cause)	699	2	2	0	0	0	0	0	0	0	0	0
power line	132	7	6	0	0	0	0	0	0	0	0	0
ashes	93	9	9	0	0	0	0	0	0	0	0	0
fireworks	43	11	11	0	0	0	0	0	0	0	0	0
spontaneous	21	13	14	0	0	0	0	0	0	0	0	0
structure	14	14	15	0	0	0	0	0	0	0	0	0
random causes	127	-	7	3	4	96	16	1	1	0	2	4

Table 1A Arkansas fine cause results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	if	rf
debris burning	4159	1	4158	1	3941	1	2747	2	1572	3	1240	3	370	6
incendiary	3989	2	946	4	748	4	748	5	745	6	744	6	188	11
miscellaneous	1424	3	1424	3	549	5	549	6	549	7	548	7	67	23
equipment use	782	4	782	5	381	7	381	8	381	9	381	9	33	33
lightning	452	5	452	6	451	6	451	7	451	8	451	8	449	5
railroad	198	6	198	7	191	8	191	9	191	1	191	1	4	45
children	153	7	153	8	129	9	129	1	129	1	129	1	7	43
smokers	122	8	122	9	122	1	121	1	121	1	121	1	9	40
camp fire	106	9	106	1	106	1	106	1	106	1	106	1	9	40
pyromania (arson)	0	0	3050	2	3050	2	3050	1	3050	1	3050	1	3050	1
other (explain in remarks)	0	0	0	0	1723	3	1723	3	1723	2	1723	2	1723	2
brush piles	0	0	0	0	0	0	1195	4	1195	4	1195	4	1195	3
trash	0	0	0	0	0	0	0	0	1178	5	1178	5	1178	4
slash disposal (logging included)	0	0	0	0	0	0	0	0	0	0	334	1	334	7
prescribed burn escape	0	0	0	0	0	0	0	0	0	0	0	0	314	8
power line break	0	0	0	0	0	0	0	0	0	0	0	0	279	9
game(improvement of area, move to other location)	0	0	0	0	0	0	0	0	0	0	0	0	265	10
grudge	0	0	0	0	0	0	0	0	0	0	0	0	170	12
exhaust	0	0	0	0	0	0	0	0	0	0	0	0	162	13
carbon sparks	0	0	0	0	0	0	0	0	0	0	0	0	128	14
incinerator, burning barrel or area	0	0	0	0	0	0	0	0	0	0	0	0	125	15
building or structure	0	0	0	0	0	0	0	0	0	0	0	0	124	16
range or meadow	0	0	0	0	0	0	0	0	0	0	0	0	120	17
electrical	0	0	0	0	0	0	0	0	0	0	0	0	119	18
stubble removal	0	0	0	0	0	0	0	0	0	0	0	0	98	19
range or pasture	0	0	0	0	0	0	0	0	0	0	0	0	91	20
burning of tobacco (in any form)	0	0	0	0	0	0	0	0	0	0	0	0	90	21
dump (city or rural)	0	0	0	0	0	0	0	0	0	0	0	0	82	22
land clearing	0	0	0	0	0	0	0	0	0	0	0	0	64	24
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	63	25
fence rows	0	0	0	0	0	0	0	0	0	0	0	0	60	26
playing with fire (matches)	0	0	0	0	0	0	0	0	0	0	0	0	56	27
heating or warmth	0	0	0	0	0	0	0	0	0	0	0	0	52	28
fuel ignition	0	0	0	0	0	0	0	0	0	0	0	0	47	29
brakes	0	0	0	0	0	0	0	0	0	0	0	0	41	30
insect or snake control	0	0	0	0	0	0	0	0	0	0	0	0	36	31

Table 1A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	if	rf
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	35	32
cooking	0	0	0	0	0	0	0	0	0	0	0	0	27	34
den tree burning	0	0	0	0	0	0	0	0	0	0	0	0	27	34
equipment crash	0	0	0	0	0	0	0	0	0	0	0	0	24	36
match or lighter	0	0	0	0	0	0	0	0	0	0	0	0	23	37
provide light	0	0	0	0	0	0	0	0	0	0	0	0	18	38
solar radiation	0	0	0	0	0	0	0	0	0	0	0	0	13	39
right-of-way or tie burning	0	0	0	0	0	0	0	0	0	0	0	0	9	40
burning car or cargo	0	0	0	0	0	0	0	0	0	0	0	0	6	44
hot box	0	0	0	0	0	0	0	0	0	0	0	0	3	46
create job	0	0	0	0	0	0	0	0	0	0	0	0	2	47
pecan harvest	0	0	0	0	0	0	0	0	0	0	0	0	2	47

Table 2A Arizona fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
undetermined	2799	1	439	3	335	4	330	4	326	4	325	4	323	4	321	4	317	4
miscellaneous	960	2	922	2	263	6	225	6	217	5	214	5	203	5	189	5	112	5
lightning	371	3	371	4	371	3	371	3	371	3	371	3	371	3	371	3	370	3
debris burning	302	4	292	5	275	5	273	5	200	6	151	6	115	6	87	8	34	15
equipment use	181	5	172	6	128	7	75	8	74	9	74	9	74	9	74	9	56	8
camp fire	69	6	62	7	49	8	49	9	49	10	49	11	49	11	49	11	13	18
smoking	49	7	47	8	43	9	41	10	41	11	41	12	41	13	41	14	41	13
arson	33	8	30	9	21	10	19	11	16	12	16	13	16	14	15	15	4	29
railroad	18	9	16	10	12	11	12	12	12	13	12	14	12	15	12	16	8	24
children	14	10	14	11	12	11	12	12	12	13	12	14	12	15	12	16	2	33
undetermined (fine cause)	0	0	2431	1	2431	1	2431	1	2431	1	2431	1	2431	1	2431	1	2431	1
other	0	0	0	0	856	2	856	2	856	2	856	2	856	2	856	2	856	2

Table 2A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
burning vehicle	0	0	0	0	0	0	102	7	102	7	102	7	102	7	102	6	102	6
trash burning	0	0	0	0	0	0	0	0	89	8	89	8	89	8	89	7	89	7
slash burning	0	0	0	0	0	0	0	0	0	0	53	10	53	10	53	10	53	9
land clearing burning	0	0	0	0	0	0	0	0	0	0	0	0	49	11	49	11	49	10
field burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	13	45	11
resource mgmt. burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	11
warming fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	14
burning building	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	16
power Line	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	17
brakeshoe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	19
exhaust - power saw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	19
pyromania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	21
cooking fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	22
exhaust - other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	22
burning dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	24
house or stove fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	26
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	27
playing with matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	27
job fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	29
aircraft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	31
r/w burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	31
logging line	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	34

Table 3A Colorado fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
undetermined	908	1	908	1	906	1	904	1	896	1	893	1	887	1	872	1
natural source	802	2	794	2	434	2	434	2	431	2	431	2	419	2	393	2
debris	451	3	415	3	415	3	362	4	328	4	328	4	311	4	257	4
other cause	287	4	227	5	223	7	177	8	171	8	163	8	150	8	95	10
open/outdoor fire	270	5	248	4	248	5	226	5	201	6	200	6	186	6	129	7

Table 3A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
equipment	228	6	227	5	227	6	225	6	224	5	224	5	222	5	103	8
incendiary	220	7	194	7	194	8	188	7	185	7	134	11	132	11	79	12
misuse of fire	192	8	179	8	179	9	168	10	162	10	148	9	145	9	96	9
smoking	122	9	118	10	118	11	118	12	110	12	110	12	110	12	59	17
structure(exposure)	4	10	3	11	3	12	3	13	3	14	3	15	3	16	0	43
undetermined	0	0	171	9	171	10	171	9	171	8	171	7	171	7	171	5
lightning	0	0	0	0	366	4	366	3	366	3	366	3	366	3	366	3
flame/torch used for lighting	0	0	0	0	0	0	142	11	142	11	142	10	142	10	142	6
hot ember or ash	0	0	0	0	0	0	0	0	94	13	94	13	94	13	94	11
fireworks	0	0	0	0	0	0	0	0	0	0	77	14	77	14	77	13
heat source: other	0	0	0	0	0	0	0	0	0	0	0	0	69	15	69	14
spark, ember or flame from operating equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	15
arcing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	16
match	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	18
hot or smoldering object, other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	19
cigarette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	20
heat from other open flame or smoking materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	21
cigarette lighter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	22
heat, spark from friction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	23
flying brand, ember, spark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	24
chemical reaction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	25
heat spread from another fire, other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	26
explosive, fireworks, other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	27
heat from direct flame, convection currents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	28
heat from powered equipment, other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	28
radiated, conducted heat from operating equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	30
heat from undetermined smoking material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	31
multiple heat sources including multiple ignitions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	32
conducted heat from another fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	33
incendiary device	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	33
radiated heat from another fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	33
backfire from internal combustion engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	36
model and amateur rockets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	36
molten, hot material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	36
warning or road flare; fusee	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	36

Table 3A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
intentional	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	40
munitions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	40
pipe or cigar	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	40

Table 4A Florida fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
debris burn	5494	1	3885	2	2541	4	2541	4	2541	4	1830	4	1830	4	1212	6	376	15
lightning	5049	2	5049	1	5049	1	5049	1	5049	1	5049	1	5049	1	5049	1	5049	1
incendiary	3396	3	3396	3	3396	2	3396	2	3396	2	3396	2	3396	2	3396	2	3396	2
unknown	3009	4	3009	4	3009	3	3009	3	3009	3	3009	3	3009	3	3009	3	3009	3
miscellaneous	2155	5	2155	5	2155	5	1375	7	628	11	628	12	628	13	628	13	0	26
equipment	1714	6	1714	6	1714	6	1714	5	1714	5	1714	5	1033	8	1033	8	117	23
children	1102	7	1102	8	1102	9	1102	9	1102	8	1102	8	1102	7	1102	7	1102	6
smoking	327	9	327	10	327	11	327	12	327	13	327	14	327	15	327	16	327	16
railroad	191	10	191	11	191	12	191	13	191	14	191	15	191	16	191	17	191	20
nonauth yard trash	0	0	1609	7	1609	7	1609	6	1609	6	1609	6	1609	5	1609	4	1609	4
nonauth piles	0	0	0	0	1344	8	1344	8	1344	7	1344	7	1344	6	1344	5	1344	5
power lines	0	0	0	0	0	0	780	10	780	9	780	9	780	9	780	9	780	7
other	0	0	0	0	0	0	0	0	747	10	747	10	747	10	747	10	747	8
auth yard trash	0	0	0	0	0	0	0	0	0	0	711	11	711	11	711	11	711	9
transportation	0	0	0	0	0	0	0	0	0	0	0	0	681	12	681	12	681	10
auth piles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	618	14	618	11
auth broadcast/acreage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	565	13
agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	548	14
recreation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	274	17
nonauth broadcast/acreage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	271	18
breakout	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	220	19
structure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181	21
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	170	22
logging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	24
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	25

Table 5A Georgia fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris	20393	1	12002	1	8674	1	6143	4	3860	4	2512	7	1240	12	0	16
incendiary	7548	2	7548	3	7548	3	7548	2	7548	2	7548	2	7548	2	7548	2
machine use	7075	3	7075	4	7075	4	7075	3	7075	3	7075	3	7075	3	7075	3
miscellaneous	3437	4	3437	5	3437	5	3437	5	3437	5	3437	4	3437	4	3437	4
lightning	2063	5	2063	6	2063	7	2063	8	2063	9	2063	9	2063	8	2063	8
children	1924	6	1924	7	1924	8	1924	9	1924	10	1924	10	1924	9	1924	9
smoking	1128	7	1128	8	1128	9	1128	10	1128	11	1128	12	1128	13	1128	13
railroad	650	9	650	10	650	11	650	12	650	13	650	14	650	15	650	15
escaped prescribed burn	0	0	0	0	3328	6	3328	6	3328	6	3328	5	3328	5	3328	5
ag fields, pastures, orchards, etc	0	0	0	0	0	0	2531	7	2531	7	2531	6	2531	6	2531	6
site prep - forestry related	0	0	0	0	0	0	0	0	2283	8	2283	8	2283	7	2283	7
construction land clearing	0	0	0	0	0	0	0	0	0	0	1348	11	1348	10	1348	10
household garbage	0	0	0	0	0	0	0	0	0	0	0	0	1272	11	1272	11
other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1240	12

Table 6A Louisiana fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	i9	r9	i10	r10	if	rf
miscellaneous	411	1	307	1	261	1	230	1	209	1	193	1	179	1	162	1	148	1	143	1	12	10
incendiary	23	2	21	3	21	4	21	5	18	7	16	8	15	9	15	10	15	10	13	11	3	15
machine	21	3	21	3	21	4	21	5	21	6	21	7	21	7	21	7	20	7	20	7	2	16
debris	18	4	18	5	18	6	17	7	16	8	15	9	15	9	15	10	15	10	11	13	0	23
escaped prescribed burn	18	4	18	5	16	7	16	8	12	9	7	10	5	11	5	12	5	13	4	14	1	19
children	4	6	4	7	4	8	4	9	4	10	4	11	4	12	4	13	4	14	4	14	2	16
lightning	3	7	2	9	2	10	2	11	2	12	2	13	2	14	2	15	2	16	2	17	2	16
camp fire	3	7	2	9	2	10	2	11	2	12	2	13	2	14	2	15	2	16	2	17	1	19
smoking	3	7	3	8	3	9	3	10	3	11	3	12	3	13	3	14	3	15	3	16	1	19
railroad	1	10	1	11	1	12	1	13	1	14	1	15	1	16	1	17	1	18	1	19	1	19
power line	0	0	108	2	108	2	108	2	108	2	108	2	108	2	108	2	108	2	108	2	108	2
breakover	0	0	0	0	48	3	48	3	48	3	48	3	48	3	48	3	48	3	48	3	48	3
house	0	0	0	0	0	0	32	4	32	4	32	4	32	4	32	4	32	4	32	4	32	4
control burn	0	0	0	0	0	0	0	0	29	5	29	5	29	5	29	5	29	5	29	5	29	5
escape	0	0	0	0	0	0	0	0	0	0	24	6	24	6	24	6	24	6	24	6	24	6

Table 6A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	i9	r9	i10	r10	if	rf
burning	0	0	0	0	0	0	0	0	0	0	0	0	17	8	17	8	17	8	17	8	17	7
road	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	8	17	8	17	8	17	7
truck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	10	15	10	15	9
pile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	12	12	10
restarted	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	10
hay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	13
unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	13
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144	1

Table 7A Maryland fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	965	1	965	1	965	1	965	1	965	1	965	1	965	1	962	1
arson	694	2	4	10	4	11	4	12	4	13	4	14	4	15	0	16
miscellaneous	443	3	434	4	306	4	213	5	173	5	152	6	138	6	42	12
equipment	438	4	438	3	434	3	434	3	434	3	434	3	434	3	418	3
children	289	5	289	5	289	5	289	4	286	4	286	4	286	4	285	4
smoking	161	6	161	6	161	6	161	6	161	6	161	5	161	5	160	5
lightning	96	7	96	7	96	8	96	8	96	8	96	8	96	8	96	8
camp fire	68	8	68	8	68	9	68	10	68	10	68	10	68	10	66	10
railroad	33	9	33	9	33	10	33	11	33	12	33	12	33	12	29	13
arson (fine cause)	0	0	699	2	699	2	699	2	699	2	699	2	699	2	699	2
power line	0	0	0	0	132	7	132	7	132	7	132	7	132	7	132	6
ashes	0	0	0	0	0	0	93	9	93	9	93	9	93	9	93	9
fireworks	0	0	0	0	0	0	0	0	43	11	43	11	43	11	43	11
spontaneous	0	0	0	0	0	0	0	0	0	0	21	13	21	13	21	14
structure	0	0	0	0	0	0	0	0	0	0	0	0	14	14	14	15
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127	7

Table 8A Michigan fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
debris burning	947	1	827	1	557	1	557	1	474	1	474	1	474	1	412	1	406	1
equipment use	483	2	446	2	446	2	357	3	357	3	357	3	291	4	291	4	253	5
miscellaneous	447	3	347	4	347	4	347	4	347	4	347	4	347	3	347	3	311	3
camp fire	270	4	222	5	222	6	222	6	222	6	155	7	155	7	155	7	139	7
lightning	201	5	201	6	201	7	201	7	201	7	201	6	201	6	201	6	201	6
unknown	139	6	139	7	139	8	139	8	139	8	139	8	139	8	139	8	139	7
children	131	7	119	8	119	9	119	9	119	9	119	9	119	9	119	9	55	14
incendiary	126	8	77	10	77	11	77	12	77	13	77	13	77	13	77	13	55	14
railroad	81	9	81	9	81	10	81	11	81	12	81	12	81	12	81	12	54	16
smoking	77	10	56	11	56	12	56	13	56	14	56	15	56	16	56	17	0	37
miscellaneous unknown	39	11	39	12	39	13	39	14	39	15	39	16	39	17	39	18	39	18
other	0	0	387	3	387	3	387	2	387	2	387	2	387	2	387	2	387	2
trash	0	0	0	0	270	5	270	5	270	5	270	5	270	5	270	5	270	4
exhaust	0	0	0	0	0	0	89	10	89	10	89	10	89	10	89	10	89	9
land clearing	0	0	0	0	0	0	0	0	83	11	83	11	83	11	83	11	83	10
recreationist	0	0	0	0	0	0	0	0	0	0	67	14	67	14	67	14	67	11
electrical	0	0	0	0	0	0	0	0	0	0	0	0	66	15	66	15	66	12
slash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	62	16	62	13
playing with fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	17
smoking (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	19
friction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	20
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	21
burning building	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	22
carbon sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	23
pyromania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	24
hunter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	25
fisherman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	26
berry/mushroom picker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	27
braking	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	28
dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	28
crash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	30
from vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	30

Table 8A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32
habitat improvement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32
job fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	32
grudge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	35
right-of-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	35

Table 9A Minnesota fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
debris	14622	1	9957	2	8281	2	8281	2	7155	2	7155	2	7155	2	7155	2	6869	2
incendiary/arson	11267	2	11267	1	11267	1	11267	1	11267	1	11267	1	11267	1	11267	1	11267	1
miscellaneous	4051	3	4051	4	4051	4	2741	5	2741	5	2741	4	2154	5	2154	4	1591	5
equipment	3191	4	3191	5	3191	5	3191	4	3191	4	2477	5	2477	4	2015	5	1185	9
railroad	1882	5	1882	6	1882	6	1819	6	1819	6	1819	6	1819	6	1819	6	1430	6
smoking	1254	6	1254	7	1254	8	1254	9	1254	9	1254	9	1254	9	1254	9	1254	8
camp fire	1129	7	1129	8	1129	9	1129	10	1129	10	1129	10	1129	10	1129	10	1129	10
children	980	8	980	9	980	10	980	11	980	12	980	12	980	12	980	12	980	12
lightning	719	9	719	10	719	11	719	12	719	13	719	13	719	13	719	13	719	13
piled	0	0	4665	3	4665	3	4665	3	4665	3	4665	3	4665	3	4665	3	4665	3
running	0	0	0	0	1676	7	1676	7	1676	7	1676	7	1676	7	1676	7	1676	4
other	0	0	0	0	0	0	1373	8	1373	8	1373	8	1373	8	1373	8	1373	7
burner	0	0	0	0	0	0	0	0	1126	11	1126	11	1126	11	1126	11	1126	11
vehicle	0	0	0	0	0	0	0	0	0	0	714	14	714	14	714	14	714	14
power line	0	0	0	0	0	0	0	0	0	0	0	0	587	15	587	15	587	15
farm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	462	16	462	16
road maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	360	17
exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	296	18
ag. operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286	19
atv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	20
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	243	21

Table 9A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
structure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	147	22
welding/cutting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	114	23
misc. tools	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97	24
prescribed fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	25
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82	26
brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	27
maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	28
wheel bearings	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	29

Table 10A Montana fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
lightning	1868	1	1868	1	1868	1	1868	1	1868	1	1868	1	1867	1	1867	1	1865	1
miscellaneous	683	2	682	2	681	2	657	2	657	2	638	2	638	2	636	2	625	2
debris burning	564	3	564	3	564	3	563	3	542	3	541	3	538	3	538	3	518	3
camp fire	447	4	17	11	17	11	17	12	17	13	17	14	11	14	11	14	0	66
equipment	156	5	156	5	156	5	156	5	156	5	156	5	156	5	156	5	132	5
false alarm	117	6	117	6	117	6	117	6	115	6	115	6	115	6	115	6	112	6
railroad	92	7	92	7	92	7	91	7	91	7	91	7	91	7	91	7	88	7
children	69	8	69	8	69	8	69	8	69	8	69	8	69	8	69	8	69	8
incendiary	61	9	61	9	61	9	61	9	61	9	61	9	61	9	61	9	61	9
smoking	60	10	60	10	6	13	6	14	6	15	6	16	6	17	6	16	0	66
power line	9	11	9	12	9	12	9	13	9	14	9	15	9	16	1	18	0	66
arson	4	12	4	13	4	14	4	15	4	16	2	17	2	18	2	17	2	22
camp fire (fine cause)	0	0	431	4	431	4	431	4	431	4	431	4	431	4	431	4	431	4
smoking(fine cause)	0	0	0	0	55	10	55	10	55	10	55	10	55	10	55	10	55	10
unknown	0	0	0	0	0	0	26	11	26	11	26	11	26	11	26	11	26	11
residential	0	0	0	0	0	0	0	0	23	12	23	12	23	12	23	12	23	12
fireworks	0	0	0	0	0	0	0	0	0	0	22	13	22	13	22	13	22	13
escaped	0	0	0	0	0	0	0	0	0	0	0	0	10	15	10	15	10	14
power line (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	15	10	14
pile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	16

Table 10A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
logging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	17
cigarette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	18
illegal camp fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	19
camp fire unattended	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	20
vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	20
car fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
clipper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
haying	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
hot brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
spontaneous combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
swather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
tractor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22
agricultural burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
barbeque pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
burn barrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
burned out of mission mtn wildernes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
child with lighter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
children with matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
construction materials	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
dozer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
electric grinder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
barrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
failure to attend	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
false alarm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
fire burning in a stump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
grain truck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
grinding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
hot saw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
human	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
hunters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
kids party	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
land clean up	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
lawn mower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30

Table 10A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
legal burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
level ii restrictions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
match or cigarette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
prescribed fire - legal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
rekindle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
shop light on a stand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
smoke from a structure fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
structure	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
trailer ramp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
welding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
wood cutter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
road grader	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30
burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30

Table 11A Nebraska fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	3702	1	3702	1	2532	1	1807	2	1132	6	1132	6	1132	5	1	41
miscellaneous	3540	2	1279	5	1279	5	1278	5	1278	4	1278	3	781	6	1	41
equipment	1731	3	1731	3	1731	3	1731	3	1731	2	1171	4	1171	3	0	48
lightning	1516	4	1516	4	1516	4	1516	4	1516	3	1516	2	1516	2	1516	2
railroad	635	5	635	6	635	7	635	8	635	9	635	9	635	9	635	6
smoking	474	6	474	7	474	8	474	9	474	10	474	11	474	12	474	9
incendiary	453	7	453	8	453	9	453	10	453	11	453	12	453	13	300	15
camp fire	97	8	97	9	97	10	97	11	97	12	97	13	97	14	97	21
children	74	9	74	10	74	11	74	12	74	13	74	14	74	15	74	25
electric fence	70	10	70	11	70	12	70	13	70	14	70	15	70	16	70	26
unknown	0	0	2261	2	2261	2	2261	1	2261	1	2261	1	2261	1	2261	1
prescribed fire	0	0	0	0	1170	6	1170	6	1170	5	1170	5	1170	4	1170	3
trash burning	0	0	0	0	0	0	726	7	726	7	726	7	726	7	726	4
agricultural burning	0	0	0	0	0	0	0	0	675	8	675	8	675	8	675	5
car or truck	0	0	0	0	0	0	0	0	0	0	560	10	560	10	560	7

Table 11A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
power lines	0	0	0	0	0	0	0	0	0	0	0	0	497	11	497	8
burning piles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	397	10
other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	377	11
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	376	12
burning without permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	346	13
combine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	308	14
road ditch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	243	16
baler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	218	17
welding or cut torch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	193	18
suspicious	0	0	0	0	0	0	0	0	0	0	0	0	0	0	153	19
spontaneous combust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	20
tractor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	94	22
miscellaneous (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89	23
discarded material	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	24
irrigation ditchbank	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	27
feed or hay grinder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	28
trailer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	28
hunters	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	30
mower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	30
dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	32
swather	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	33
well motor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	34
shredder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	35
atv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	36
corn picker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	37
grass fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	37
matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	39
sprayer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	40
cutting torch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41
haystack mover sled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41
maintainer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41
unattended burning permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41
welding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	41

Table 12A New Jersey fine cause analysis

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
incendiary	9028	1	8174	1	8174	1	7763	1	7763	1	7763	1	7763	1	7708	1
miscellaneous	4244	2	4160	2	3646	3	3646	3	3646	2	3646	2	3646	2	3087	2
children	4003	3	3655	3	3655	2	3655	2	3254	3	3254	3	3254	3	3009	3
smoking	1770	4	1657	5	1657	5	1657	5	1657	5	1657	5	1657	4	1453	5
equipment use	1750	5	1662	4	1662	4	1662	4	1662	4	1662	4	1401	6	1107	7
false alarm	1375	6	1375	7	1375	7	1375	7	1375	7	1375	7	1375	7	1375	6
camp fire	1191	7	1161	8	1161	8	1161	8	1161	8	857	9	857	9	801	8
debris burning	1044	8	1024	9	1024	9	1024	9	1024	9	1024	8	1024	8	771	9
railroad	817	9	793	10	793	10	793	10	793	10	793	10	793	10	615	10
lightning	186	10	186	11	186	12	186	13	186	14	186	15	186	16	186	17
other	0	0	1561	6	1561	6	1561	6	1561	6	1561	6	1561	5	1561	4
unknown	0	0	0	0	514	11	514	11	514	11	514	11	514	11	514	11
pyromania	0	0	0	0	0	0	411	12	411	12	411	12	411	12	411	12
mischief	0	0	0	0	0	0	0	0	401	13	401	13	401	13	401	13
illegal camp fire	0	0	0	0	0	0	0	0	0	0	304	14	304	14	304	14
power line/ other electrical equipment	0	0	0	0	0	0	0	0	0	0	0	0	261	15	261	15
matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	16
carbon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	164	18
highway traveler	0	0	0	0	0	0	0	0	0	0	0	0	0	0	159	19
improper ash/charcoal disposal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	149	20
vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	140	21
car	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	22
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	109	23
brush pile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104	24
burning building	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	25
trash disposal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83	26
truck	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69	27
farm machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	28
leaves	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41	29
camp fire (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	30
camper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	31
hiker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	32
trail bike/atv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	33
spontaneous combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	34
highway accident	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	35
harassment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	36
job fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	36

Table 12A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
munitions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	38
valid ag permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	38
smoking (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	40
fisherman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	41
grudge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	42
hunter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	42
animal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	44
valid camp fire permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	45
equipment use (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	46
chain saw	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	46
chimney sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	48
hedge row/field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	48
brake shoe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	50
crime concealment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	50
aircraft	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	52
logging machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	52
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	54
picnicker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	54
den tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	56
tie burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	56
game food/cover	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	58
timber operator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	58
valid rxb permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	58

Table 13A North Dakota fine cause analysis

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
equipment use	525	1	523	1	523	1	523	1	510	1	510	1	508	1	508	1	386	1
debris burning	406	2	406	2	392	2	388	2	384	2	384	2	384	2	374	2	304	3
lightning	294	3	294	3	292	3	292	3	261	3	261	3	261	3	261	3	230	4
other	286	4	286	4	286	4	234	4	230	4	230	4	196	4	188	5	0	34
undetermined	215	5	29	1	29	13	28	14	22	16	22	17	22	18	22	18	0	34
open/outdoor fire	153	6	151	7	40	12	40	13	39	14	39	14	39	15	22	18	0	34
children	152	7	152	6	150	6	149	6	146	6	146	6	146	6	146	6	116	7

Table 13A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
smoking	137	8	137	8	137	7	137	7	136	7	136	7	136	7	136	7	109	8
miscellaneous	102	9	102	9	102	9	102	9	98	9	27	15	24	17	24	17	0	34
re-ignition	85	10	85	1	85	10	76	11	74	12	74	11	68	12	65	12	3	33
incendiary	63	11	63	1	63	11	52	12	48	13	47	13	47	13	46	13	0	34
not specified	27	12	27	1	27	14	27	15	25	15	25	16	25	16	25	16	21	20
structure fire	20	13	16	1	15	15	15	16	15	17	15	18	15	19	15	20	11	29
railroad	13	14	13	1	13	16	13	17	13	18	13	19	13	20	13	21	0	34
natural	12	15	12	1	12	17	12	18	11	19	11	20	11	21	11	22	8	32
camp fire	3	16	3	1	3	18	3	19	3	20	3	21	3	22	3	23	0	34
undetermined (fine cause)	0	0	194	5	194	5	194	5	194	5	194	5	194	5	194	4	194	5
open/outdoor fire (fine cause	0	0	0	0	130	8	130	8	130	8	130	8	130	8	130	8	130	6
fireworks	0	0	0	0	0	0	78	10	78	10	78	9	78	9	78	9	78	9
bale	0	0	0	0	0	0	0	0	76	11	76	10	76	10	76	10	76	10
miscellaneous (fine cause)	0	0	0	0	0	0	0	0	0	0	72	12	72	11	72	11	72	11
power lines	0	0	0	0	0	0	0	0	0	0	0	0	45	14	45	14	45	12
control burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	15	39	13
incendiary (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	14
combine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	15
railroad (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	15
reignite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	17
train	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	18
pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	19
garbage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	21
spark	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	22
crop	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	23
vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	24
other (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	24
arson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	26
county	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	27
stubble	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	28
tree	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	29
deliberate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	31

Table 14A Oregon fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
lightning	2570	1	2570	1	2570	1	2570	1	2570	1	2570	1	2570	1	2570	1
debris burning	1634	2	1634	2	1634	2	1634	2	1634	2	1634	2	1634	2	826	2
equipment use	1616	3	1616	3	1616	3	1606	3	1439	3	1279	3	1279	3	797	3
miscellaneous	1001	4	775	5	775	5	750	4	750	4	750	4	750	4	506	4
recreationist	968	5	968	4	797	4	662	5	662	5	662	5	662	5	503	5
smoking	399	6	399	6	399	6	399	6	399	6	399	6	271	6	211	7
arson	268	7	268	7	268	7	268	7	268	7	268	7	268	7	135	12
juveniles	260	8	260	8	260	8	260	8	260	8	260	8	260	8	133	13
railroad	80	9	80	10	80	11	80	12	80	13	80	14	80	15	0	65
under invest	7	10	7	11	7	12	7	13	7	14	7	15	7	16	7	64
other miscellaneous	0	0	226	9	226	9	226	9	226	9	226	9	226	9	226	6
camp fire not put	0	0	0	0	171	10	171	10	171	10	171	10	171	10	171	8
warming fire	0	0	0	0	0	0	170	11	170	11	170	11	170	11	170	9
power lines	0	0	0	0	0	0	0	0	167	12	167	12	167	12	167	10
burning vehicle	0	0	0	0	0	0	0	0	0	0	160	13	160	13	160	11
cigarette	0	0	0	0	0	0	0	0	0	0	0	0	128	14	128	14
sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117	15
inadequate mop-up	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115	16
unattended fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115	16
other equip related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108	18
other debris burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	106	19
bad burn conditions too	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	20
other recreation related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102	20
other arson related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99	23
inadequate clearing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	93	24
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	25
burning building	0	0	0	0	0	0	0	0	0	0	0	0	0	0	78	26
hold-over from other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	27
farm machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	28
heat - vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	29
failure to mop-up	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	30
child playing with	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	31
dumping hot ashes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	31
railroad	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	33
camp fire unattended	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	34

Table 14A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
inadequate control force	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	34
other slash -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	34
other smoker related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	37
cutting or weld	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	38
spontaneous combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	38
failure to patrol	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	40
other logging related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	41
juvenile using fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	42
burning match dropped	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	43
rubbish disposal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	44
child using fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	45
owner electric service	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	45
burning prohibited matter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	47
fail to follow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	48
rotary saw friction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	48
engine exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	50
inadequate fuel break	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	50
juvenile play with	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	50
power saw exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	53
emotional distress	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	54
equip electric wiring	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	54
fire line inadequate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	54
cover up criminal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	57
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	57
other child-less than	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	57
power saw-not logging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	57
track maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	57
other juvenile (13-18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	62
other railroad related	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	62
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	22

Table 15A Tennessee fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	3393	1	3393	1	2247	1	1157	2	976	4	682	4	395	6	0	40
incendiary	2030	2	178	6	178	7	178	8	54	15	54	16	54	17	0	40
fire bug	447	3	447	3	447	4	447	5	447	6	447	6	447	5	447	5
miscellaneous	407	4	407	4	407	5	407	6	293	7	293	8	293	8	0	40
equipment	338	5	338	5	338	6	338	7	200	8	200	9	200	10	0	40
smoking (adult)	119	6	119	7	119	8	119	9	119	9	119	10	119	11	119	9
railroad	115	7	115	8	115	9	115	10	113	10	113	11	113	12	0	40
machine use	100	8	100	9	100	10	100	11	100	11	100	12	100	13	100	13
children (<12 yrs)	80	9	80	10	80	11	80	12	80	12	80	13	80	14	80	16
camp fire	71	10	71	11	71	12	71	13	71	13	71	14	71	15	71	18
lightning	56	11	56	12	56	13	56	14	56	14	56	15	56	16	56	20
power line	49	12	49	13	49	14	49	15	49	16	49	17	49	18	49	21
burning building	37	13	37	14	37	15	37	16	37	17	37	18	37	19	37	23
smoking	30	14	30	15	30	16	30	17	30	18	30	19	30	20	30	26
children	16	15	16	16	16	17	16	18	16	19	16	20	16	21	14	31
fireworks	11	16	11	17	11	18	11	19	11	20	11	21	11	22	11	34
electric fence	3	17	3	18	3	19	3	20	3	21	3	22	3	23	3	37
fire bug (fine cause)	0	0	1852	2	1852	2	1852	1	1852	1	1852	1	1852	1	1852	1
trash	0	0	0	0	1146	3	1146	3	1146	2	1146	2	1146	2	1146	2
brush/leaves	0	0	0	0	0	0	1090	4	1090	3	1090	3	1090	3	1090	3
other (explain)	0	0	0	0	0	0	0	0	559	5	559	5	559	4	559	4
field clearing	0	0	0	0	0	0	0	0	0	0	294	7	294	7	294	6
land clearing	0	0	0	0	0	0	0	0	0	0	0	0	287	9	287	7
dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	186	8
burning building (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108	10
hot ashes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107	11
exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104	12
power line (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	13
maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	86	15
burning vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	17
other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	19
fireworks (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	22
electric fence (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	24
field	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	25
game burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	27

Table 15A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	28
electrical short	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	29
job fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	29
grudge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	31
welding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	31
right-of-way maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	35
carbon sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	36
fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	38
smoking (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	39

Table 16A Texas Forest Service fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	if	rf
debris burning	1645	1	1193	1	1193	1	1193	1	1008	1	1008	1	819	1
miscellaneous	1086	2	1086	2	804	2	804	2	804	2	665	2	654	2
lightning	669	3	669	3	669	3	483	3	483	3	483	3	483	3
incendiary	435	4	435	5	377	6	377	6	377	6	377	6	246	7
equipment use	404	5	404	6	404	5	404	5	404	5	404	5	269	6
railroads	75	6	75	7	75	8	75	9	75	10	75	11	17	27
smoking	61	7	61	8	61	9	61	10	61	11	61	12	26	21
camp fire	56	8	56	9	56	10	56	11	56	12	56	13	34	19
children	42	9	42	10	38	11	38	12	38	13	38	14	24	25
brush pile burning	0	0	452	4	452	4	452	4	452	4	452	4	452	4
other	0	0	0	0	344	7	344	7	344	7	344	7	344	5
origin traceable to lightning	0	0	0	0	0	0	186	8	186	8	186	8	186	8
unsafe burning of household trash	0	0	0	0	0	0	0	0	185	9	185	9	185	9
transmission lines	0	0	0	0	0	0	0	0	0	0	139	10	139	10
amusement	0	0	0	0	0	0	0	0	0	0	0	0	73	11
origin traceable to trains	0	0	0	0	0	0	0	0	0	0	0	0	58	12
spite	0	0	0	0	0	0	0	0	0	0	0	0	58	12
burning leaves and garden spots	0	0	0	0	0	0	0	0	0	0	0	0	52	14
farm equipment (hay balers, tractors, etc.)	0	0	0	0	0	0	0	0	0	0	0	0	44	15
trash dumps	0	0	0	0	0	0	0	0	0	0	0	0	38	16
control burning, no firebreaks	0	0	0	0	0	0	0	0	0	0	0	0	37	17
origin traceable to smoking	0	0	0	0	0	0	0	0	0	0	0	0	35	18
vehicles (catalytic converters)	0	0	0	0	0	0	0	0	0	0	0	0	34	19
welding equipment use	0	0	0	0	0	0	0	0	0	0	0	0	26	21
pasture and field burning	0	0	0	0	0	0	0	0	0	0	0	0	25	23
prescribed burning	0	0	0	0	0	0	0	0	0	0	0	0	25	23
warming or cooking	0	0	0	0	0	0	0	0	0	0	0	0	22	26
playing with matches	0	0	0	0	0	0	0	0	0	0	0	0	14	28
oil field equipment	0	0	0	0	0	0	0	0	0	0	0	0	12	29
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	11	30
logging equipment (skidders, trucks, chainsaws)	0	0	0	0	0	0	0	0	0	0	0	0	11	30
bush hogs, lawn mowers, weed eaters, etc.	0	0	0	0	0	0	0	0	0	0	0	0	8	32
construction debris	0	0	0	0	0	0	0	0	0	0	0	0	6	33
subdivision development, clearing	0	0	0	0	0	0	0	0	0	0	0	0	4	34
right-of-ways utility co.s and highways	0	0	0	0	0	0	0	0	0	0	0	0	2	35

Table 17A Texas volunteer fire department fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	17407	1	17407	1	13410	2	13410	2	11612	2	11612	2	11612	2	7764	2
miscellaneous	16088	2	3267	4	3267	5	1293	8	1293	9	1293	10	1293	10	0	29
equipment use	5503	3	5503	3	5503	3	5503	3	5503	3	3875	4	3875	4	0	29
lightning	1362	4	1362	5	1362	6	1362	6	1362	7	1362	8	0	15	0	29
smoking	1338	5	1338	6	1338	7	1338	7	1338	8	1338	9	1338	9	0	29
incendiary	1177	6	560	7	560	8	560	9	560	10	560	11	560	11	0	29
children	543	7	258	10	258	11	258	12	258	13	258	14	258	14	0	29
camp fire	445	8	445	8	445	9	445	10	445	11	445	12	445	12	0	29
railroad	274	9	274	9	274	10	274	11	274	12	274	13	274	13	0	29
other	0	0	13723	2	13723	1	13723	1	13723	1	13723	1	13723	1	13723	1
unsafe burning of household trash	0	0	0	0	3997	4	3997	4	3997	4	3997	3	3997	3	3997	3
transmission lines	0	0	0	0	0	0	1974	5	1974	5	1974	5	1974	5	1974	4
pasture and field burning (including grass, crop)	0	0	0	0	0	0	0	0	1798	6	1798	6	1798	6	1798	5
welding equipment use	0	0	0	0	0	0	0	0	0	0	1628	7	1628	7	1628	6
origin traceable to lightning	0	0	0	0	0	0	0	0	0	0	0	0	1362	8	1362	7
origin traceable to smoking	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1338	8
vehicles (catalytic converters, faulty mufflers)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1297	9
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1279	10
burning leaves and garden spots	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1244	11
farm equipment (hay balers, tractors, etc.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1149	12
site preparation burning (preparing previously)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1084	13
oil field equipment (pump jacks, faulty electric)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	985	14
trash dumps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	502	15
warming or cooking	0	0	0	0	0	0	0	0	0	0	0	0	0	0	445	16
bush hogs, lawn mowers, weed eaters, etc.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	390	17
amusement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	368	18
right of ways utility co.s and highways	0	0	0	0	0	0	0	0	0	0	0	0	0	0	294	19
origin traceable to trains	0	0	0	0	0	0	0	0	0	0	0	0	0	0	274	20
control burning, no firebreaks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	259	21
playing with matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	258	22
construction debris (boards, panels, cardboard)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	254	23
spite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	24
prescribed burning (forest brush control)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	154	25
subdivision development, clearing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	26
logging equipment (skidders, trucks, chainsaws)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	27
sawdust piles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	28

Table 18A Utah fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
lightning	2638	1	2638	1	2638	1	2638	1	2638	1	2638	1	2638	1	2638	1
miscellaneous	976	2	535	5	337	6	337	6	337	6	220	6	220	6	0	42
false alarm	826	3	826	2	826	2	826	2	826	2	826	2	826	2	826	2
debris burning	598	4	598	3	598	3	444	4	444	4	444	4	444	4	184	6
equipment use	593	5	593	4	593	4	593	3	593	3	593	3	477	3	223	4
camp fire	237	6	237	7	237	7	217	7	96	11	96	12	96	13	96	11
incendiary	196	7	196	8	196	9	196	9	196	8	196	8	196	8	0	42
children	69	8	69	9	69	10	69	11	69	12	69	13	69	14	30	26
railroad	68	9	68	10	68	11	68	12	68	13	68	14	68	15	0	42
smoking	16	10	16	11	16	12	16	13	16	14	16	15	16	16	11	35
unknown	0	0	441	6	441	5	441	5	441	5	441	5	441	5	441	3
other	0	0	0	0	198	8	198	8	198	7	198	7	198	7	198	5
agriculture	0	0	0	0	0	0	174	10	174	9	174	9	174	9	174	7
uncontrolled unattended	0	0	0	0	0	0	0	0	121	10	121	10	121	10	121	8
power line	0	0	0	0	0	0	0	0	0	0	117	11	117	11	117	9
vehicle fire	0	0	0	0	0	0	0	0	0	0	0	0	116	12	116	10
camp fire (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	39
arson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	11
electrical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92	13
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	14
exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	15
children (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	23
unattended	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	16
matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	17
fire arms use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	18
no permit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	18
cutting welding grinding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52	20
dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52	20
uncontrolled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	22
brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	24
rr brakes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	25

Table 18A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
catalytic converter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	26
smoking (fine cause)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	33
rr exhaust carbon particle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	28
structure fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	28
rr equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	30
blasting charge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	31
trash barrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	31
prescribed burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	34
spontaneous combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	35
land clearing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	37
rekindle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	38
coal mine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	39
gas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	41

Table 19A Virginia fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	8678	1	8672	1	8671	1	8671	1	8671	1	8671	1	8669	1	8497	1
miscellaneous	4276	2	3869	3	3834	2	3595	2	3546	2	3414	2	3354	2	2723	3
incendiary	4160	3	3937	2	3307	3	3304	3	3289	3	3280	3	3228	3	3001	2
equipment use	2145	4	2134	4	2134	4	2093	4	1977	4	1975	4	1971	4	1483	6
smoking	1797	5	1769	5	1769	5	1769	5	1769	5	1769	5	1768	5	1767	4
children	1588	6	1583	6	1581	6	1581	6	1581	6	1581	6	1578	6	1530	5
lightning	854	7	854	7	854	7	852	7	852	7	852	7	852	7	851	7
railroad	491	8	490	9	490	10	490	10	490	10	490	10	490	10	469	10
camp fire	329	9	325	10	325	11	325	11	325	11	325	11	325	11	300	12
unknown	0	0	685	8	685	8	685	8	685	8	685	8	685	8	685	8
arson	0	0	0	0	668	9	668	9	668	9	668	9	668	9	668	9
power line	0	0	0	0	0	0	285	12	281	12	281	12	281	12	281	13
vehicle	0	0	0	0	0	0	0	0	179	13	179	13	179	13	179	14

Table 19A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
structure	0	0	0	0	0	0	0	0	0	0	144	14	144	14	144	15
under invest	0	0	0	0	0	0	0	0	0	0	0	0	122	15	122	16
atv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	17
lawn mower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	84	18
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67	19
undetermined	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	20
person	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54	21
juvenile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53	22
land clearing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	23
hot ashes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	24
cutting torch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	25
electrical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	25
pile	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	27
cigarette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	28
welding	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	29
spon comb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30
car	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	31
catalytic conv	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	32
investigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	32
burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	34
carbon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	35
roadside	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	36
suspect arson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	37
tractor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	37
act of god	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	39
bushhog	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	39
false alarm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	39
logging	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	42
rekindle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	42
stove	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	42
firearms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	45
dump	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	46
farmer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	46
squirrel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	48

Table 19A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
grinder	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	49
sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	49
trailer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	49
combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	52
flare	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	52
motorcycle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	52
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	452	11

Table 20A Vermont fine cause analysis

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
debris burning	1104	1	663	1	660	1	432	2	313	2	313	2	227	5	8	35
miscellaneous	725	2	576	3	276	4	275	4	274	4	260	4	257	3	51	11
equipment use	183	3	181	4	179	5	178	6	178	6	100	8	100	8	1	36
children	127	4	126	5	124	6	123	7	123	7	123	6	123	6	32	16
incendiary	97	5	97	6	95	7	95	8	95	9	95	9	95	9	40	15
camp fire	94	6	93	7	93	8	93	9	93	10	93	10	93	10	76	8
smoking	88	7	88	8	84	9	83	10	83	11	83	12	83	13	23	21
railroad	80	8	80	9	80	10	80	11	80	12	80	13	80	14	55	10
lightning	45	9	45	10	45	11	45	12	45	13	45	14	44	15	44	14
burning	0	0	594	2	594	2	594	1	594	1	594	1	594	1	594	1
unknown	0	0	0	0	313	3	313	3	313	2	313	2	313	2	313	2
brush	0	0	0	0	0	0	232	5	232	5	232	5	232	4	232	4
barrel	0	0	0	0	0	0	0	0	120	8	120	7	120	7	120	5
power lines	0	0	0	0	0	0	0	0	0	0	92	11	92	11	92	6
pile	0	0	0	0	0	0	0	0	0	0	0	0	90	12	90	7
burn out of control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	9
matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	49	12
cigarette	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	13
sparks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	17
arson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	18
electirc fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	19

Table 20A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	if	rf
unattended	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	19
fireworks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	21
wind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	21
rekindle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	24
undertermined	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	24
set	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	26
unpermitted burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	27
exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	28
permited burn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	29
stove	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	29
lighter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	31
pit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	32
ashes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	33
debris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	33
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	288	3

Table 21A Washington fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
none	2832	1	1035	3	1035	3	1035	3	1035	3	1035	3	1035	3	1035	3	1035	2
miscellaneous	1855	2	867	5	867	4	867	4	867	4	867	4	867	4	867	4	800	4
lightning	1378	3	1036	2	1036	2	1036	2	1036	2	1036	2	1036	2	1036	2	1035	2
debris burning	1182	4	586	6	586	5	586	5	586	5	586	5	586	5	586	5	582	5
recreation	1043	5	957	4	536	6	490	6	489	6	489	6	489	6	489	6	478	6
children	258	6	214	7	198	8	175	8	134	8	112	9	96	9	81	9	80	9
arson	223	7	128	8	128	9	128	9	128	9	128	8	128	8	128	8	118	8
smoker	103	8	64	9	64	10	64	11	64	11	64	11	64	11	64	11	62	12
railroad	65	9	23	10	23	11	23	12	23	13	23	13	23	13	23	13	22	14
logging	64	10	23	10	23	11	23	12	22	14	22	14	22	14	22	14	20	16
none (fine cause)	0	0	4070	1	4070	1	4070	1	4070	1	4070	1	4070	1	4070	1	4070	1

Table 21A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
camp fire	0	0	0	0	437	7	437	7	437	7	437	7	437	7	437	7	437	7
other	0	0	0	0	0	0	69	10	69	10	69	10	69	10	69	10	69	11
fireworks	0	0	0	0	0	0	0	0	43	12	43	12	43	12	43	12	43	13
playing with fire	0	0	0	0	0	0	0	0	0	0	22	14	22	14	22	14	22	14
incendiary	0	0	0	0	0	0	0	0	0	0	0	0	16	16	16	16	16	17
smoking	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	17	15	18
under investigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	19
unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	20
random causes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	10

Table 22A Wisconsin fine cause analysis results

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
miscellaneous	2892	1	2605	1	2605	1	2605	1	2605	1	2227	1	1853	1	1853	1	1193	1
debris burning	2353	2	2212	2	1558	2	1093	3	1093	3	1093	3	1093	3	746	6	175	18
incendiary	1591	3	1481	3	1481	3	1481	2	1100	2	1100	2	1100	2	1100	2	972	2
equipment use	1184	4	943	5	943	5	943	5	943	5	943	5	943	5	943	4	179	17
camp fires	1004	5	960	4	960	4	960	4	960	4	960	4	960	4	960	3	753	4
railroad	564	6	491	7	491	8	491	8	491	8	491	8	491	8	491	8	322	12
lightning	307	7	307	8	307	9	307	10	307	11	307	12	307	13	307	14	307	13
smoking	175	8	167	9	167	10	167	11	167	12	167	13	167	14	167	15	58	33
children	68	9	68	10	68	11	68	12	68	13	68	14	68	15	68	16	68	29
other	0	0	904	6	904	6	904	6	904	6	904	6	904	6	904	5	904	3
brush piles	0	0	0	0	654	7	654	7	654	7	654	7	654	7	654	7	654	5
incinerator, burning barrel	0	0	0	0	0	0	465	9	465	9	465	9	465	9	465	9	465	6
excitement	0	0	0	0	0	0	0	0	381	10	381	10	381	10	381	10	381	7
power line	0	0	0	0	0	0	0	0	0	0	378	11	378	11	378	11	378	8
fire works	0	0	0	0	0	0	0	0	0	0	0	0	374	12	374	12	374	9
household trash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	347	13	347	10
broadcast	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	336	11
improper ash disposal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	301	14
non-road logging or farm equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	206	15
leaf/needle piles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	191	16

Table 22A Continued

Cause	i1	r1	i2	r2	i3	r3	i4	r4	i5	r5	i6	r6	i7	r7	i8	r8	if	rf
car exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135	19
diesel engine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133	20
structure fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	21
bus or truck exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	91	22
playing with matches	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	90	23
equipment use	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76	24
cooking	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	25
experimenting with fire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	26
vehicle or aircraft crash	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	27
warming	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	27
cutting torch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	30
off-road recreation vehicle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	31
party	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	32
small motors	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	34
grudge or spite	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	46	35
pyromaniac	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	36
landowner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	37
spontaneous combustion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	38
motorist	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	39
dumps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	40
brake shoe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	41
arson of buildings or cars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	42
sportsman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	43
slash burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	44
electric fence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	45
smoke out animals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	46
construction equipment exhaust	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
pest control	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	47
hot box	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	49
occupant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	50
hiker/sightseer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	51
visitor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	52
game range	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	53
cargo fire or accident	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	54
tie burning	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	55

APPENDIX B

Wildfire Data Repository

User Manual version 1.0

(http://wildfireserver.tamu.edu/WebSiteMap1/default.aspx)

Table of Contents

INTRODUCTION

The wildfire data system was designed in order to allow wildfire agencies to submit wildland fire data for later analysis. The system is a web based data submission system that will accept data one fire incident at a time or in a bulk data upload. Bulk data may be submitted in either a text format (*.csv,*.txt) or a Microsoft Excel document format (*.xls,*.xlsx). Currently the system is not designed to accept any other data formats at this time.

DATABASE BASIC DESIGN

The data accepted into the system is based loosely on what the National Association of State Foresters had previously asked during their period of data acquisition. The database core data is comprised of 6 primary modules. These modules describe the core components of an individual wildland fire event.

Subset Module

This module is comprised of five pieces of fire information. The county is used to describe the location of a fire event. The total acres describe the overall size of the wildland fire event. The number of injuries and fatalities describe the injuries and fatalities that were associated with the fire event and the extinguishing of the fire. Of these five data pieces, county is the most important piece of information as it describes the location that the fire event occurred.

Fire Cause Module

The fire cause module allows the user to select up to 3 fire causes for a single fire incident. The causes of the fire should occur in order for which they apply. The primary cause is most relevant cause. The secondary and tertiary causes can be added to an incident to further support the primary cause; however, these causes may be left blank if the user does not believe they are necessary.

> *Example:* If a fire was caused by a power line falling to the ground the primary cause would be a called a power line, but if a contributing factor to the fire was the fact that the power line fell on top of a brush pile then the second cause could be agricultural debris burning

Land Ownership Module

Land ownership is used to describe the party or class of people that was affected by a particular fire event. Much like the fire cause module the user is allowed to enter up to 3 classes of owners. The primary owner is the party/class of people that were most affected by a wildland fire event. A secondary/tertiary owner can be a person/class of people that were also affected by the fire event but were not as affected as the primary owner.

Example: If a fire has started in a national forest and leaves this area to consume some private lands next to the national forest then the owner could potentially be both. The order depends on the total acres burned of each area. If more acreage was consumed in the national forest then this would be the primary owner and the private owner would be the second owner.

Location Module

The location module will accept three different types of location information. A user may insert one of each type of location information if the user desires. An instance of location data is to describe the initial starting point of a wildland fire event. The three formats for location data are Latitude/Longitude, USPLS, and UTM (Northing, Easting). Fire data in the bulk entry module should be entered in the order by which the user believes is the most accurate. If USPLS is believed to be more accurate than another method of location then the user should tag this location information in the first location field.

The Latitude and Longitude information is assumed to be in the WGS84 coordinate system. WGS84 is used because this is the default coordinate system on most GPS units. The user is required to enter both a valid coordinates for both the latitude and longitude in order for the data to be evaluated for a submission or the user will be prompted of the error.

USPLS data is to be submitted at a minimum level of accuracy. This level is that of the section. The user may desire to include the aliquot information either down to the quarter level or quarter-quarter level of accuracy. This information will be converted automatically to a geographic coordinate. Also the user must include a meridian code as specified by the United States Bureau of Land Management (http://www.blm.gov/lr2000/codes/CodeMeridian.htm).

UTM data will be accepted if the northing, easting, and zone are included in the submission. Without a valid UTM zone the location will not be evaluated. To maintain current BLM standards UTM coordinates are assumed to be in NAD 83 datum.

Fire Date and Time Module

The date and time of the fire event in further analysis of a group of wildland fire events. The date and time of a wildland fire event is as important as knowing the location of a specific wildland fire event. The data system accepts up to three fire times that include a start time (time of ignition), second time, and third time. The start time of the fire event will be used in conjunction with the location of the fire by the data system to retrieve weather data at the time of the fire. In short fire date and time information should be entered in chronological order.

Fire Weather Module

Fire weather is a module that is created by the data system autonomously based on the location and temporal information that the user provides the system. Weather data is

gathered by the closest weather station to the location of the initial starting point of a fire event. Weather data is courtesy of Weather Underground.
(http://www.wunderground.com)

BASIC CONSIDERATIONS BEFORE DATA ENTRY

The user should consider some items before beginning the data submission process. First of all the user must decide which data entry method is best for them. The two data entry methods as mention before are the single fire entry and a bulk data upload.

The main item that the user should consider is the state of the data that is to be entered into the data system. Does the dataset have a primary key. A primary key requirement is basically meaning data must have a way of uniquely identifying each fire event in a dataset. A unique identifier is single attribute of a fire or a conglomeration of several attributes that distinctly describe a single fire event for the submission of fire data. If the user is utilizing the web form based submission for a single fire event then this key will be generated automatically for the user. However the user should be mindful of duplicates when using the single fire entry form to be a good steward of the Wildfire Data Entry system.

In addition to a primary key the user must also consider that this system does perform a series of data integrity checks that help insure the integrity of the data system. The first check of the data is performed on the temporal information of a wildland fire event. The start time of a fire must occur first in a wildland fire event set of fire dates and times. If this does not occur then the user will be made aware of this error. Finally the location information is verified as to if the provided location information is describing a location that exist inside of the provided county of origin. The system does allow the user to declare that the county is unknown but further location information will not be accepted becuase this further location information cannot be verified.

Finally if the user is entering data in bulk they must realize that the bulk upload process does make the assumption that the user has some basic SQL knowledge. Sample SQL is provided later in this manual but the SQL samples are not meant to fit every data situation. If the user does believe that they may not be able to utilize basic SQL given some examples the user should consider the single fire event web form.

GAINING ACCESS TO WILDFIRE DATA REPOSITORY AND DATA ENTRY

The application has limited access that requires a user to register with the system administrator. The User must provide the administrator their contact information (first name, last name, and email address). All users are members of the same group so anyone with access can upload wildfire information.

LOGGING INTO WEBSITE

To access the wildfire data repository web form the user must go to the main website (http://wildfireserver.tamu.edu/WebSiteMap1/default.aspx). When at the main web The user will click on the Enter Data button (Figure B1).

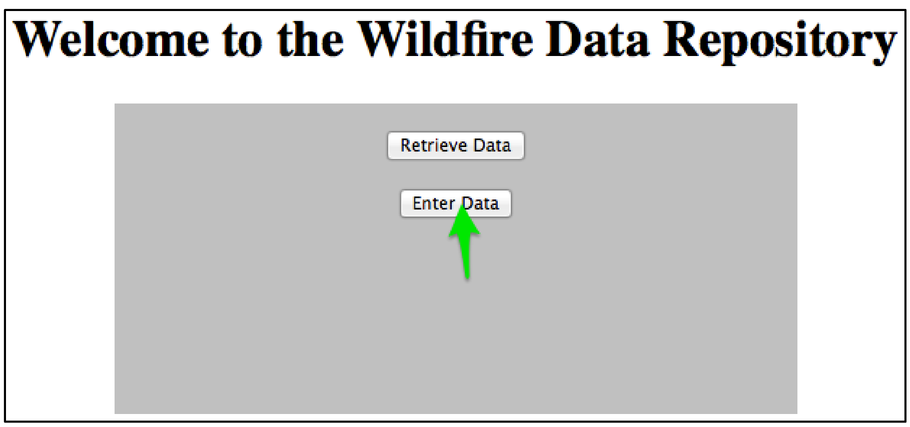


Figure B1 Represents the default entry page of the wildfire data repository.

Next the user must login via the log in that was provided by the administrator sent to them by email (Figure B2). The new user creation portion of the website has been disabled for security purposes.

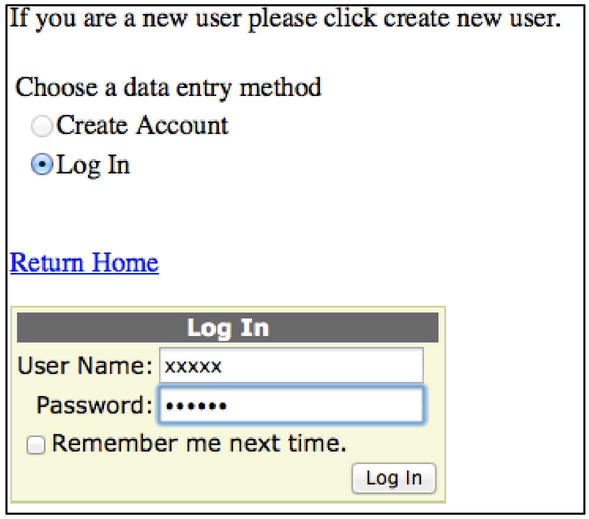


Figure B2 Login page where user enters website.

DATA ENTRY: WEB FORM

After logging in the user will select the Use Web Form radio button and then select enter (Figure B3).

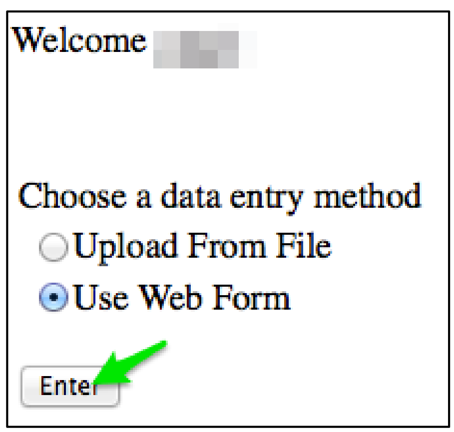


Figure B3 User form entry page**.**

The user will then see a tabbed panel that will allow them to enter segments of data of their choosing. To navigate between tabs the user will simply click on each individual tab. If a user decides to cancel the submission simply click logout. To submit the user clicks the Submit Fire button.

Subset Tab

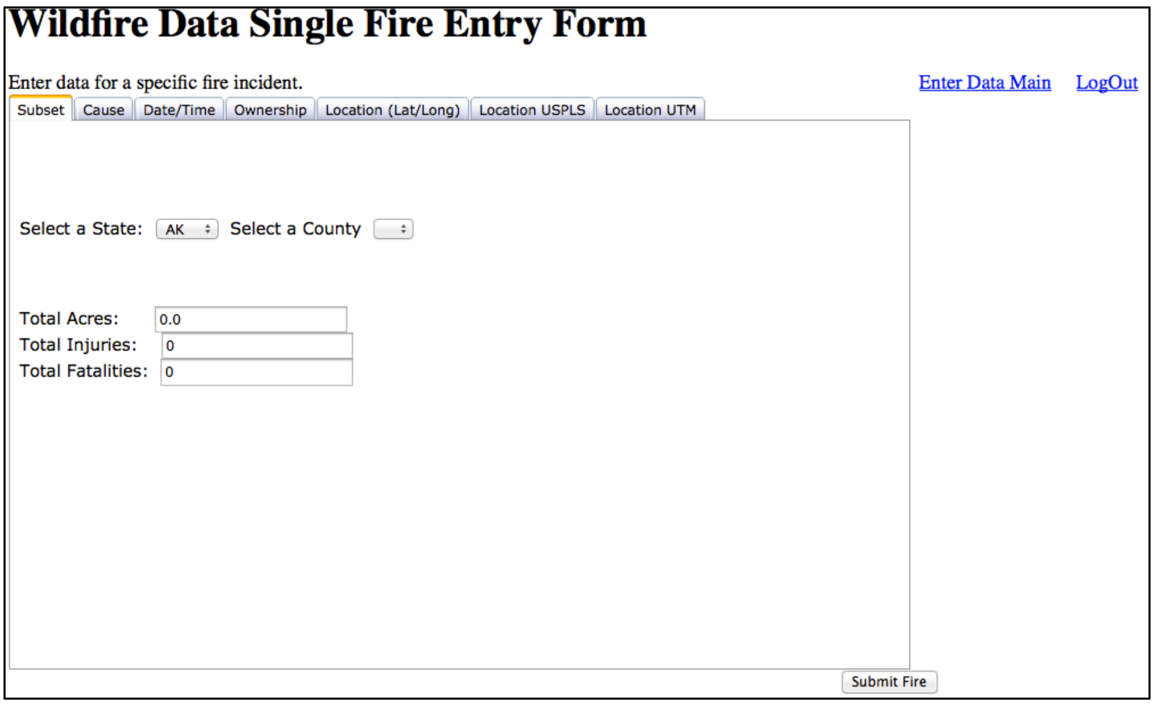


Figure B4 Subset tab for entering basic submission data**.**

This area of the user form is designed to allow the user to enter the state and county of the wildland fire incident (Figure B4). These fields are the only fields that are required to enter a wildland fire incident. The Acres textbox allows the user to enter any number of acres to the nearest tenth of an acre. The number of injuries and fatalities textboxes allow the user to enter the whole number of each if there are not any fatalities or it is unknown simply leave the default value of zero.

Cause Tab

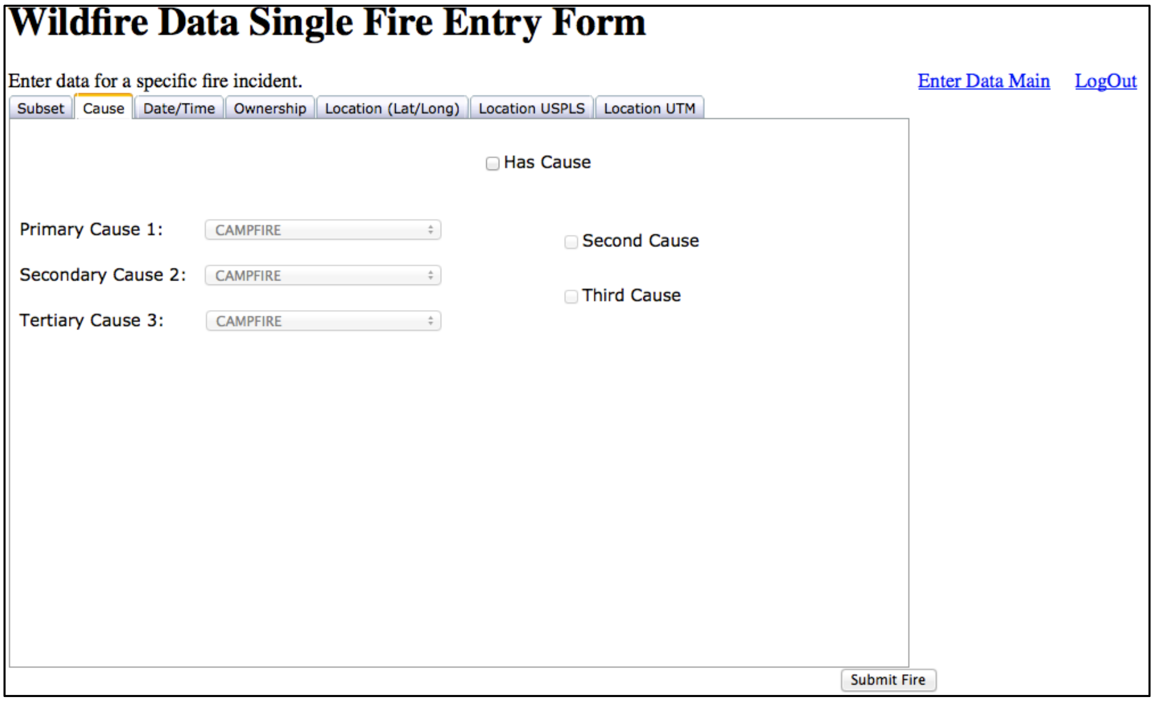


Figure 5B Cause tab for entering cause information.

If the user has cause information they will check the box labeled Has Cause. When this is checked the Primary Cause 1 drop down list will become active (Figure B6).

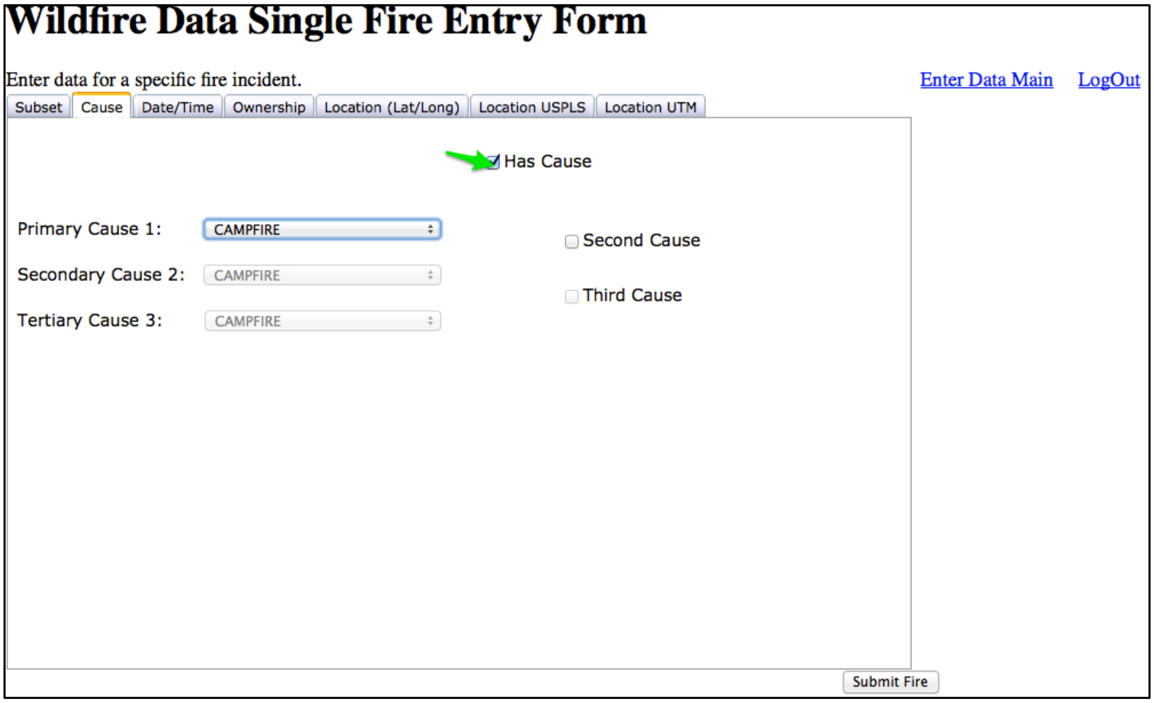


Figure B6 The location of the has cause box and the activated primary cause 1 drop down list**.**

The drop down list allows the user to choose a wildfire cause that best describes the primary cause of the wildland fire incident (Figure B6). If the user has more than one cause they may utilize the second/third cause check boxes located on the right of the tabbed form (Figure B7).

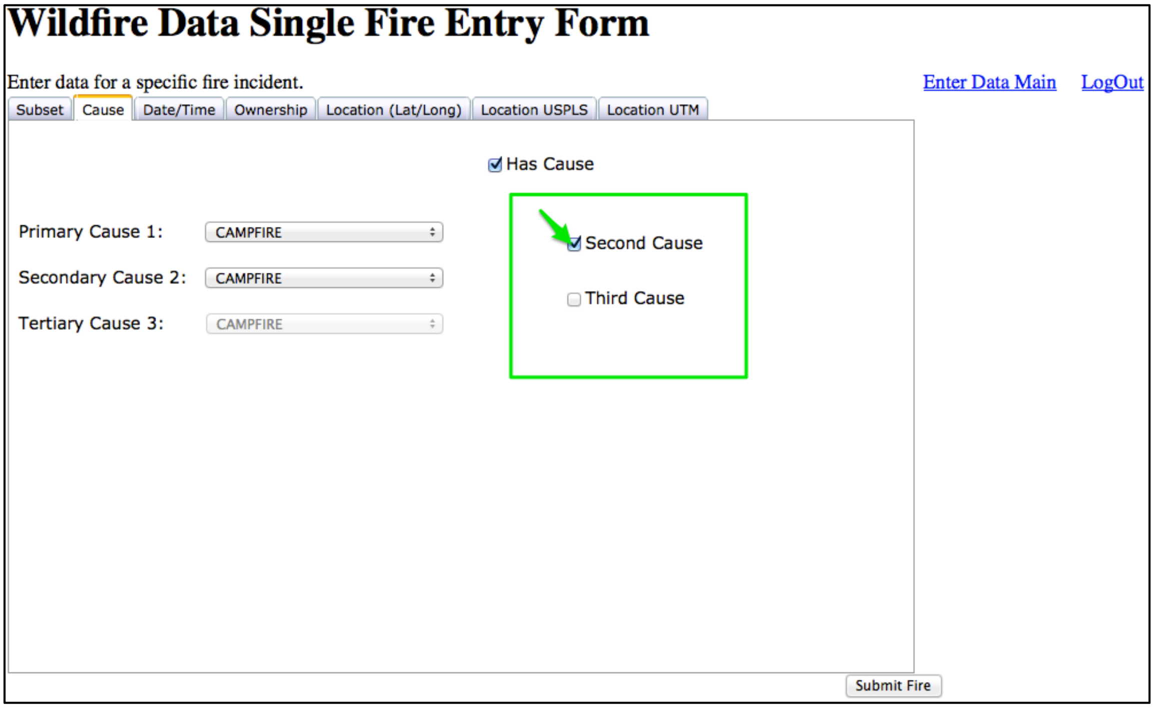


Figure B7 Location of the Second/Third cause check boxes

Date/Time Tab

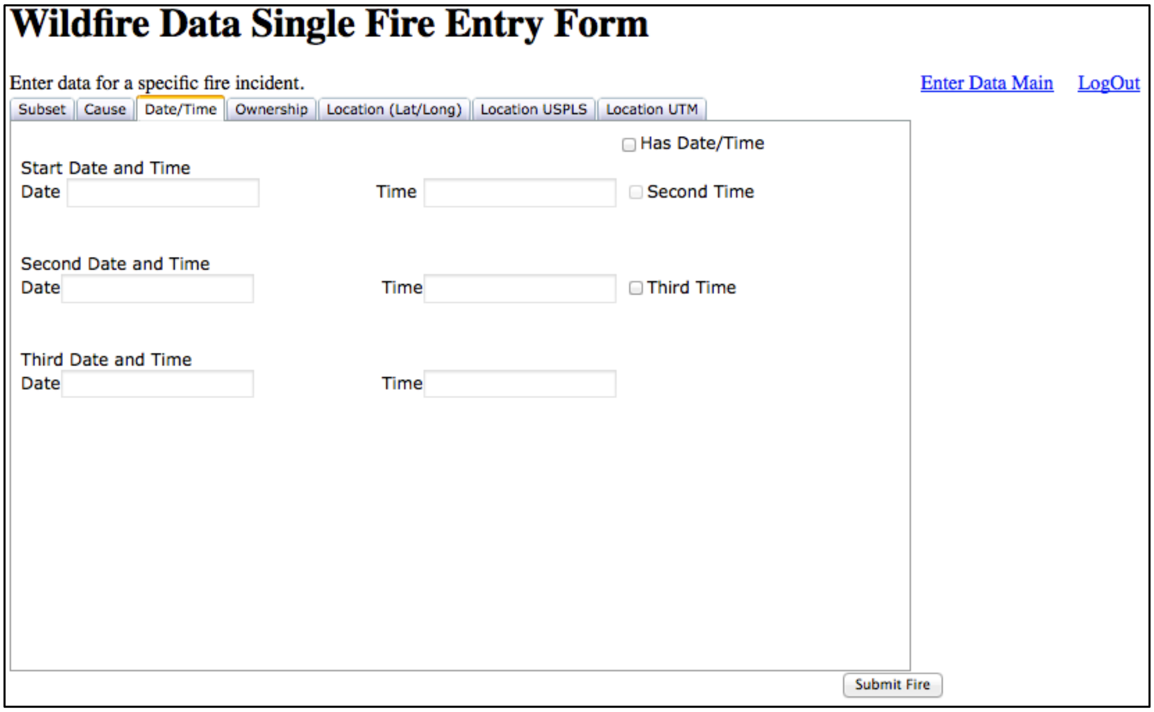


Figure B8 Date/Time tab for entering date and time information associated with a wildland fire incident.

To enter data and time information the user must check the box next to Has Date/Time. Once this box is checked the user will be able to enter data into the start date and time boxes. The format for the date is YYYYmmDD and the format for the time is 24hr (HH:mm) as seen in Figure 9.

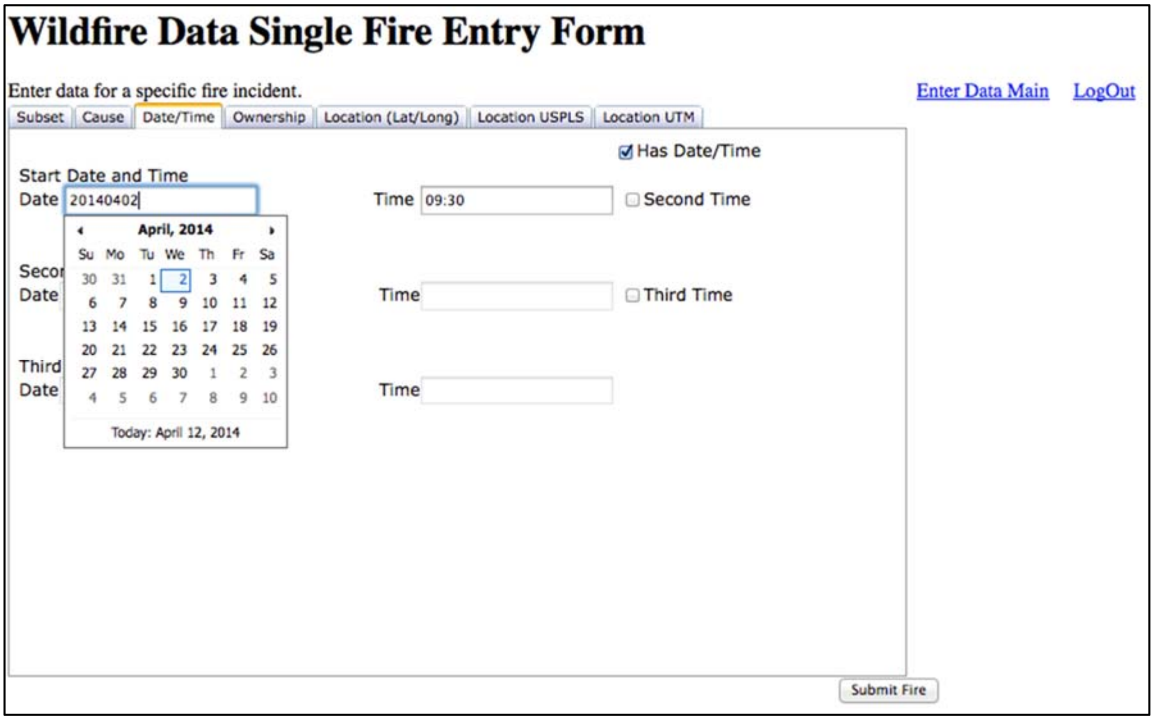


Figure B9 Date textbox example and time textbox example.

If there is more than one time associated with the wildland fire incident the user can check the second/third check boxes to enter multiple dates and times (Figure B9). If the user does not enter a time in the correct format the system will prompt the user of the error. If the user had entered fire incident times in an incorrect chronological order the system will not accept the submission and the user will be prompted to correct this information.

Ownership Tab

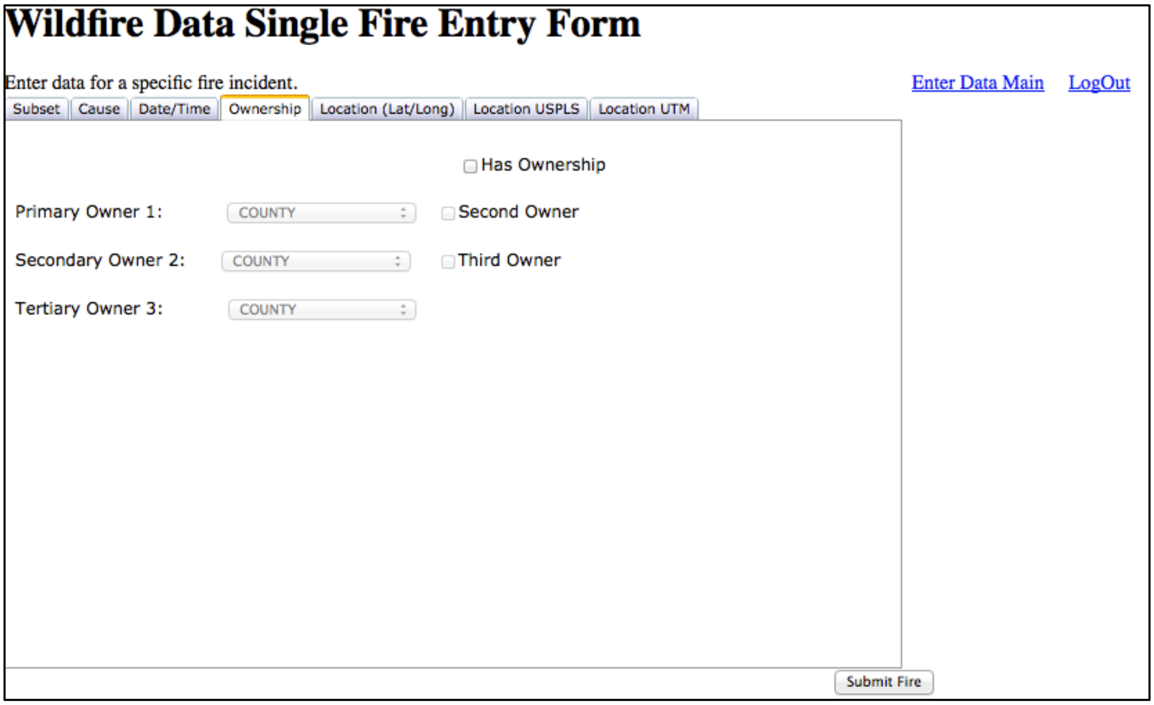


Figure B10 Ownership tab for entering information about who owns the land.

Ownership information is to be entered in the order by the most responsible party for the land that the fire occurred. The user is able to enter data after they have checked the Has Ownership box (Figure B10). If the user wants to enter more than one owner they may activate this feature by checking the second/third owner boxes (Figure B11).

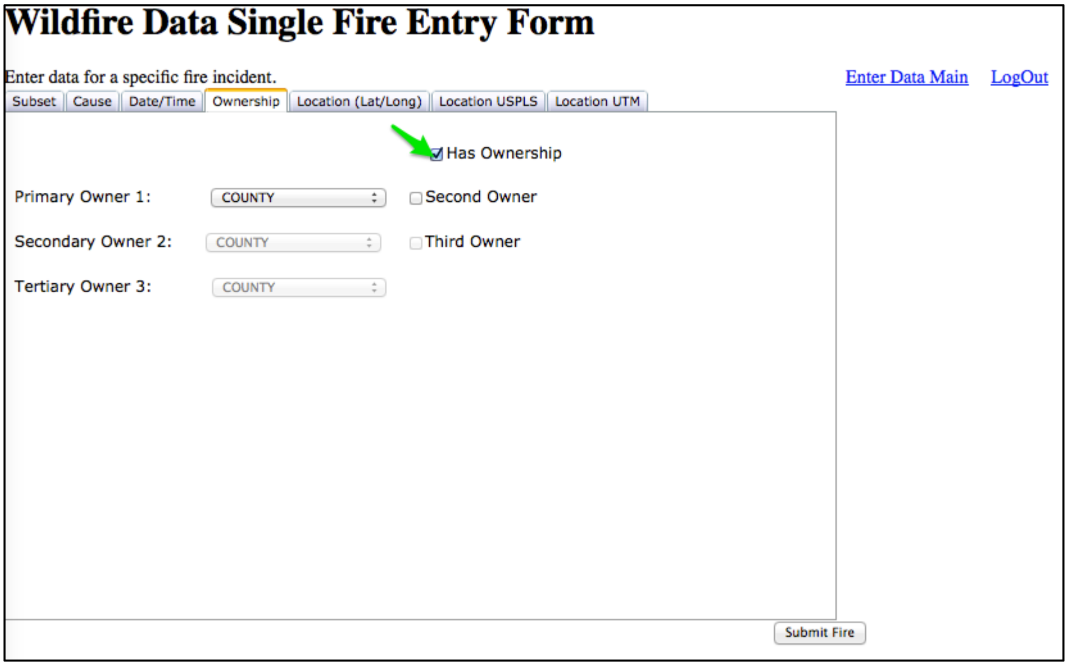


Figure B11 Ownership tab showing the has ownership box checked.

Location (Lat/Long) Tab

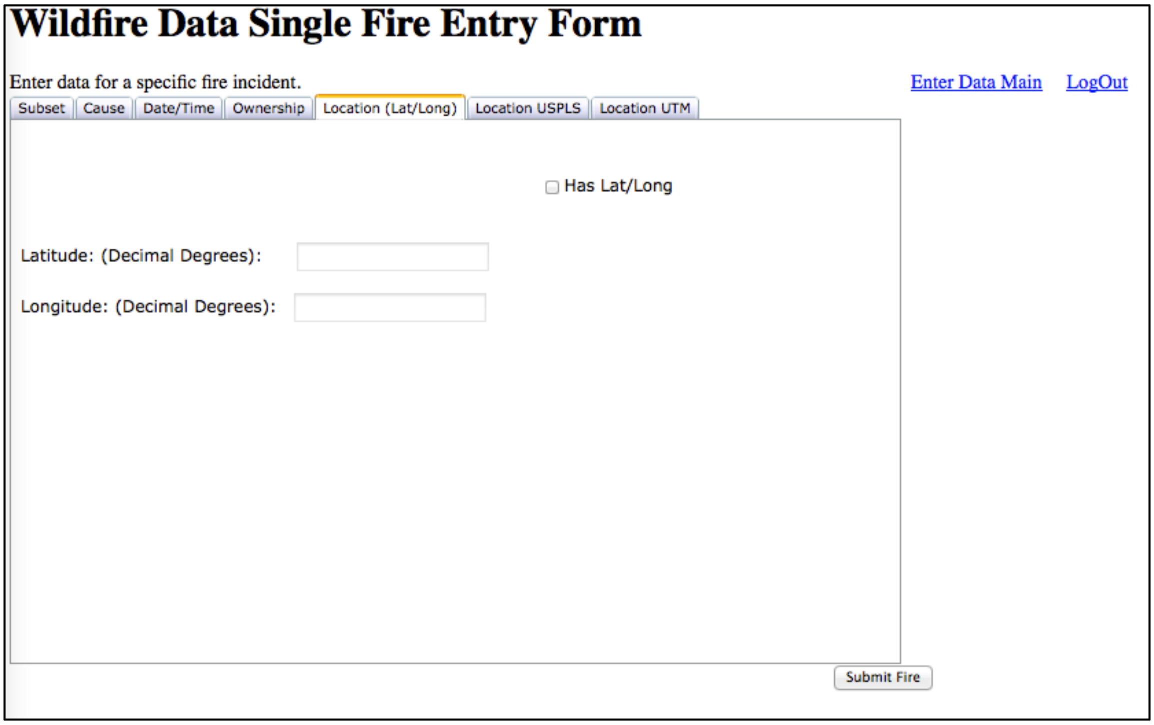


Figure B12 Location (lat/long) tab for entering latitude and longitude of a fire start location.

The location data entered in this tab is to describe the location that the wildfire started. Latitude should be entered as a positive number and longitude is to be a negative number. These location values will then be further processed to determine if they describe a point that occurs with in the boundary of the county that was specified on the Subset tab. If the location is outside of the county the user will be prompted to re-enter the data.

Location USPLS Tab

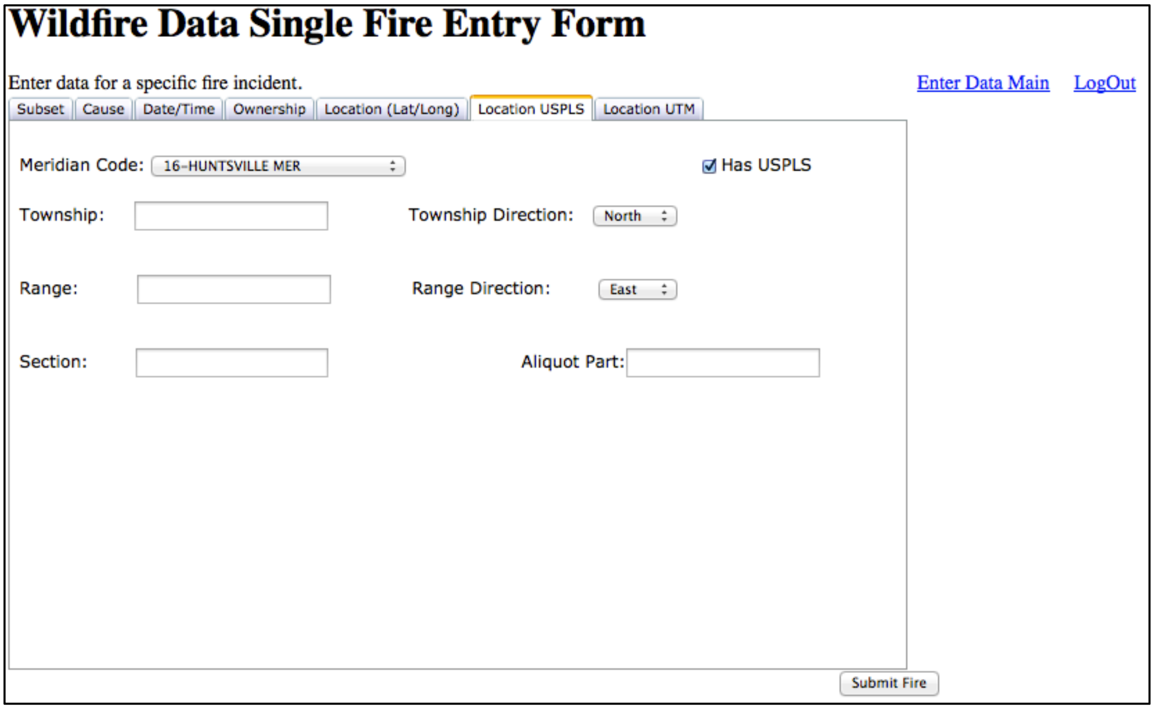


Figure B13 Location USPLS Tab to describe the location of the fire start.

USPLS data must be entered to the section level of location. The Aliquot is optional however the user may enter either the quarter or the quarter-quarter information. The location will be verified by the system that the location occurs inside the county that was entered in the Subset tab. If the USPLS location cannot be verified by the Bureau of Land Managements database then the location is considered invalid as well and the user will be prompted to re-enter the data.

Location UTM Tab

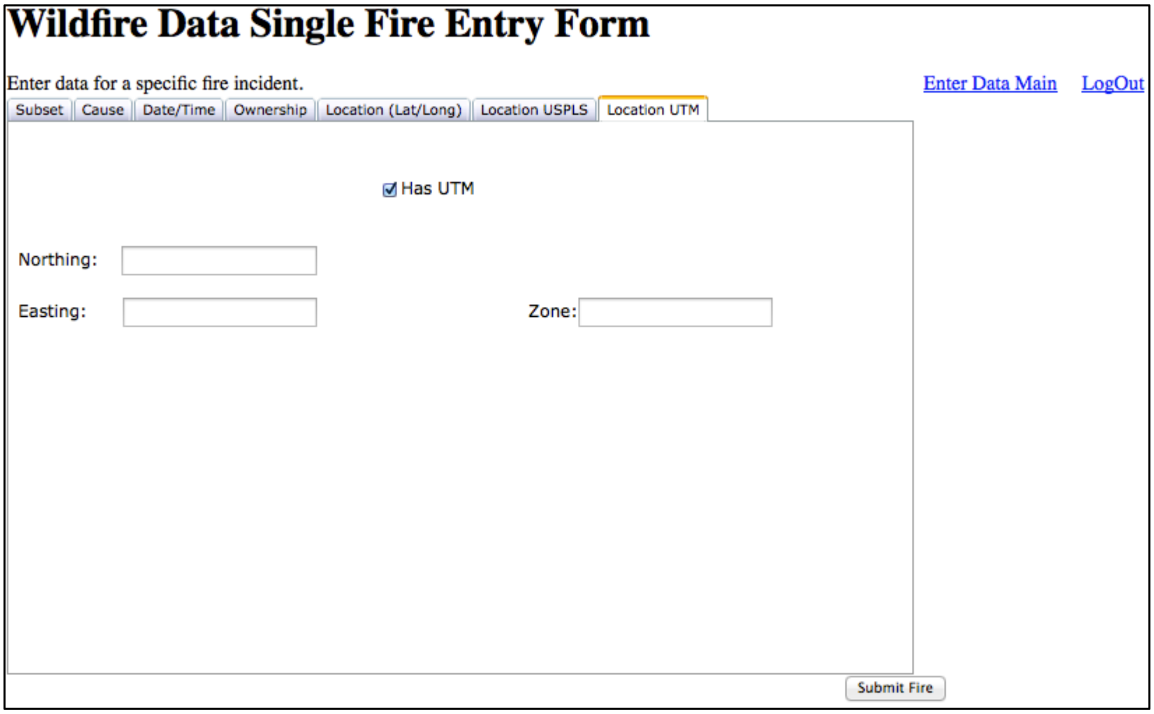


Figure B14 Location UTM Tab describing the location that the fire started.

UTM coordinates are to be entered as positive numbers. The user is required to specify the UTM zone. If the zone is not entered the user will be alerted to the error. Also these coordinates will be verified as to if they are describing a location inside of the county that was specified on the Subset tab.

DATA ENTRY: UPLOAD FROM FILE

As a user it is possible for wildland fire data to be uploaded from a file. The system accepts files in the format of text (*.csv, *.txt) and Microsoft Excel (*.xls, *.xlsx). To start this process the user is to select the Upload From File radio button after they login (Figure B15).

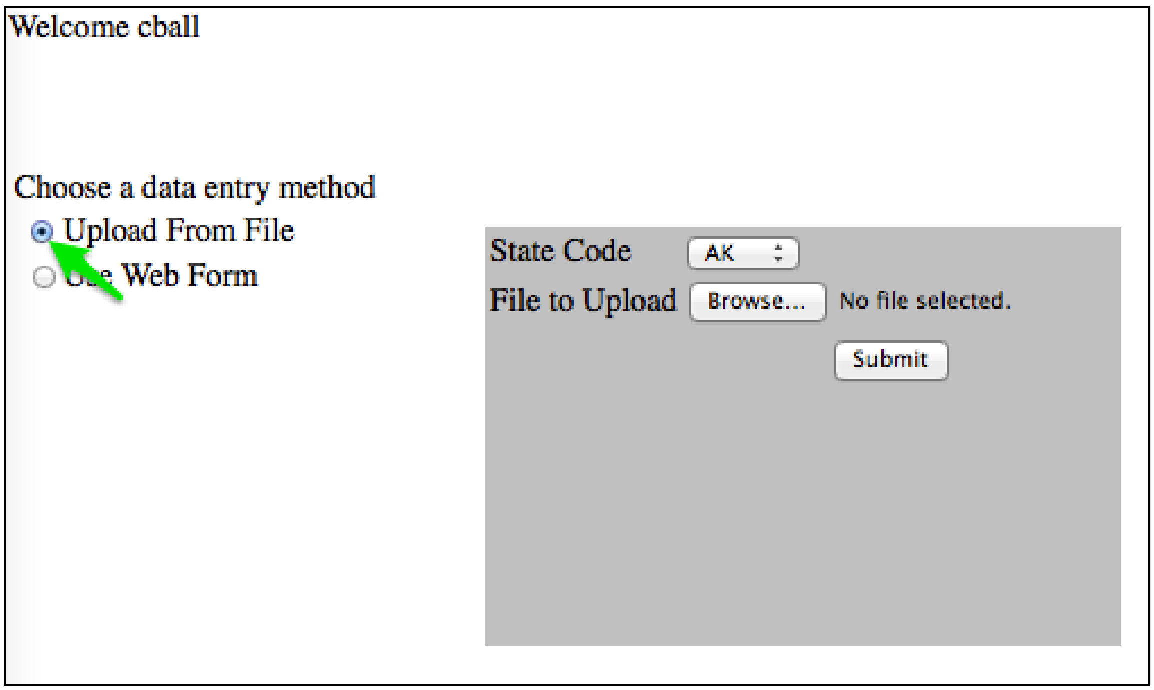


Figure B15 Upload from file radio button and first form.

Using the dropdown list select the state that data represents. Then browse to the file that contains the data on your local computer (Figure 16). Then press the submit button.

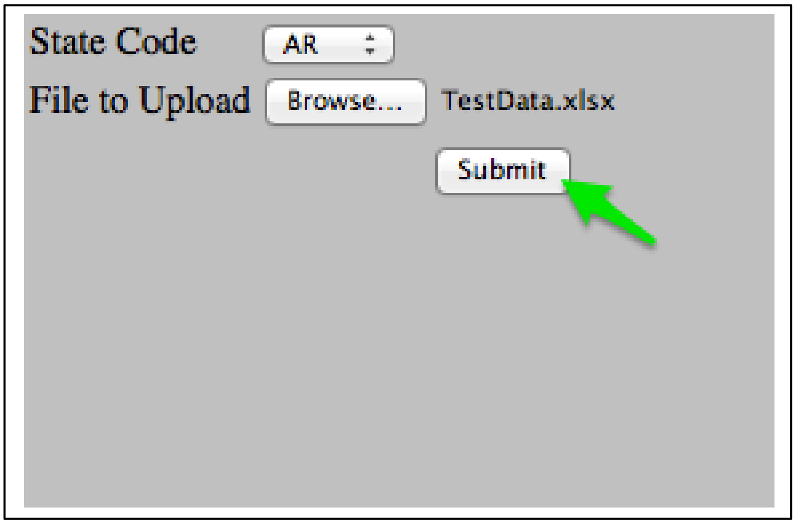


Figure B16 File upload form example.

Field Definitions Form

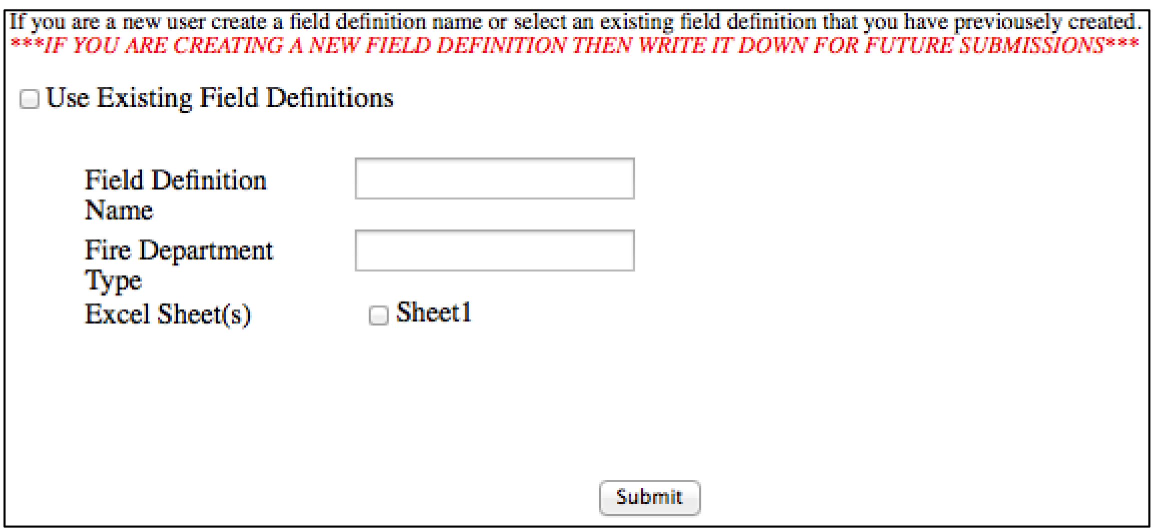


Figure B17 Field Definitions Form.

This form allows the user to select from field definitions that were previously created by the user or it allows the user to create a new set of field definitions. Clicking the Use

Existing Field Definitions check box provides access to previous field definitions. If the user is a new user previous field definitions are not available and new definitions are needed in order to proceed with the submission.

To select a previous field definition click the check box Use Existing Field Definitions and then select from the available definitions in the drop down list. Field definitions are stored by name. After a selection has been made, select the applicable excel sheet using the mouse and click submit (Figure B18).

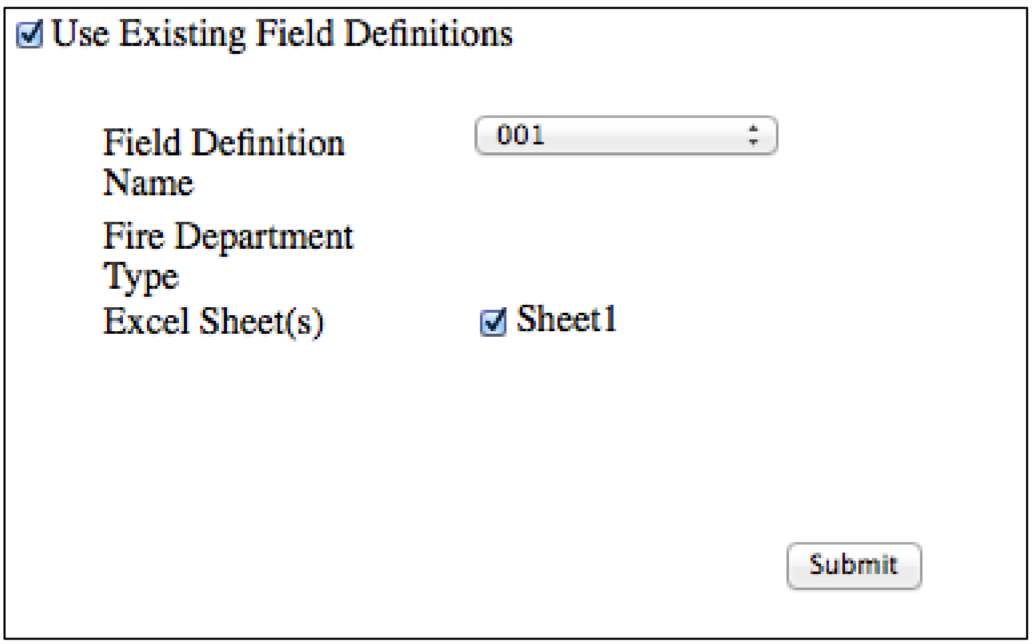


Figure B18 Sample of previous field definition selection.

Upon clicking Submit the user will then be directed to the Submission Process Step 2/3: Verify Field Definitions & Submit Data File form. This will be discussed in a later section.

Creating a New Field Definition

When creating a new field definition the user must document the name of the definition so that they can utilze this definition on a later submission. The process of creating a new field definition is a fairly long process. It is suggested that the user use a systematic naming convention like *StateCodeXXX*. The *XXX* represents a version number that can be easily identified later as to which version is up to date with the current format of the data being uploaded. The Fire Department Type Field is used to identify which fire department submitted the data. Some states receive wildland fire data from the volunteer fire departments separate from the non-volunteer fire departments. An example of this can be seen in Figure B19.

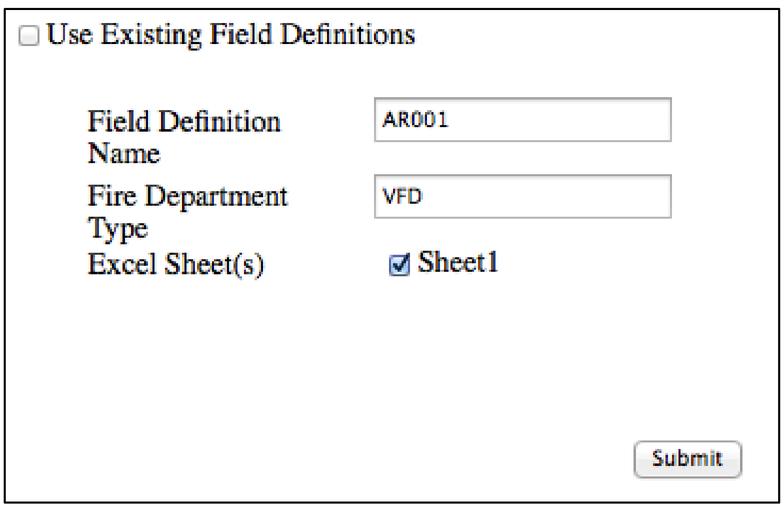
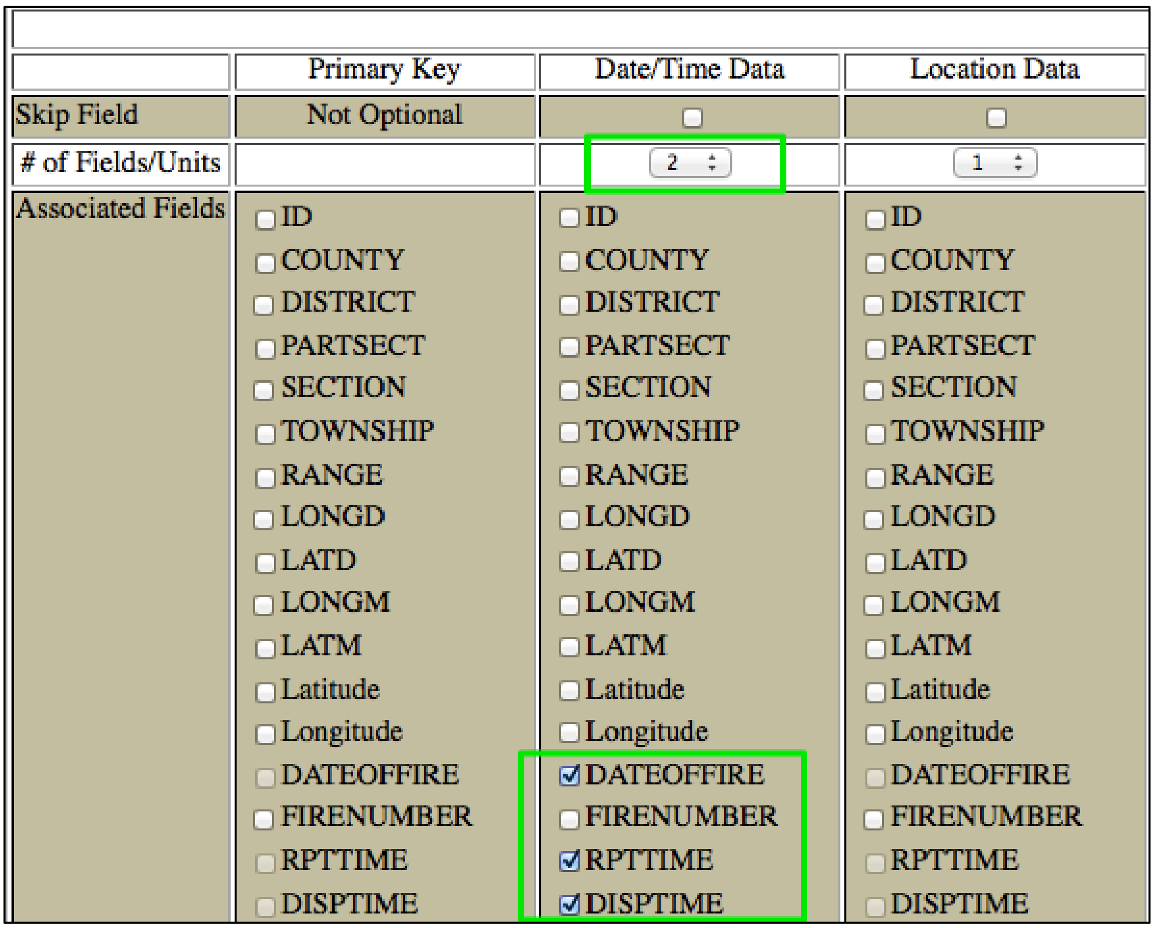


Figure B19 Sample field definition identification data entry form.

Upon clicking submit the user is taken to a page that outlines the overall submission process. The user is then to click continue.

Submission Process Step 1

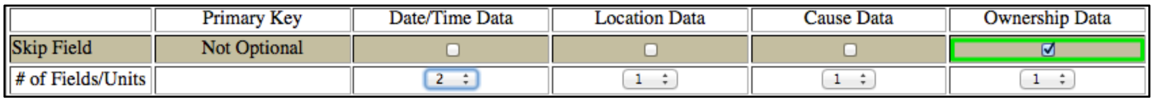
The first step of the submission process the user is required to select the fields that represent all of the data associated with the column heading on this form. For example if there are more than one Date/Time associated with a record of a fire event then the user will select all items that comprise the dates and times (Figure B20). If more than one date and time exist then the user must specify how many are to be represented using the drop down list below the column name.



	Primary Key	Date/Time Data	Location Data
Skip Field	Not Optional	☐	☐
# of Fields/Units		2	1
Associated Fields	☐ ID	☐ ID	☐ ID
	☐ COUNTY	☐ COUNTY	☐ COUNTY
	☐ DISTRICT	☐ DISTRICT	☐ DISTRICT
	☐ PARTSECT	☐ PARTSECT	☐ PARTSECT
	☐ SECTION	☐ SECTION	☐ SECTION
	☐ TOWNSHIP	☐ TOWNSHIP	☐ TOWNSHIP
	☐ RANGE	☐ RANGE	☐ RANGE
	☐ LONGD	☐ LONGD	☐ LONGD
	☐ LATD	☐ LATD	☐ LATD
	☐ LONGM	☐ LONGM	☐ LONGM
	☐ LATM	☐ LATM	☐ LATM
	☐ Latitude	☐ Latitude	☐ Latitude
	☐ Longitude	☐ Longitude	☐ Longitude
	☐ DATEOFFIRE	☑ DATEOFFIRE	☐ DATEOFFIRE
	☐ FIRENUMBER	☐ FIRENUMBER	☐ FIRENUMBER
	☐ RPTTIME	☑ RPTTIME	☐ RPTTIME
	☐ DISPTIME	☑ DISPTIME	☐ DISPTIME

Figure B20 Submission process step 1 example of multiple field selection.

The user will note that as items are selected they unavailable for selection in other columns. The primary Key field is not optional and must have an item selected. If a user does not have a particular column of data they may select the skip field check box (Figure B21).



	Primary Key	Date/Time Data	Location Data	Cause Data	Ownership Data
Skip Field	Not Optional	☐	☐	☐	☑
# of Fields/Units		2	1	1	1

Figure B21 Example of the skip field check box.

After all fields are selected the user will click the continue button at located at the bottom of the web page (Figure B22).

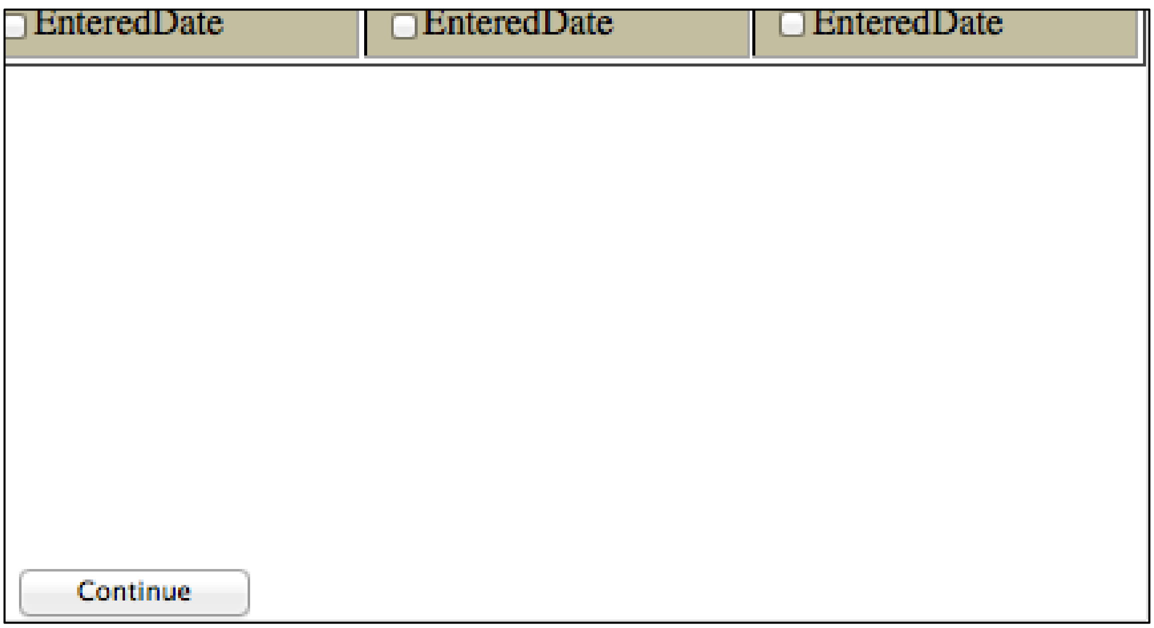


Figure B22 Location of the continue button.

Submission Process Step 2

Step 2 requires the user to build small queries to manipulate the data in the data file to the required format for the Wildfire Data System. The queries are based mostly on simple string manipulation. These simple SQL operations may no be necessary and a user can simply enter the field instead of creating a query operation.

The user should note that the columns from the previous page are now tabs in a panel. Each tab represents the work area for the user to work on specific columns of data. A text box has been provided with some sample SQL for each table. For example, the Key Fields tab has text providing a sample of how to concatenate two fields (Figure B23).

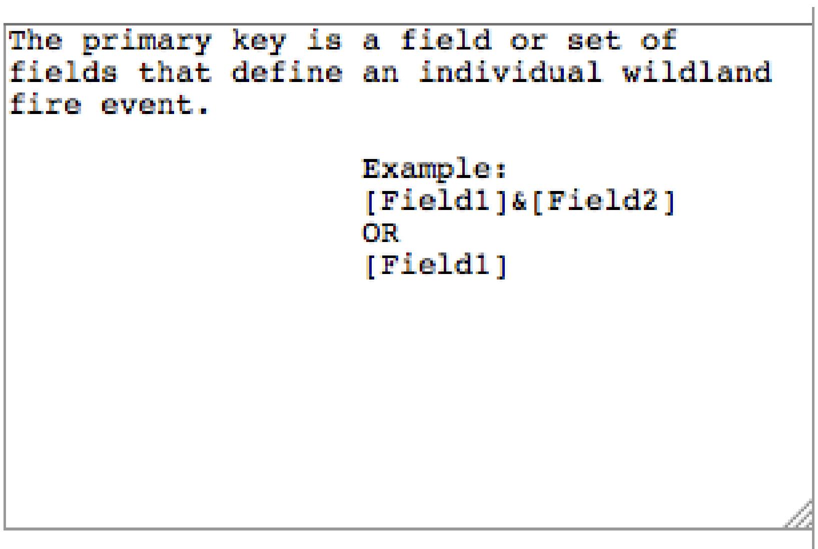


Figure B23 Example of the help text provided with the key Fields tab.

Each field has its own area for SQL to be entered. A Field description is not required but it is preferred. To add a field to the SQL text box simple select the field in the SQL

Fields list and click Add Field. The field will automatically be added to the text box (Figure B24).

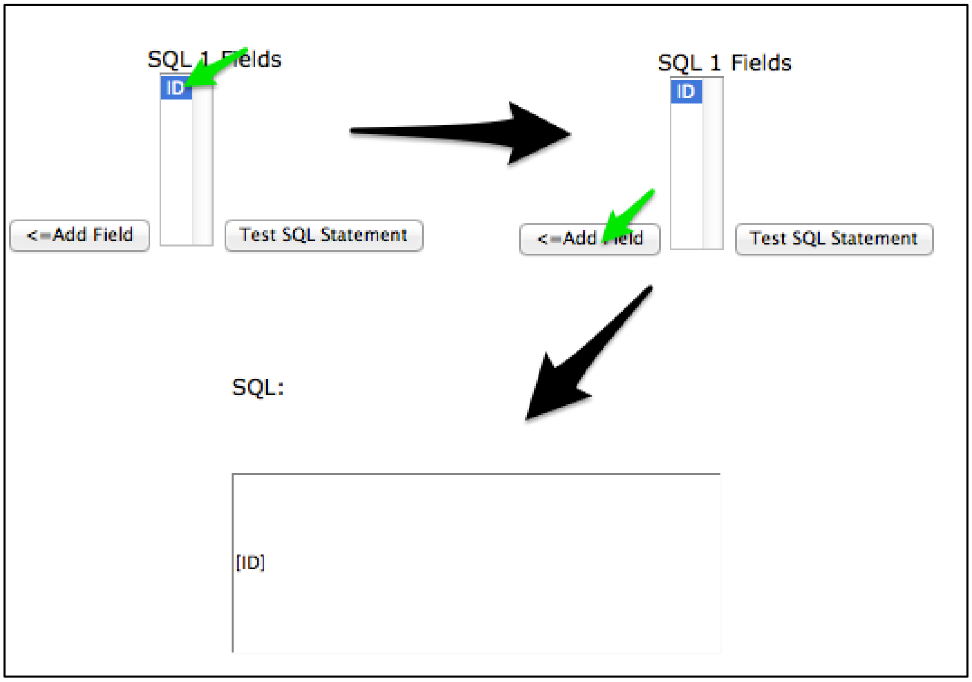


Figure B24 How to add a field to the SQL text box.

If a user has created a simple sql statement a user can see if this statement is valid by clicking the Test SQL Statement button (Figure B25).

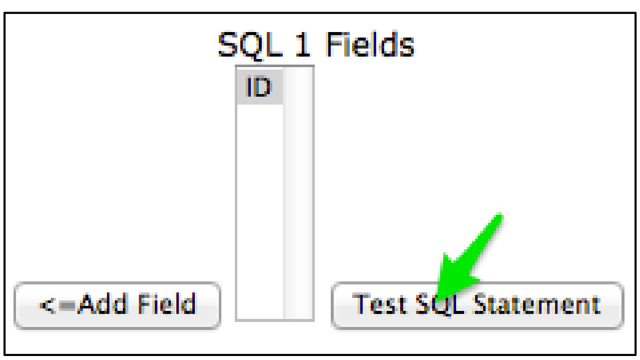


Figure B25 Test SQL statement button.

If the statement is not valid then the user will be prompted as such. The output can be viewed at the bottom of the page (Figure B26).

ID
1
2
3
4
5
6
7
8
9
10

Figure B26 Sample output for test SQL statement button.

Key Fields Tab

The purpose of this tab is to create the primary key. The key can be a single field or a concatenation of fields. To concatenate fields utilize the '&'.

Example:

[Field1]&[Field2]

Date/Time Fields Tab

If in the previous form the user selected that there were more than one time associated with the fire event then there will be multiple SQL areas activated. However, if the user only selected one field then the Date Time Field 1 SQL area will be the only active area. The Date/Time data should be in the format YYYY-MM-DD-HHMISSMMM for submission to the database. A sample has been provided below.

> Example Statement:
>
> YEAR([DATEOFFIRE])&'-'&MONTH([DATEOFFIRE])&'-'&DAY([DATEOFFIRE])&'-'&[RPTTIME]

Notice that the date and time fields are delimited by a dash. This dash is imperative in order for the submission to be processed.

Location Fields Tab

Location data is used to determine the location of the start of the wildland fire incident. The database will take up to 3 different types of location information and each of these three types can be submitted with one submission. The user must select what type of location information they are using so that the database can parse the location information correctly (Figure B27). All location information will be verified as to if the location resides in the county of the fire event/record.

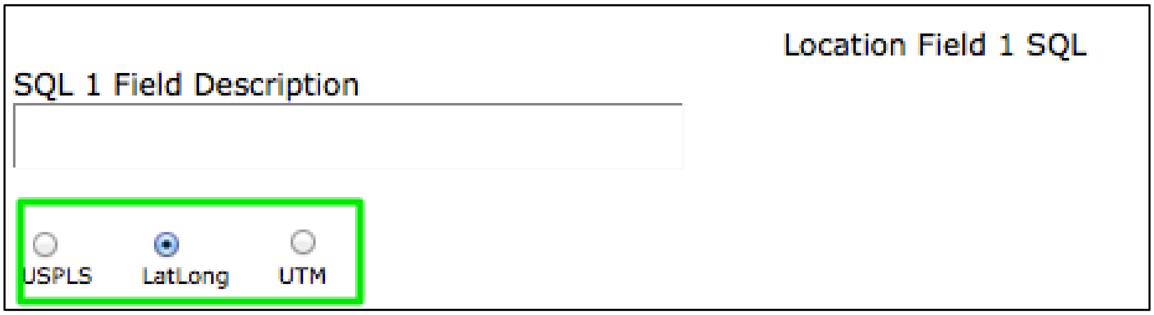


Figure B27 Radio buttons used to select the location format.

USPLS Location Information

USPLS location information should be entered down to the section level so that the location can be verified with respect to the county. Meridian information submitted must be in the same format as defined by the Bureau of Land Management (http://www.blm.gov/lr2000/codes/CodeMeridian.htm). The USPLS data will be submitted in the following format:

State, Principal Meridian, Township #, Township Fraction, Township Direction, Range #, Range Fraction, Range Direction, Section, Aliquot Part,0

The output should be as follows:

"UT,26,17,0,S,14,0,E,16,SENE,0"

If an item is not in the dataset being uploaded simply place the commas with no data. The database system will handle the empty data.

Sample SQL:
‘UT,’&’26,’&[TWN]&’,’&’0,’&[TDir]&’,’&[Rng]&’,’&’0,’&[RDir]&’,’&[Sect]&’,,’

Latitude and Longitude

Points of latitude and longitude are assumed to be in the coordinate system of WGS84 by the database system. The preferred format for the points is as follows:

36.05, -96.032 *Decimals can extend 10 digits.

Sample SQL:

```
[Latitude]&',-'&[Longitude]
```

UTM Coordinates

The coordinates for UTM must have an associated zone that corresponds to the northing and easting for the particular record. If a zone is not present the record will be omitted in the submission. The preferred format for the location is as follows:

4009555.25,629501.0625,15

Sample SQL:

```
[Northing]&','&[Easting]&','&[Zone]
```

Cause Fields Tab

The cause of the fire should be entered as a single field or a concatenation of fields. If more than one cause is present they are to be in the order of the association with the fire event. The primary cause of the fire is Cause Field 1 and the second cause is in the Cause Field 2 area of the form. In the next section the user will map the cause fields to the database predefined causes.

Ownership Fields Tab

Ownership data is entered in the same order that fire cause is entered. The primary owner or most affected owner goes in the Ownership Field 1.

Fire Size Field Tab

The size of a fire is to be in units of acres. If the data being submitted is not in acres a mathematical calculation can be done using the SQL box otherwise simple place the field in the box.

Sample SQL:

Convert square feet to acres using SQL

```
[AcresField]/ 43560
```

Number of Injuries Tab

The number of injuries refers to the number of people injured by the fire or during the extinguishing of the fire.

Number of Fatalities Tab

Like the number of injuries, the number of fatalities is the number of fatalities associated with the fire itself and the extinguishing of the fire.

County Field Tab

The county data can be in any format the user has in their native dataset. An example could be if the user's state uses their own three digit code for coding counties. The next form will handle this and county coding will be mapped to the wildfire data system format.

Submission Process Step 2: Definitions of Cause, Ownership and County Codes

If the user has any cause, ownership or county codes that do not directly correspond with the native database coding structure; the user will have to manually select the best matching correlation to the native database field definition. The user will notice the interface for this form is once again a tabbed panel. If a panel is active it will require the user to interact with the data.

County Code Defs

As an example in this manual the user may have blank county codes in their data submission. If there does exist blanks in their submission they will be apparent on this form (Figure B28). Notice that there is a response of Unknown. So if the user does not know they do not have to guess as to what county the null data represents.

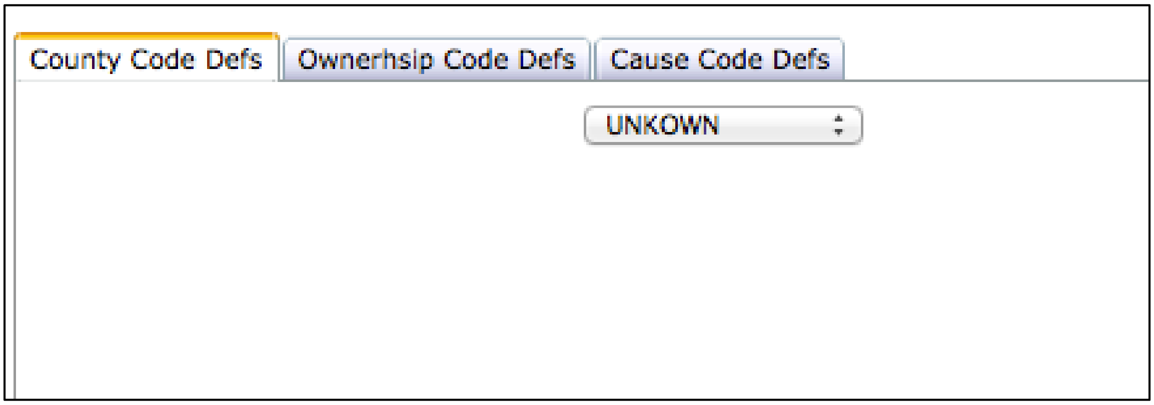


Figure B28 Example of blank/null values in county data.

Ownership Code Defs

There are seven possible ownership codes that may be matched with a single ownership. Matching the ownership codes is simply done by selecting the from the dropdown list the best possible matching ownership code (Figure B29).

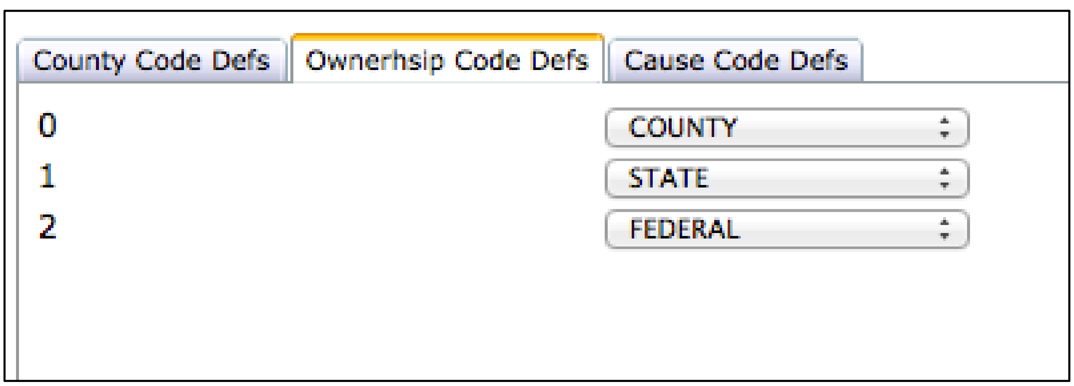


Figure B29 Example of ownership code matching.

Cause Code Defs

There are 16 possible choice for mapping fire cause codes with the users native cause codes. There is the option for not recorded, unknown, and undetermined. Not recorded would represent the scenario where the cause was never recorded. Unknown would be an instance where the cause is simply not known to the fire investigator. Undetermined is the instance where the fire investigator has investigated the fire and was unable to determine a cause for the wildland fire incident. An example of these cause code mappings can bee seen in Figure B30.

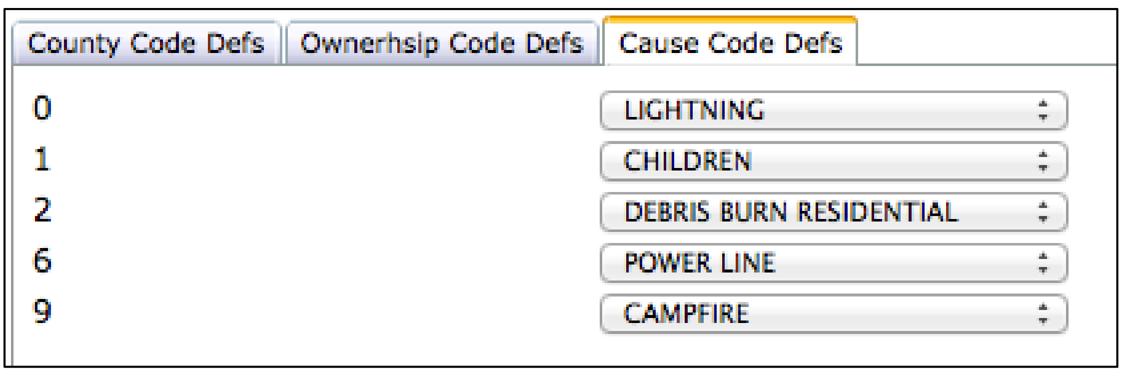


Figure B30 Example cause code mapping.

Submission Process Step 2/3: Verify Field Definitions & Submit Data File

This step of the submission process provides the user the ablity to view the data that they are submitting. If the data does not look right they user can stop the submission process at this moment. If the user reaches this form from a previously create field definition then the use can simply use the back button to select a different field definition. However, if the results in the data grid view are not correct and the user reached this page after creating a new field definition then they must close the browser window and re-login. After they log back in they will be able to create a new field definition for submission. If all data looks correct the user should click continue.

Submission Process Step 3: Verify Location Data

The user is given one more look at the location information that they have provided to the data system. If all of the data looks correct the user should simply click continue to perform the location verification process. This is the process by which the data system takes the location information and determines if the location is inside of the county for a given fire record. This process may take some time to complete depending on the size of the data set being submitted.

Submission Process Step 4: Accept/Override/Delete the locations out of submitted county or cancel the entire data submission

In this step the user is provided the location data that did not occur within the county that was provided in the fire record (Figure B31).

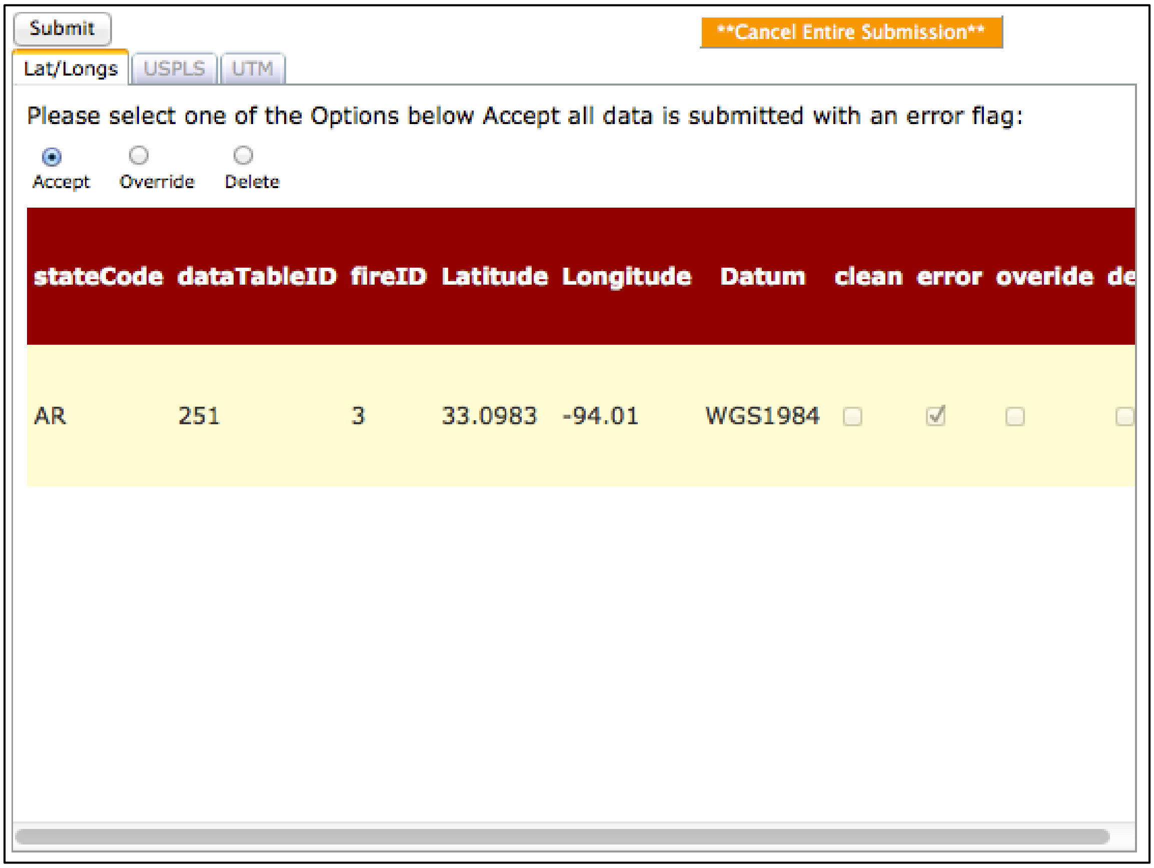


Figure B31 Submission process step 4 Form.

A user can select from three options in this step. The user can accept the errors by default. By accepting the errors the data will still be a part of the final submission but an error flag will be placed next to the location data to alert the end user of the error. Alternatively if the user believes the data to be accurate they may choose to override the error. In this case the data will again be submitted to the database but there will be an override flag next to the data. This will tell the end user that the data did in fact have an error by definition of the database system, but the user submitting the data did not agree with this error. Finally the user can select delete. If the user selects delete the data will not be included in the final dataset. The user will make these choices for all data location data present in the data submission. If the user at this point believes they need to restart the data submission process then they may select to cancel the entire submission using the Cancel Entire Submission button. If the user select this all uploaded information will be remove and no submission will take place.

Step 4:Accept/Override/Delete Date/Time errors or cancel the entire data submission

This step of the submission process once again is a data verification step. If any of the fire date/times appeared out of chronological order (DateTime1, DateTime2, DateTime3). Then the user is given the same option as they were in the location verification step. The location verification step can provide an explanation of the user's options. Once again the user is still able to cancel the entire submission with the Cancel Entire Submission button. The next form will load slowly because all data is being transformed into the final data submission product and weather data is being processed so the user must be patient for the final form to load.

Final Verification of All Data and Final Submit/Reject Submission

The user can now see exactly what is going to be submitted to the database system. Each tab represents the individual tables in the data system. The user should review all data that is to be submitted to the database. If the user does agree with the data that is to be submitted to the database they will click submit or if they do not agree they may click Cancel Entire Submission. Upon clicking submit the user will be redirected to logout page where the user will log out of the data system.

APPENDIX C

Wildfire Data Repository

Operations Manual Version 1.0

Table of Contents

CONCEPTUAL MODEL OF SYSTEM

The wildfire data repository system itself is a database that allows users to dynamically enter data. The dynamic data entry system does require users to possess some basic SQL knowledge when performing a bulk data upload. However, if a user is simply entering data one record at a time they do not need any SQL knowledge.

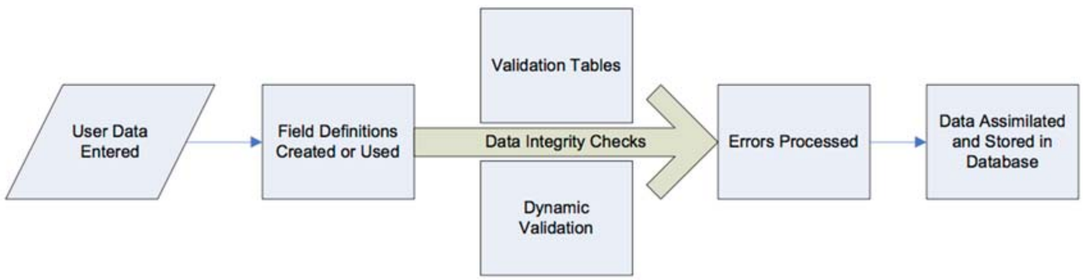


Figure C1 Basic process diagram.

The system itself is relatively simple (Figure C1). A user is asked to upload data either in bulk or enter data one record at time. The more complicated portions of the system are the creation of field definitions and data integrity checks. The creation of field definitions is imperative to the operation of the database system.

Field definitions allow multiple users and multiple data file formats. A field definition is a SQL code snippet that is stored for data processing purposes. A set of code snippets forms a set of field definitions that act as a data cypher for a specific submission of data. These definitions process a dataset into the database as a homogeneous unit in terms of data format and data quality.

The data integrity checks are the primary process of forming a quality dataset that makes this data system unique. Data can be validated using two different methods in the database system. One method is the use of validation tables. Validation tables ensure quality of data by physically mapping data from a native format to a known format. This process of data validation is relatively crude in a sense that the database must already know what data is going to be submitted to the database and the user must have some knowledge of the validation terms. In cases where the data format/context is relatively unknown a dynamic validation procedure can be performed on the data. This is the second method of data validation.

Dynamic data validation is a process that requires the data system to have an artificial intelligence. Artificial intelligence is used to describe the active processing of data submitted to the data system. The system itself reads the data and applies the knowledge that the system has been given to determine the validity of submitted data. In a sense the process of dynamic data validation can enable more complex validation methodologies to ensure the integrity of data.

Once data has been checked for integrity the user is then prompted as to the errors that have been made in the data entry process. The user is then allowed to decide whether or not to accept/override/delete the error records in the data submission. When a user accepts the errors they data will not be submitted to the system. However, in the case that a user overrides these errors the data will be accepted to the system; but the system will flag the data as a user override. By flagging an error as a user override any analysis of the data in the database system can easily remove these records, as they do not maintain the defined level of accuracy prescribed by the database system. Finally if a user decides to delete the errors from the data submission then only records with error data will be deleted from the data submission. Either the acceptance or deletion is preferred for future analysis of data submitted to the database system.

Utilizing this system of data entry and processing can enable a database to have a level of accuracy that is not apparent in many database systems like it. The system itself allows for the integrity of data to be improved upon as the system grows over time. With more accurate data, the data housed by the database can be more readily used with out having to perform costly data cleansing techniques prior to analysis.

SPECIFIC OPERATION OF WILDFIRE DATA SYSTEM

The first step in the data processing of the wild fire data system requires a user to log into the system (Figure C2). This identifies specific information that the user has previously entered into the data submittal system. For example, a user is tied to their field definitions so that they do not have to re-enter this information every time a data submission is performed. The login information is stored in two different places in the database system. The actual user name and password details are encrypted in the database system in a table created by the IIS. The user contact information and user ID are stored in a database table that is read by the web application to retrieve user submittal information.

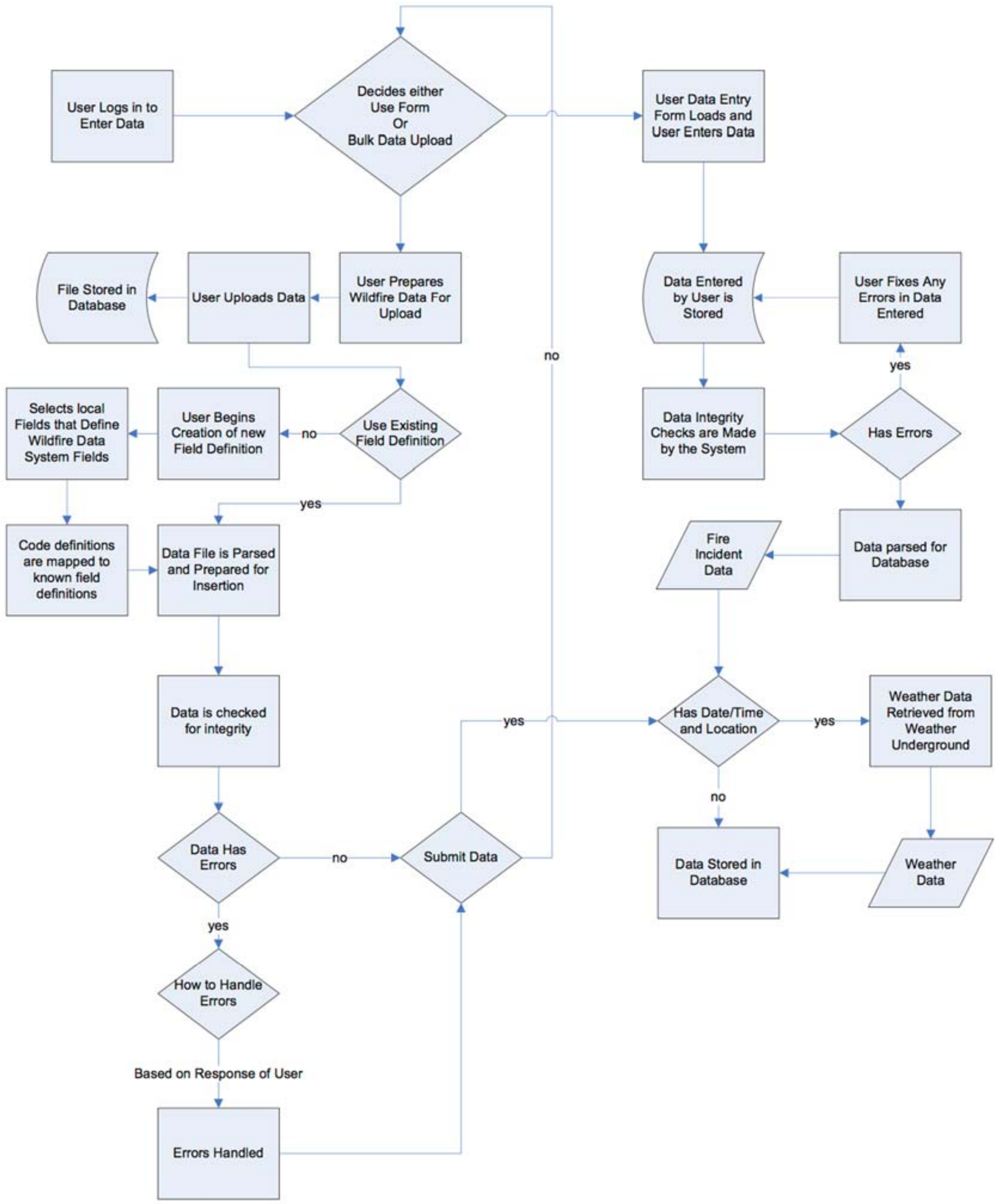


Figure C2 Data flow diagram of wildfire data repository.

USER FORM VERSE BULK UPLOAD

After a user logs into the database system they choose either a bulk file upload or a single fire incident upload. Both of these data upload methods have error checking as a central process. The first of these checks is the mapping of wildland fire cause to a validation table that has been created and stored in the database. Land ownership and county of fire origin have also been validated using this technique. Dynamically the database will not accept any location information that is not inside of a submitted county location. Also fire date/time information must be in chronological order to be valid in the data system. These constraints are placed on the database in the database design phase and are checked by the web application reading and interpreting data that has been submitted.

The single fire incident upload differs from the bulk data upload in how they verify location information. This was done to increase processing speed for a user that is entering fire data one incident at a time. The two methods of location validation yield the same result with different processing speeds.

For signal fire uploads, the core process relies on Google to verify location information to the county level (Google). Google provides county information for any point that is submitted inside of the United States. This method of county verification is preferred over that of utilizing ArcServer because of the time that ArcServer takes to process this information. The bulk data entry method relies on ArcServer for the processing of because of licensing requirements of Google. Google will not allow a certain number of calls per day to their servers without a fee.

In addition to utilizing Google for information, the Bureau of Land Management provides points of latitude and longitude for United States Public Land Survey (USPLS) information (Bureau of Land Management). This service also ensures that all USPLS information is valid per their requirements. The USPLS information is only accepted if the information provided is at least to the section level of location detail. The points of latitude and longitude are then further verified as to their location relative to the county of fire origin.

Fire date and time information is validated using a simply coding structure. This coding structure reads all date and time information and re-orders them as to their chronological order. If the order is incorrect the user is prompted to the error.

Errors from the above are processed in three different ways as described in the conceptual model section. In terms of processing, there exist one major difference between the user form and the bulk data upload. The user form does not allow the user to submit any fire information that contains an error. The bulk data upload does allow a submission of error. If the user does choose to proceed with a data submission that has errors the database accounts for this by flagging the data as having errors. The reason for this is that in a bulk submission not all data will have errors. A user may decide to proceed with a submission if the number of errors is relatively small in comparison to the overall number of records being submitted. If the user decides to cancel the submission they are taken back to the login screen but their field definition information is still stored in the database system so that they may choose to reuse the information after their data has been cleansed of the errors that they were prompted.

After all data integrity checks have been done and data errors have been handled fire weather information will be added to the data that has been submitted to the system. The fire weather data is added using the weather underground application interface (Weather Underground). The web application utilizes the start time and location information to gather weather information about a specific wildland fire event. Weather information is only retrieved for data that does not have an error. For example, if date/time information is available for a fire record and location information has an error then the application will not try and retrieve weather information for this fire event. This is done so that if an end user is analyzing data the only complete data will have weather information for fire events that have been verified to the county level and have fire start times that have also been verified by the fire data system.

INTERACTIONS WITH ArcSDE DATABASE

The data submitted to the wildfire data system is intended to be spatial data. In order to convert static data to spatial data there needs to be a place to store such data. ArcSDE provides a location for such data to be stored. The ArcSDE database is separate from the database that the web application interacts with for the user to upload wildland fire data. This was done to relieve strain from the data-viewing portion of the web application. The data submittal portion of the application has a potential to be actively handling multiple input and output operations simultaneously and it was felt that by separating these components the strain of the operation would not affect the performance of the data-viewing portion of the application.

Data from the data processing database is fed to the ArcSDE database every night at two o'clock in the morning. This process is not done by the web application. The process is handled by the spatial database itself. The process of converting static data to spatial data is started by the ArcSDE database by dumping all spatial data from the feature class containing the fire information. Then the ArcSDE database extracts data from the data submittal database to perform a complete refresh of the spatial data that has been submitted using a defined database process script. This was intended to provide the end user with up to date wildfire information daily.

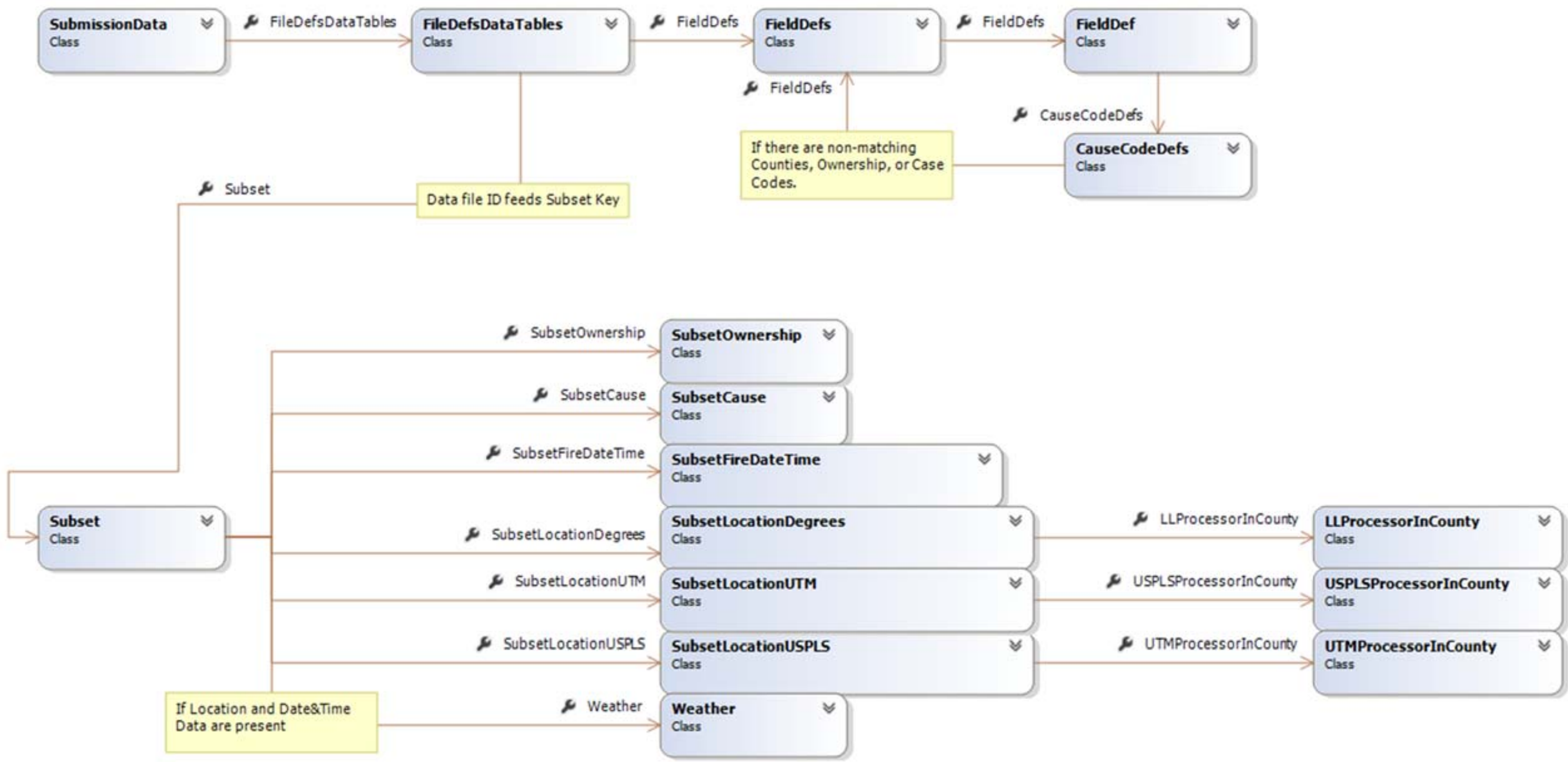


Figure C3 Coding structure diagram.

CODING STRUCTURE OF WILDFIRE DATA SYSTEM

The coding structure of the web application that feeds data to the wildfire data system was designed in a modular format. The reason for this was for ease of maintenance and additions to the data system that will occur over time. The modules are divided into two main portions.

The first main portion is the data file handler as seen in Figure 3. The process of uploading a file is simple in nature but this data system had to have the capability to handle more than one file format as well as the ability to handle single fire instance data uploads. To do this the SubmissionData module was created. This module processes two different file formats as well as a unique coding structure to handle data submitted on the user form. After a file has been uploaded, the FileDefsDataTables module creates a pseudo data table that is stored in memory for the purposes of preforming the data validation and manipulation operations in the case of a bulk data upload or for a single wildfire instance. The data table itself is given a unique identification code by this module and further processing can occur at this point to handle concurrent database operations.

The second portion of the coding structure is dedicated to the processing and validation of the data. The FieldDefs module is only activated when a user is submitting a bulk data upload. If the user is submitting a single fire instance via the web form then this module is not used. This module allows to the user to create and store a data cypher to process the submitted data in either data format that the system is able to process. A significant portion of data processing occurs in the CauseCodeDefs module where the data is read by the application and interpreted as to the matching of cause, ownership and county to the validation tables. The user at this point in the process is asked to map their data to these validation tables. Once this process is done the pseudo data set is passed to the Subset module.

All data going into the Subset data table has been verified to its integrity at this point and a temporary subset data table is created in the data processing database at this point. The subset data table contains the minimum required data fields for a fire incident and is the base data table that all other data tables rely upon.

Each subsequent module after the subset module represents individual tables in the data processing database that are dependent upon a data record existing the the subset data table. The SubsetOwnership and SubsetCause modules simply create temporay tables in the database for later submission of all final data as the integrity of this information was checked in the previous module CauseCodeDefs. The three different location modules process location information in the same generic way. These modules parse location information into an ESRI usable format using a string parsing method and through the ESRI ArcServer 10.0 Web ADF component the location is validated to their location relative to the county that is stored in the temporary subset data table. Each location table (Latitude/Longitude, USPLS, UTM) have their own processing module as the coordinate system and data formats are different from each other. If there is an error in the location data web application will direct the user to a web form for the handling of these errors.

The SubsetFireDateTime module does on rely on any special coding objects as they are a part of the generic C# set of data types. The string date and time information is converted to the data type date and processed based on the order that the user has defined in the FieldDefs module. If errors exist in the data the web application will handle them in the same way that errors in the location are handled with a web form. Both the location modules and the SubsetFireDateTime modules temporarily store data in the database for final submission.

The last step of the code processes the weather data. The Weather module only begins processing if the submitted data has both a valid data/time and location information. The Weather module does have a built in ten second lag so that licensing constraints by weather underground are not an issue. When this module is done processing, if processing is to occur, the user is shown all the data that has been submitted and is given the option to submit the data or cancel the entire submission. When the user selects to submit the data the web application inserts the data into the actual database tables and the temporary data tables are removed, but if the user cancels the submission only the temporary data tables are removed.

From an administration stand point more data can be added to the wildfire data system simply by adding data tables that are tied to subset. For example, if a future administrator wanted to add vegetation information the process would begin by creating a new data table in the submission database. This table would then need a module dedicated to processing such information similar to that of what already exist in the code. Then the administrator would simply add the module to the web application data processing portion of the application.

FUTURE CONSIDERATIONS

Many things have been learned through the process of creating the wildfire data system. This documentation is only meant as a guide for the future implementation of data processing and database systems. Below are some suggestions for future additions based on what has been learned in the creation of this data system.

INTEGRATION OF SECURITY

In the current version of the application/data system security is not fully integrated with the functioning of the application. In the future security should be fully integrated. Meaning that the data tables that containing the user name and password should also contain the user contact information. This was not done in the present version because security was a second thought as tighter security rules were placed on the web application by Texas A&M University.

PROCESSING SPEED

Through the creation of the proof of concept web application/data system that is presented in this paper it was noted that the processing speed demonstrated by the current methodologies was slow. Later in the discovery of other methods, it was found that there were other ways of processing the spatial data that did not take up as much time.

The current processing time for the utilization of ArcServer 10.0 web ADF for the verification of spatial data turned out to be a very daunting process in terms of speed for which it processes. In the creation of the web form it was found that other sources of spatial data were much faster. One such source was Google as they do provide the county information that is required for this particular web application/data system. Even though Google is a black box on how the processing of coordinates is done the speed that the information is processed is truly a benefit to the application in terms of the feasibility of deployment on a larger scale. Google is not the only corporate entity that distributes spatial data in relatively large quantities for free. There are other entities out there.

A more sustainable option to verify location information may be found in the utilization of spatial querying. Spatial databases allow a user to perform the same task that the ADF components allowed but the data is extracted much faster than traditional ArcObject commands. Spatial querying would also make the application not as dependent on one single software vendor as it is in its present state.

OTHER DATA FORMATS

Data comes in many formats. The formatting of data is an ever-evolving cycle. An example of this is found in the current application. When Microsoft released Excel 2007 the format of the data changed from *.xls to *.xlsx. The change may seam minor but the method of processing the two different formats does matter when uploading data to a database.

The current application does accept Excel 2003-2010 data formats as well as any text file format. If this application is to be released full scale a developer must allow more than just the two formats of data. It is suggested that all Microsoft data formats be accepted including Access. In addition future research must be conducted for the potential extension of the functionalities of the data system to directly connect to other databases either in a live format or an ad hoc format. This will allow the end user many options to utilize the web application for data upload. There will most likely not exist one single format for which data can be submitted over the course of time.

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