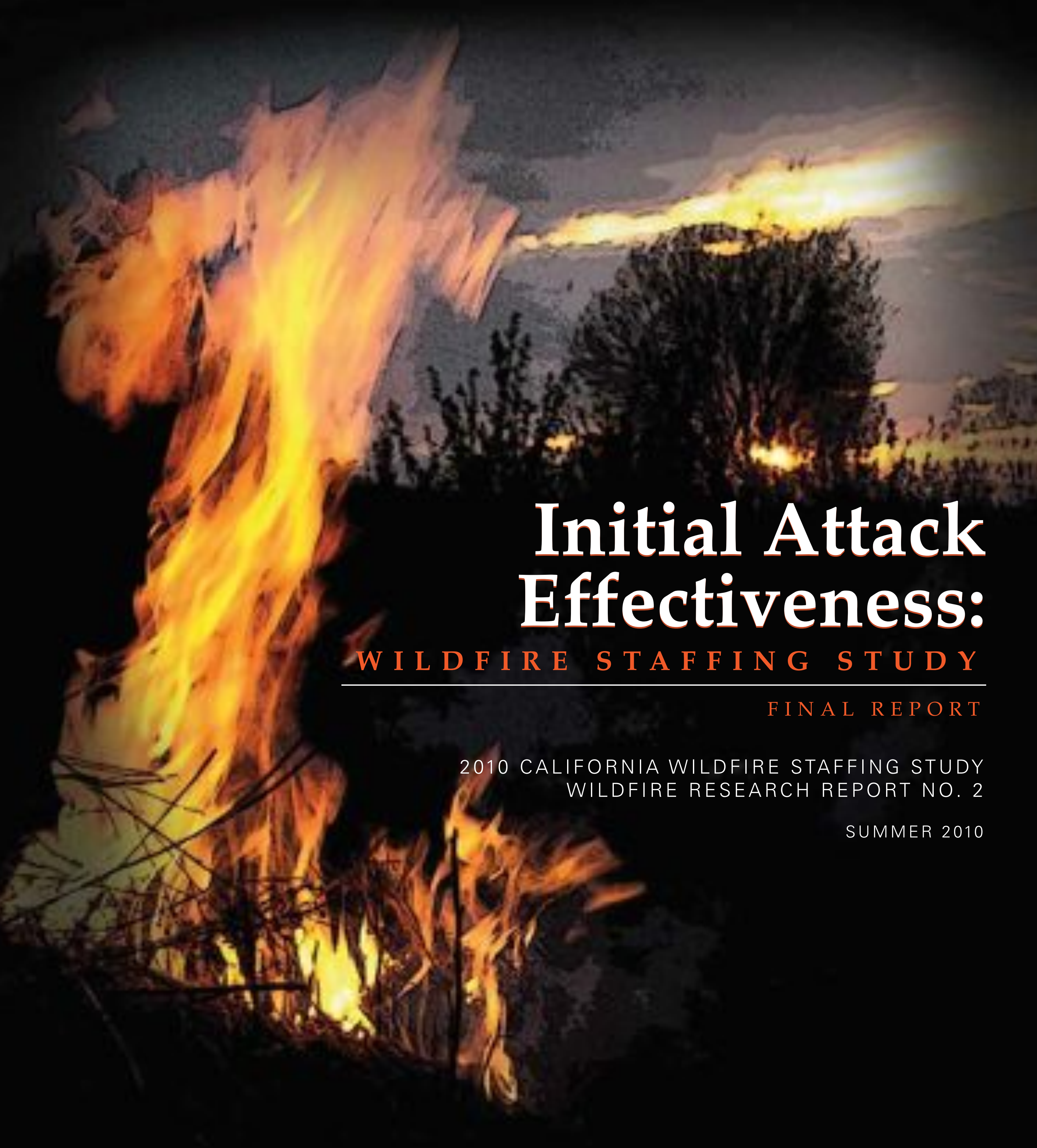

Initial Attack Effectiveness:

WILDFIRE STAFFING STUDY

FINAL REPORT

2010 CALIFORNIA WILDFIRE STAFFING STUDY
WILDFIRE RESEARCH REPORT NO. 2

SUMMER 2010

SAN DIEGO STATE UNIVERSITY

Prepared by Matt Rahn, Ph. D.
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(619) 846-1916

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EXECUTIVE SUMMARY

The ability to effectively and economically control wildfires in California depends on our capacity to provide adequate firefighter staffing.

The success of the California wildland firefighting community depends upon aggressive initial attack and response. Current fire suppression goals focus on keeping 95 percent of all wildfires at ten acres or less. These wildland fire success standards are threatened because the size, frequency, and intensity of wildfires has significantly increased in recent years. Modern trends suggest that although the percent of wildfires kept below ten acres has remained relatively unchanged, the total number of fire events and the number of extremely large fires has dramatically increased statewide; of the twenty largest documented fires in California's history, half of them have occurred since 2000. The success of an initial attack operation can significantly influence the ultimate outcome of a wildfire event, and thus places an extraordinary burden and expectation on emergency responders. In reality, the outcome of a fire event is affected by a myriad of factors, many of which are not easily accounted for during an actual wildfire.

It is important to clarify within this document that when a reference is made to 2-, 3-, 4-, or 5- person staffing, it refers to the number of actual firefighters actively working on a hose lay test trial. Engine company staffing includes a company officer in addition to the firefighters, however the company officer is not considered part of the hose lay test. The company officer's duties include operating the engine and command and control of the incident and firefighters.

In brief, this study concludes that by increasing the number of personnel on an individual hose lay, the efficiency, effectiveness and overall ability to potentially control a wildland fire are significantly increased, thus enhancing emergency response and increasing the ability to protect California from modern wildfires. Across all trials, generally the most significant gains were observed on extended hose lays, where changing the staffing from 2 to 3 firefighters can increase efficiency by as much as 50%.

Initial attack effectiveness

"It is incumbent on all fire departments to extinguish each fire with all dispatch, thus ending the damage and destruction fire is known to create. If that is our goal, we must appraise our approach to fire and pledge to give it a swift, solid sock so that the first blow will score a knockout and end the contest."[1]

PROJECT NEED

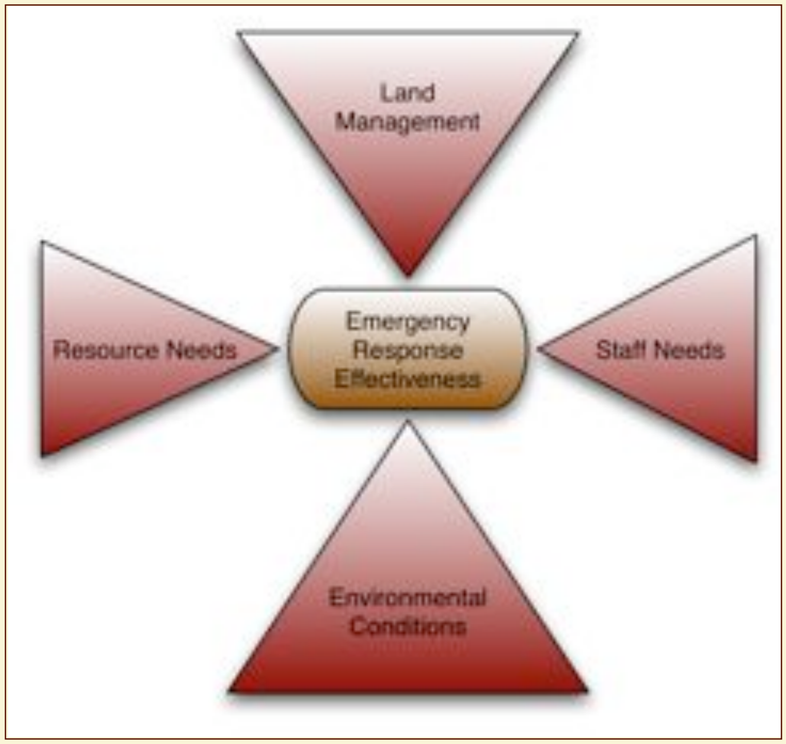
Initial Attack and Fire Suppression

Since the 1970's we have experienced a nationwide increase in wildfire intensity, rising from an average of three million to a staggering seven million acres burned each year, with further increases projected.[2] From 1975 to 2002, an average of 132,000 acres have burned in California annually. Of the twenty largest documented fires in California's history, half of them have occurred since 2000. This startling trend has placed a considerable demand on emergency responders to limit the overall impact of wildfires across the state.

Failures in fire suppression occur when wildfires exceed the suppression goals established by the firefighting community, i.e. keeping 95% of all wildfires below ten acres. This is not simply an arbitrary size, but rather represents the size of a wildfire that is logistically manageable and typically has minor economic and physical impacts.[3] Failures occur as a result of extreme environmental conditions, inadequate resources or a combination of both.

Extreme environmental conditions are associated with the overall fuel or vegetation load, weather conditions and other climatic influences These factors can work in concert together to significantly influence the outcome of a wildfire event, altering the forward rate of spread.[4] The California wildland firefighting community must adapt firefighting practices in response to fires that now occur during extreme environmental conditions in order to maintain their suppression goals.

The availability of adequate resources and staffing to combat wildfires also has a direct impact on meeting fire suppression goals. Suppression failures generally happen when the resources available for an initial attack response are ineffective or insufficient at controlling the fire. This can occur when firefighting resources throughout a region are spread too thin due to excessive activity or when adequate resources are not provided, particularly at the outset of a wildfire event.



Wildfire Effectiveness

Emergency response effectiveness is driven by four factors: 1) land management practices, 2) existing environmental conditions, 3) equipment resources available to fight a fire, and 4) the number of firefighters dispatched to an incident. When one variable is unbalanced (e.g. extreme environmental conditions or insufficient staffing) the result is an inability to effectively contain wildfires.

METHODS

Santa Margarita Ecological Reserve

Since 1962, this 4,500-acre Reserve has been owned and managed by San Diego State University as an outdoor "laboratory and classroom." The Reserve is located in the hills above Temecula, along the border with San Diego County and Highway 15. The Reserve has been extensively used as a testbed for wildfire research in southern California.

All staffing trials were conducted during ideal weather conditions, between 65-80F, wind speed at 0-6mph, moderate humidity, and variable cloud cover. Two locations within the Reserve served as the course for the test trials, representing approximately 25% and 0% slopes.

Firefighters conducted simple hose lays along existing roads in the Reserve, with a fully charged hose-line. To ensure the continued integrity of the road surface throughout the trials, all water was sprayed off of the roads.

Testing began in November 2009, and was completed in March 2010. Appendix A shows the actual locations of the test trials at the Santa Margarita Ecological Reserve.

Staff Efficiency Assessment

The primary objective of this study is to evaluate different staffing levels, from 2- to 5-firefighters on both a 1,000-foot and 2,000-foot simple hose lay over 0% or 25% slopes. Trials were conducted with firefighters from diverse ages, experience levels, and physical conditions. Firefighters were randomly assigned to different crews, with an individual participating in up to three trials in a single day (with rests of at least one hour between trials). Each participant wore full wildland personal protective equipment (PPE).

At the start of each trial, the resting heart-rate was recorded for each participant, and then again at the end of each trial. A single individual crew member in each trial was outfitted with a Garmin® GPS and heart-rate monitor to record the total distance traveled and track the heart-rate throughout the trial.

Controlled test trials were used to compare efficiencies under staffing levels from 2- to 5-firefighters on a hose lay. Observers recorded the time between each 100-foot section of hose and the total time to complete 1,000 and 2,000 feet. Observers also recorded any delays that occurred during the hose lay, along with the number of firefighters that were actively involved in laying each 100-foot section of hose. In instances when hose lines broke or other major faults occurred, the trial was terminated and the data were not included in the final analysis.

For each simple hose lay, ten canvas hose packs were used, with two hundred feet of hose in each pack. Each participant wore a full hose-pack at the start of the trial. New sections of hose were deployed (by unrolling the hose) from the packs worn by the nozzle person. Once all hose was taken from a firefighters pack, they returned to the starting line at the beginning of the trial for a replacement hose-pack (rotating through all crew members) until all 2,000 feet of hose was used.

During the test trials, the firefighters produced a continuous "wet line" while they actively advanced the hose lay "extinguishing" the (hypothetical) fire. The trial was run at 100 psi, using a 3/8" smooth bore nozzle. For the 25% slope test trial, pressure was increased to 150 psi at the 1,400-foot mark, to overcome friction loss and elevation. 100-foot sections of synthetic hose, with the modified Wildland Firefighting Hose Clamp for single jacket hose was used.

Again, for clarification, when there is a reference made to 2-, 3-, 4-, or 5-person staffing, this refers to the number of actual firefighters <u>actively</u> working on a hose-lay test trial. All members of that crew are actively engaged in the hose-lay; both extending the hose and retrieving additional hose from the starting line.

RESULTS

Staff Condition and Monitoring

Throughout the study, several observers were present to monitor the conditions of the firefighters during the trials.

In general, the environmental conditions were favorable for this type of strenuous activity, if not ideal. This of course assisted in creating a controlled experimental environment where replication and standardization is critical. However, these conditions may not represent the actual physical stress endured by firefighters during a wildfire. During a real wildfire, firefighters can be exposed to extreme temperature conditions, high wind-speeds, dehydration, and exceedingly poor air quality; all of which may significantly influence the overall efficiency and effectiveness during initial and extended attack fires.

Staff Characteristics

The physical parameters for each staff member were recorded for each trial. Overall, no significant differences in hose-lay efficiencies were detected among the various ages, heights, weights, or experience levels of the firefighters deployed in each trial. This is most likely due to the randomization of staff across each test trial. The only major anomaly detected was that firefighters with more experience typically had fewer delays during the trials (although this was not statistically significant).

Hose Lay Results

The table below describes the total number of trials for each type of test conducted. The sample size was generally large enough to reduce the amount of variability in trial times, providing rather consistent results across each type of trial. Because of the extreme physical demand that a 2,000-foot trial places on a two-person crew on a twenty-five percent slope, it was decided that a smaller number of these trials would be conducted. However, the variability between these trials was also minimal.*

The primary data analysis focused on several key factors. Comparisons were conducted across the various staffing levels (from 2- to 5-firefighters on a hose-lay) and the slope for the trial course (0% or 25% slope) for the following:

- A comparison of the average time per 100-foot section of hose
- The number of firefighters working on each 100-foot section of hose
- A comparison of the average time to complete 1,000 and 2,000-foot hose lays
- A comparison of the distance traveled during each trial
- The number of delays recorded during each trial
- A comparison of the average heart rates (and changes in heart rates)

A summary description of each analysis and associated discussion is provided in the following sections. An analysis of variance (ANOVA) was used to determine whether there were any statistically significant differences between the various staffing levels and the trial times. Appendix B provides the actual statistical results from the data analysis.

NUMBER OF HOSE-LAY TEST TRIALS

Staffing	0% Slope	25% Slope
2 person	8	3*
3 person	7	7
4 person	8	8
5 person	7	7

100-FOOT HOSE SEGMENTS

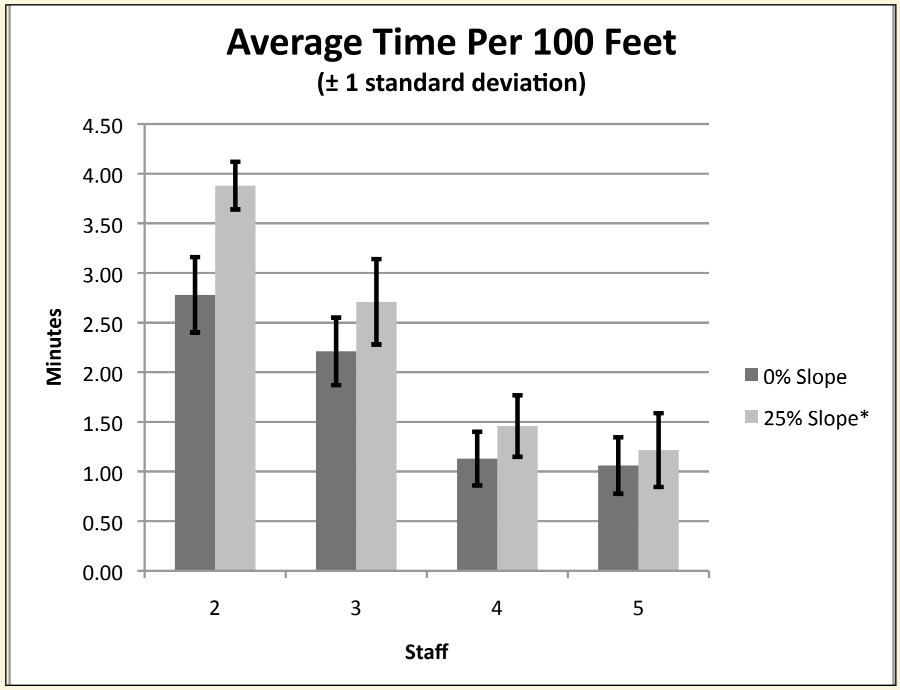
Average Times

Overall, the average time to extend the hose-line an additional 100 feet was over one minute. The variability seen in the data is inversely related to the number of staff included in each hose-lay; the fewer number of staff resulted in somewhat higher variability in the time it takes to extend the hose-line by 100 feet.

There is an obvious and expected trend in the data. As more staff are added to the hose-lay, the time it takes to lay 100-feet of hose decreases. When going from 2-person to 3-person staffing on a hose-lay, efficiency increased by 21 and 31 percent (for 0% and 25% slope, respectively). When going from 3-person to 4-person, the efficiency increases by 49 and 47 percent (or 0% and 25% slope, respectively). No significant increases in efficiency were observed when increasing from 4-person to 5-person staffing.

The variability in the data are relatively low throughout each of the different staffing levels (2, 3, 4, or 5). This means that there are relatively consistent and reliable results within each staffing level. For example, the mean time for a 3-person hose lay was very consistent, regardless of the individual firefighters involved. The main factor that influenced the time it took to lay 100-feet of hose had to do with the delays that occurred. Typically, the times were surprisingly similar (when no delays occurred). The most severe delays occurred when the firefighters were waiting for more hose to arrive.

Increased staffing increases hose laying efficiency, but only to a point. Generally, increasing the number of people on on a hose-lay shows dramatic improvements mainly at lower staffing levels



Hose-Lay Efficiency per 100 feet

The whole objective of standardized training is to decrease the variability and increase the reliability of an emergency response. Cal Fire provides some of the most rigorous training in the United States, and exemplifies the kind of support that should be provided to firefighters. This is clearly demonstrated throughout this study, where limited variability (shown as standard deviation) exists between similar trials.

"Due to our continuous training and high standards, we are able to maintain an exemplary consistency among our crew members, when laying hose on the fire ground."

1,000-FOOT TIME TRIALS

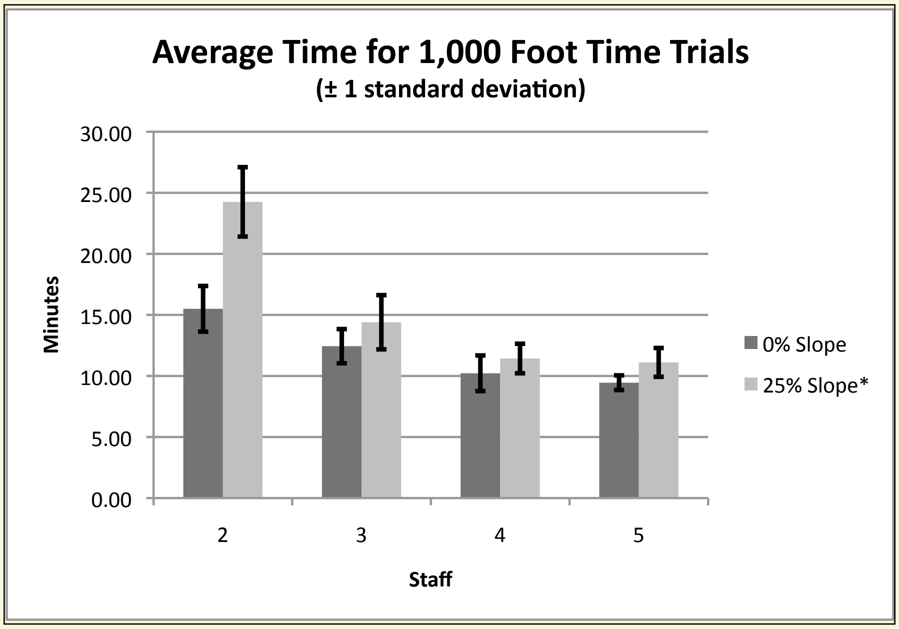
Average Times

The rationale behind measuring a 1,000-foot time trial is simple: often the initial attack on a fire involves a single engine company that arrives first at the incident (the first responders). Depending on conditions, location, and other variables, additional support engines may show up within a reasonable amount of time. Therefore, in some cases, the staffing may only be limited for a relatively short period of time.

However, the importance of those first few moments of a wildfire cannot be overstated. Given the right conditions, the ability for an engine company to effectively stop a wildfire below the targeted ten acres often depends on how efficient that first crew is at attacking the fire. Therefore, the first thousand feet are pivotal to the success or failure of containing the incident.

Again, we can see a dramatic trend in the data. During the first 1,000-feet of a hose-lay, the most statistically significant difference occurred between the 2-person crew, and all other crews, particularly on the steeper slopes. Surprisingly, a 2-person crew (on 0% slope) is 20% less efficient than a 3-person crew, but on a 25% slope they become over 40% less efficient than a 3-person crew, and nearly 55% less efficient than a 4-person crew. When comparing a 3-person to a 4-person crew, efficiency increased only slightly. No significant differences were observed between a 4-person and 5-person crew

In the first 1,000 feet of an initial attack, adding on a single firefighter to a 2-person crew can have a dramatic increase in efficiency - over 40%



Hose-Lay Efficiency - 1,000 foot time trial

For the first 1,000 feet of a simple hose lay, there are no significant differences between a 3, 4, or 5-person crew (although you can see a slight increase in the time it takes a 3-person crew to reach 1,000 feet).

This is simply explained: during the start of a hose lay, each firefighter has 200 feet of hose in their packs. This means that the first 600-1,000 feet can be reached easily, while still maintaining a relatively high number of staff actively advancing the hose lay. A 2-person crew on the other hand, is limited to starting with only 400 feet, and as the second person heads back for more hose, only a solitary firefighter remains on the hose, responsible for clamping, extending, and dragging hose, alone. This creates a significant risk and burden.

2,000-FOOT TIME TRIALS

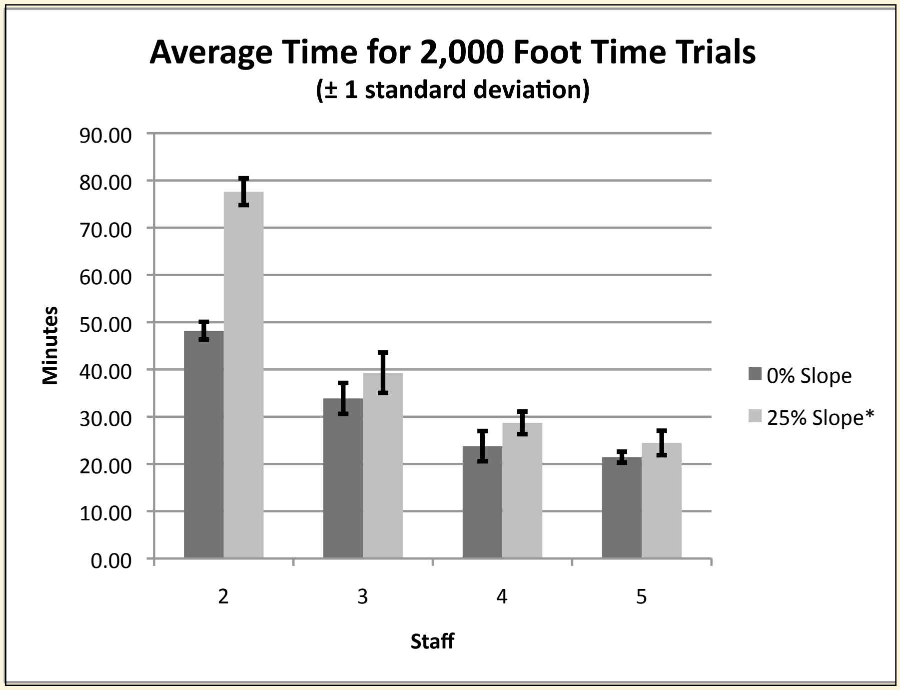
Average Times

During an initial attack, it is not uncommon for firefighters to use hundreds or even thousands of feet of hose. A 2,000-foot hose-lay is not an unreasonable expectation, particularly in wildland fires where there are vast roadless areas and open space. During extreme wildfire events, firefighters may spread out across large areas, with individual engine companies spaced far apart.

The average time for a 2,000-foot trial was similar to what we observed during the 1,000-foot trials, only more dramatic. There is a significant increase in the time it takes for a 2-person crew to complete a 2,000-foot hose-lay in comparison to all others. Most notably, changes in staffing from 2-person to 3-person experienced a 30% and 50% increase in efficiency across a 0% and 25% slope. This equates to an overall increase in nearly 15 minutes and 40 minutes (respectively). The consequences to initial attack are profound.

Similarly, the average trial time for a 3-person crew in comparison to a 4-person crew increased by roughly 28% and 37% across a 0% and 25% slope (respectively). However, there are no significant gains observed by increasing staffing levels from 4-person to 5-person crews. The primary reason for this discrepancy is related to the average number of firefighters that are actively extending the hose, and the number of delays observed during the trials (discussed below).

During an extended hose-lay of 2,000-feet, fatigue and distance significantly impair the ability of a smaller engine company to adequately respond



Hose-Lay Efficiency - 2,000 foot time trial

Again, it has to be emphasized that this project was conducted under "ideal" environmental conditions. While the experimental trials imposed serious physical demands on the firefighters, it pales in comparison to the type of conditions that a firefighter experiences during a real fire event. Rarely will a wildfire occur along a graded road or relatively stable slopes. Fires are in rugged, inaccessible areas that often push firefighters to the limits of safety and physical endurance.

Even though a 15 to 40 minute difference in trial times may seem insignificant, it certainly is not; the window of opportunity that a firefighter has in containing a wildfire (below the 10-acre target) is surprisingly small. Success is usually accomplished at the onset of an initial attack, and missing this opportunity can be disastrous.

2,000-Foot Time Trials

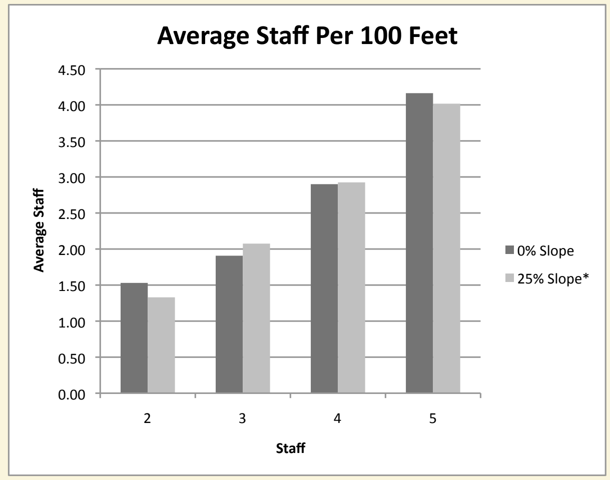
Average Staff

During each segment of the hose lay, we calculated the average number of firefighters that were actively engaged in laying hose (as opposed to those retrieving more hose). On average, each experimental trial experienced one less person actively involved in the hose lay for 3-, 4-, and 5-person staffing.

The average crew on a 2-person hose-lay was between 1.25 to 1.5 firefighters. That translates into only one firefighter actively laying and advancing the hose-line for approximately 1,300-feet of the trial, while the other firefighter retrieves additional hose. Under these limited staffing conditions, firefighters are placed at extreme risk and endure unreasonable physical demands (discussed below). The consequences in the real world are catastrophic and very expensive.

Delays

For each trial, a number of delays occurred for a variety of reasons. These delays were recorded, and typically added to the trial time (for that particular 100-foot section, and the overall time of the entire test). The single most time consuming delay recorded was a lack of hose being readily available. Typically, once the hose lay was extended past 1,200-feet, there would be regular intervals where the hose lay could not advance because the firefighters were waiting on more hose to arrive. For both the 2- and 3-person staffing, a majority of the decreases in efficiency were a direct result of the lack of hose. Firefighters waiting for hose while the fire expands is simply unacceptable. While similar hose delays were recorded under the 4-person trial, no significant differences in times were observed, because the delays were relatively short (seconds rather than minutes).



DELAYS	
No Hose	**35**%
Hose Issues	20%
Clamp Issues	37%
Other	8%

% DELAY - NO HOSE	
2 Staff	**75**%
3 Staff	59%
4 Staff	36%
5 Staff	5%

FIRE PROGRESSION

FARSITE Fire Progression Models

FARSITE is a fire growth simulation model that uses spatial information on topography and fuels along with weather and wind data. It incorporates the existing models for surface fire, crown fire, spotting, post-frontal combustion, and fire acceleration into a 2-dimensional fire growth model. FARSITE is widely used by both state and federal wildland firefighter command and control.

A simulation model was created, demonstrating a moderately high risk environmental condition. We compared the results of this simulation to the ability for firefighters under different staffing conditions to adequately respond. The fire was simulated in a region of Southern California where the shrub ecosystem is typical of Southern California wildlands.

*Fire Simulation Conditions**
Start Time: 1400 hr
Temperature: 100 Degrees
Relative Humidity: 7%
Winds Speed and Direction: East at 25mph.

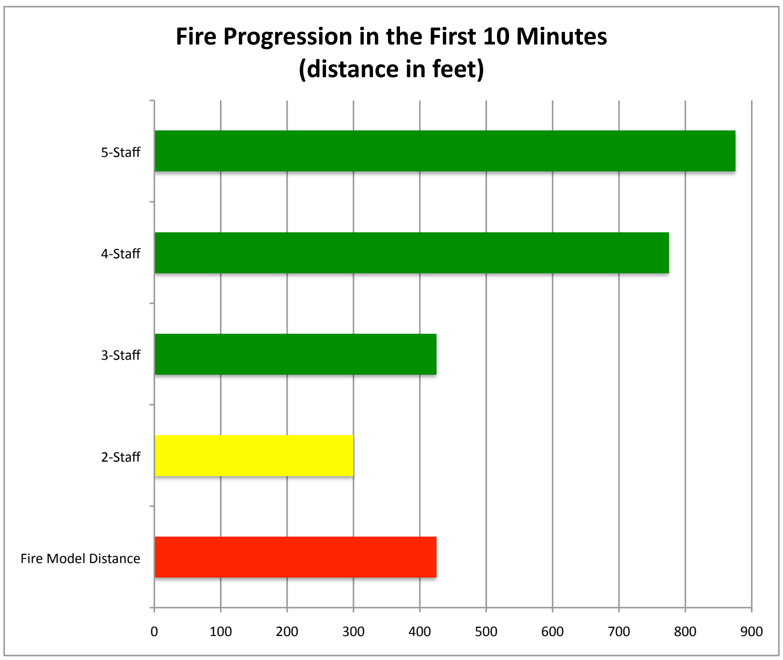
**Since the hoselay trials were conducted under much more moderate weather conditions than those projected in the computer modeling, the simulated suppression results may be more efficient than achieved during an actual fire.*

Comparing Staff Efficiency with Wildfires

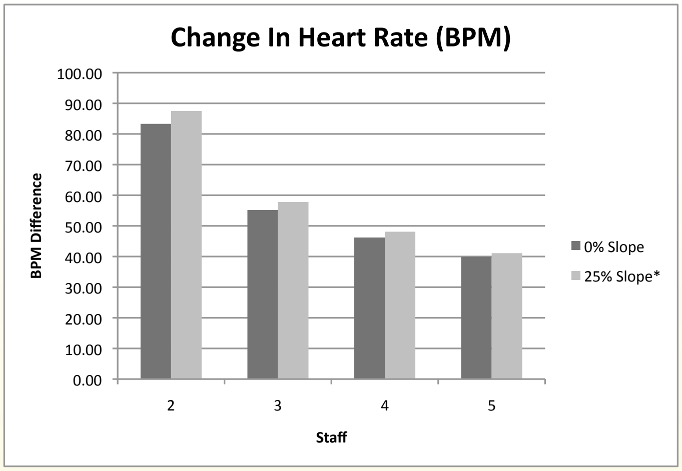
As a fire progresses, it encompasses an ever increasing area, but also expands away from the ignition point. This fire progression can be measured as a rate of spread, or the linear distance a fire travels away from the ignition point over time. Similarly, the initial attack effectiveness can also be measured along a linear path.

We created simulations of a high risk fire scenario, where the linear progress can be compared to the progress of a 2- to 5-person crew. We compared the fire progression models to the data collected for each staff level (2- to 5-persons) in a combined effort across both 0% and 25% slopes. While the comparisons are not perfectly matched, it highlights one important concept: under different fire scenarios, increased staffing levels are able to contain a fire, and keep pace with its spread, while lower staffing levels fall far behind the progression of a fire, thus running the risk of a suppression failure. In particular, 2-person staffing is seriously deficient in keeping ahead of the projected wildfire.

This is not a surprising result. As a fire spreads, ground crews attack the fire from the perimeter, and the first 10-30 minutes of the initial attack are the most important. As noted earlier, a 2-person crew can be between 15 to 40 minutes slower than a 3-person crew. This could have a devastating result. In this simulated fire, an ignition occurs at 1400 hours, under windy conditions, high heat, and low humidity; a typical Santa-Ana condition bringing in hot dry air from the desert into coastal shrublands.



FIREFIGHTER HEALTH



Heart-Rate Change

The most extreme heart-rate changes were observed in 2-person crews. By only adding one additional crew member, the change from resting to ending heart-rates was decreased by approximately 34%. Similar decreases were observed across 3-, 4-, and 5-person crews, but the decreases were not nearly as dramatic.

Heart-Rate Monitoring

A resting heart-rate was recorded for each firefighter prior to starting each trial, with a final heart-rate recorded at the end of each trial. The change in the heart rate was calculated as a change in beats-per-minute. Generally, heart attacks are the leading cause of firefighter deaths in the United States.[5] In fact, firefighters are more likely to suffer a heart attack while executing duties than other American workers while on the job.[5]

The typical responsibilities of a firefighter is a leading contributor to the health risk they face. Firefighters often go from a state of sleep to near 100 percent alertness and extreme physical exertion in only a matter of minutes. When combined with the heavy equipment and gear they carry through extended periods of intense heat and brutal environmental conditions, firefighters experience the limits of what the human body was meant to withstand. Repeated exposure to these conditions can lead to cardiac arrests, where the heart's electrical impulses become rapid (ventricular tachycardia) or chaotic (ventricular fibrillation).[5]

Heart-Rate Monitoring

During each test trial, a single firefighter was equipped with a heart-rate monitoring device (Garmin Forerunner 305). This device collected much more than just the starting and ending heart-rates of the firefighters. It collected data on the total distance traveled during the trials, mean heart-rates, and peak heart rates. The most startling difference was the peak heart rates recorded by 2-person crews, and that they traveled a half mile farther to complete a 2,000 foot hose lay as opposed to a 3-person crew. The American Heart Association advises that peak heart rates should be roughly 220 bpm minus your age. Therefore, for a 25 year-old firefighter, peak heart rates should not exceed 195 bpm. Firefighters often experienced peak heart rates well beyond acceptable limits. This again was conducted under "ideal" conditions, lacking the intensity, heat, and stress that a wildfire creates.

	2-PERSON	3-PERSON	4-PERSON	5-PERSON
Distance Traveled	8,200 feet (1.55 miles)	5,600 feet (1.06 miles)	4,400 feet (0.83 miles)	3,800 feet (0.71 miles)
Average Heart Rate	0% Slope: 179 25% Slope: 185	0% Slope: 175 25% Slope: 175	0% Slope: 154 25% Slope: 175	0% Slope: 155 25% Slope: 170
Peak Heart Rate	0% Slope: **210** 25% Slope: **221**	0% Slope: 202 25% Slope: **210**	0% Slope: 188 25% Slope: 195	0% Slope: 186 25% Slope: 191

CONCLUSIONS

Primary Findings

The results from this study unequivocally show that lower levels of staffing result in higher physical stress and significantly lower efficiencies for initial attack effectiveness. The most dramatic gains in efficiency, and decreases in stress occurred when firefighters on a hose lay were increased from 2- to 3-firefighters. Additional increases were observed when comparing 3- to 4-person crews, while very slight increases were observed when comparing 4- to 5-person crews.

From an economic perspective, the most efficient and beneficial change would be to increase staffing levels from two- to three-firefighter crews available for actual hose-lays and firefighting. On a typical engine, this would mean that there should be a minimum of three firefighters, and one company officer. The officer is not actively engaged in laying hose, but is instead responsible for the tactical command of the fire: giving orders, planning tactics, managing the engine, and ensuring the safety of the firefighters. What this study suggests is that the efficiency and safety of our firefighters requires a minimum increase in year-round staffing from 3.0 to 4.0 (using the historic terminology of engine staffing levels). Therefore, providing four staff per engine would provide the most significant potential gains in initial attack effectiveness and overall efficiency. Recall, the intensity and size of wildland fires have dramatically increased in the past decade; lower staffing levels may be unable to adequately respond to modern wildfire events.

This is of paramount importance to the safety and security of California. Even seemingly minor decreases in wildfire impacts can result in significant economic savings. For example, if the devastating 2003 wildfires in San Diego County were decreased by only 1% to 10%, the region could have experienced an economic savings of between $25,000,000 to $250,000,000 (respectively).[3]

Similar Studies

Earlier this year, the National Institute of Standards and Technology completed a similar staffing study, focused on structure fires. More than 60 full-scale fire experiments were conducted to evaluate the effect that crew size, first-engine arrival time, and subsequent arrival times had on safety and effectiveness on low-hazard residential fires.[6]

The 2010 NIST study also demonstrates that four-person crews operated between 25-30% faster than lower staffed crews. Also, adding a fifth person did not decrease times dramatically. The NIST study specifically addressed hose lay times as well; two-person crews took 57 seconds longer than three-person, and 87 seconds longer than four-person crews. The most striking difference was between two-person and five-person crews, where higher staffing increased initial hose lay efficiency by more than two minutes.

Our wildland study provides very similar results when compared to the 2010 NIST structure fire study. They both conclude that two person crews are simply inefficient (and dangerous) when compared with higher levels of staffing.

Future Research

This is the first study that critically and scientifically evaluates the potential effect different staff levels should have on initial attack effectiveness and firefighter health. An actual wildland fire is fraught with uncertainty and complexity: managed landscapes, changing environmental conditions, staffing, and resources can all have an influence on the progression and suppression of a wildfire. Future research must focus on addressing these concerns.

Future Need

- Test Fire Training Research
- Actual Fire Event Tracking and Efficiency Evaluations
- Evaluations of Resource use in wildfires

LITERATURE CITED

1) Loeb, D.L. 1992. In the Beginning-Initial Attack, Part 1. Fire Chief.

2) National Interagency Fire Center. 2007. Fire information: Wildland fire statistics, 1960-2006). Boise, ID.

3) Rahn, M.E. 2009. Wildfire Impact Analysis: The 2003 Wildfires in Retrospect. San Diego State University.

4) McCarthy, G.J. and K.G.Tolhurst. 1998. Effectiveness of firefighting first attack operations by the Department of Natural Resources and Environment from 1991/92 - 1994/95. Research Report No.45. CFTT Orbost and Creswick Research Stations, Australia.

5) Federal Emergency Management Agency, United States Fire Administration, and National Fire Data Center. 2002. Firefighter Fatality Retrospective Study. April 2002/FA–220, Prepared by TriData Corporation.

6) National Institute of Standards and Technology. 2010. Report on residential fireground field experiments. NIST Technical Note 1661.

ACKNOWLEDGEMENTS

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San Diego State University - Santa Margarita Ecological Reserve

CDF Firefighters

CAL FIRE

Certain commercial equipment or materials may be identified in this document in order to describe the experiments conducted. This is not intended to endorse a particular kind of equipment, but to rather suggest options or materials that may be necessary, or improve wildfire response and efficiency.

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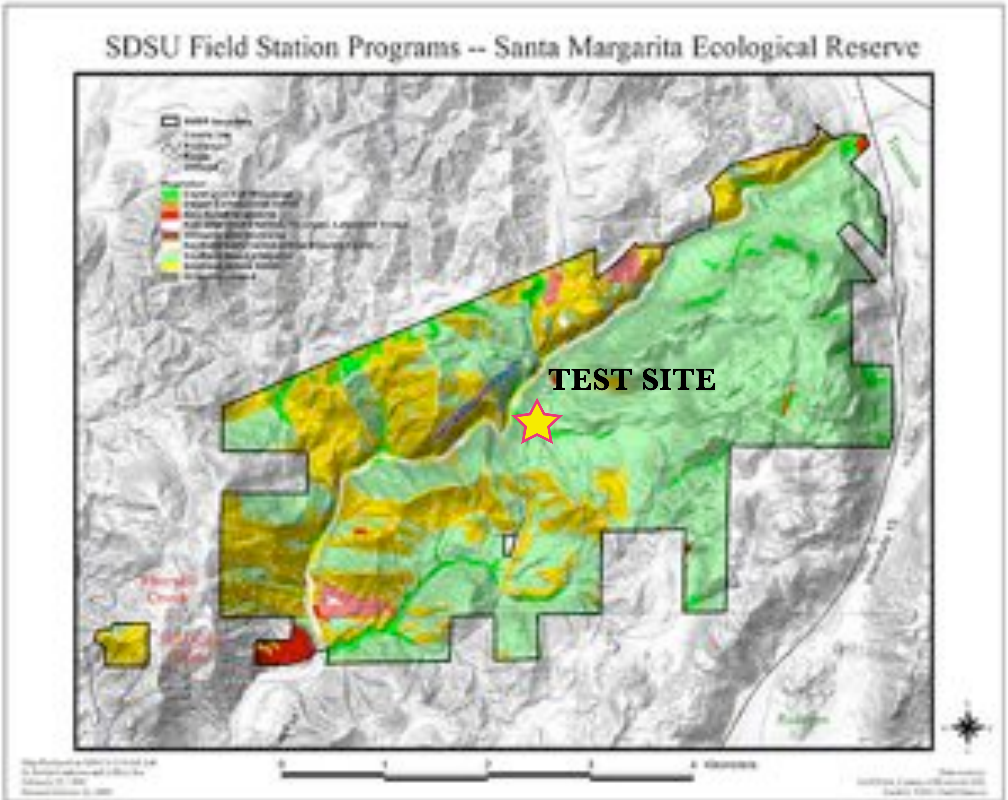
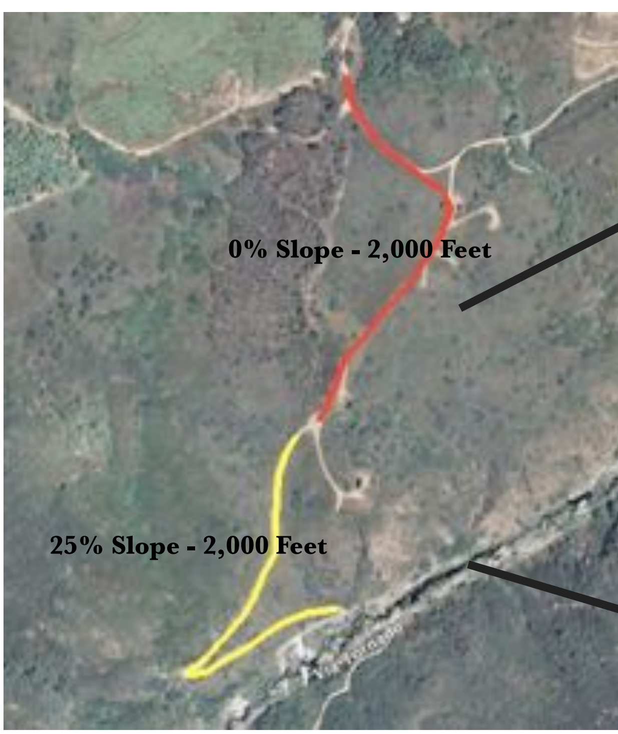
APPENDIX A
SANTA MARGARITA ECOLOGICAL RESERVE
STAFFING STUDY LOCATION





Appendix B
Summary Statistics

100 Foot Hose Segments - Average Time to Complete

0% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=8)	2.78	0.38
3-Person (n=7)	2.21	0.34
4-Person (n=8)	1.13	0.27
5-Person (n=7	1.06	0.28

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	16.283	3	5.428	52.558	0.000
Within Groups	2.685	26	0.103		
Total	18.968	29			

25% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=3)	3.88	0.24
3-Person (n=7)	2.71	0.43
4-Person (n=8)	1.46	0.31
5-Person (n=7	1.22	0.37

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	20.696	3	6.899	53.287	0.000
Within Groups	2.719	21	0.129		
Total	23.415	24			

1,000 Foot Simple Hose Lay - Average Time to Complete

0% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=8)	15.50	1.87
3-Person (n=7)	12.44	1.20
4-Person (n=8)	10.22	1.10
5-Person (n=7	9.45	0.60

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	170.186	3	56.729	33.714	0.000
Within Groups	43.748	26	1.683		
Total	213.934	29			

25% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=3)	24.26	1.27
3-Person (n=7)	14.40	1.40
4-Person (n=8)	11.43	1.21
5-Person (n=7	1.11	0.81

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	1294.371	3	431.457	310.602	0.000
Within Groups	29.171	21	1.389		
Total	1323.542	24			

Appendix B
Summary Statistics

2,000 Foot Simple Hose Lay - Average Time to Complete

0% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=8)	48.20	1.87
3-Person (n=7)	33.87	3.27
4-Person (n=8)	23.78	3.19
5-Person (n=7	21.44	1.16

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	3444.839	3	1148.280	177.771	0.000
Within Groups	167.942	26	6.459		
Total	3612.781	29			

25% Slope

Staff Level	Average Time (minutes)	Standard Deviation
2-Person (n=3)	77.63	2.82
3-Person (n=7)	39.30	4.27
4-Person (n=8)	28.70	2.38
5-Person (n=7	24.45	2.58

Analysis of Variance Results

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance
Between Groups	6632.483	3	2210.828	226.595	0.000
Within Groups	204.891	21	9.757		
Total	6837.374	24			

W I L D F I R E   I M P A C T   A N A L Y S I S :
2 0 0 3   W I L D F I R E S   I N   R E T R O S P E C T

Final Report

2009 CALIFORNIA WILDFIRE ECONOMIC STUDY

Wildfire Research Report No. 1

Spring 2009

SAN DIEGO STATE UNIVERSITY

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Wildfire Impact Analysis

CONTENTS

Introduction

California Wildfire History

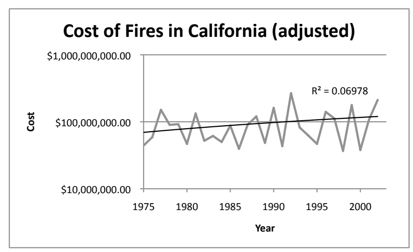
California is well known as a diverse state. It contains roughly 25% of the flora known from the continental United States, and has the highest level of species diversity in country[1]. There are more diverse landforms, climates, ecosystems, and species in this state than any other area of comparable size in the country[2]. This diversity comes at a cost; many of our ecosystems are driven by disturbance events, like the fire-adapted ecosystems of southern California.

With rapid population growth and increases in the demand for housing, the interface between the urban and wildlands has intensified in California. Maintaining the fragile balance between the natural and urban environment poses a significant challenge for residents and land managers. As a result of severe land use change, California has experienced significant increases in the frequency and intensity of wildfires. These fire events create a myriad of economic, social, and environmental impacts, with both long- and short-term implications.

Since the 1970's we have been experiencing a nationwide increase in fire intensity, rising from an average of three million to a staggering seven million acres burned each year, with further increases projected[3]. From 1975 to 2002, an average of 132,000 acres have burned in California annually. Unfortunately, this trend has been changing. Of the twenty largest documented fires in California's history, half of them have occurred since 2000. This startling trend has placed a considerable demand on emergency responders to limit the overall impact of wildfires.

Changes in fire frequency and intensity have been correlated with urban growth, drought conditions, non-native invasive plants, and climate change. Regardless of the cause, we are now faced with a significant challenge of managing risk and safety.

Despite the dramatic increase in fire frequency and intensity, the annual cost of fire suppression has remained relatively steady. From 1975 to 2002, the annual cost of fighting fires averaged $94.7 million (adjusted for inflation).



Annual fire suppression costs in California, 1975-2002 (adjusted for inflation)

Typically, the cost of a fire is reported as the total cost of suppression (staff, equipment, and supplies). However, these costs represent a mere fraction of the actual economic impact associated with many of our larger wildfires. The goal of this report is to evaluate the 2003 San Diego wildfires, and provide an estimate of the overall economic impact that wildfires have on our community, businesses, infrastructure, and natural areas. This report provides detailed insight into the costs and benefits of fire suppression, staffing, and resources. It also provides guidance for policy makers, and a model for future risk assessments and management decisions.

ASSESSMENT METHODS:

ASSESSING ECONOMIC IMPACTS FROM WILDFIRES IN SAN DIEGO COUNTY

Limited and dispersed information hinders the ability to conduct simple, and rapid economic assessments of wildfire impacts. The data collected in this report includes the basic information available and necessary to conduct a thorough economic impact analysis. Gaps in information and lack of suitable data are identified where appropriate.

Large wildfires cause dramatic ecological and economic impacts, warranting special attention and analysis. Typically, an economic assessment of wildfires focuses on only the more obvious variables, such as acreage burned and number of personnel, with often inadequate temporal and spatial perspectives. Historic reporting highlights suppression costs, federal assistance, or loss of structures. Unfortunately, this does not adequately capture the total economic impact from a wildfire event. The analysis provided herein attempts to rectify the disparity between suppression costs and the total economic impact from a wildfire.

Selecting Indicators for Economic Analysis

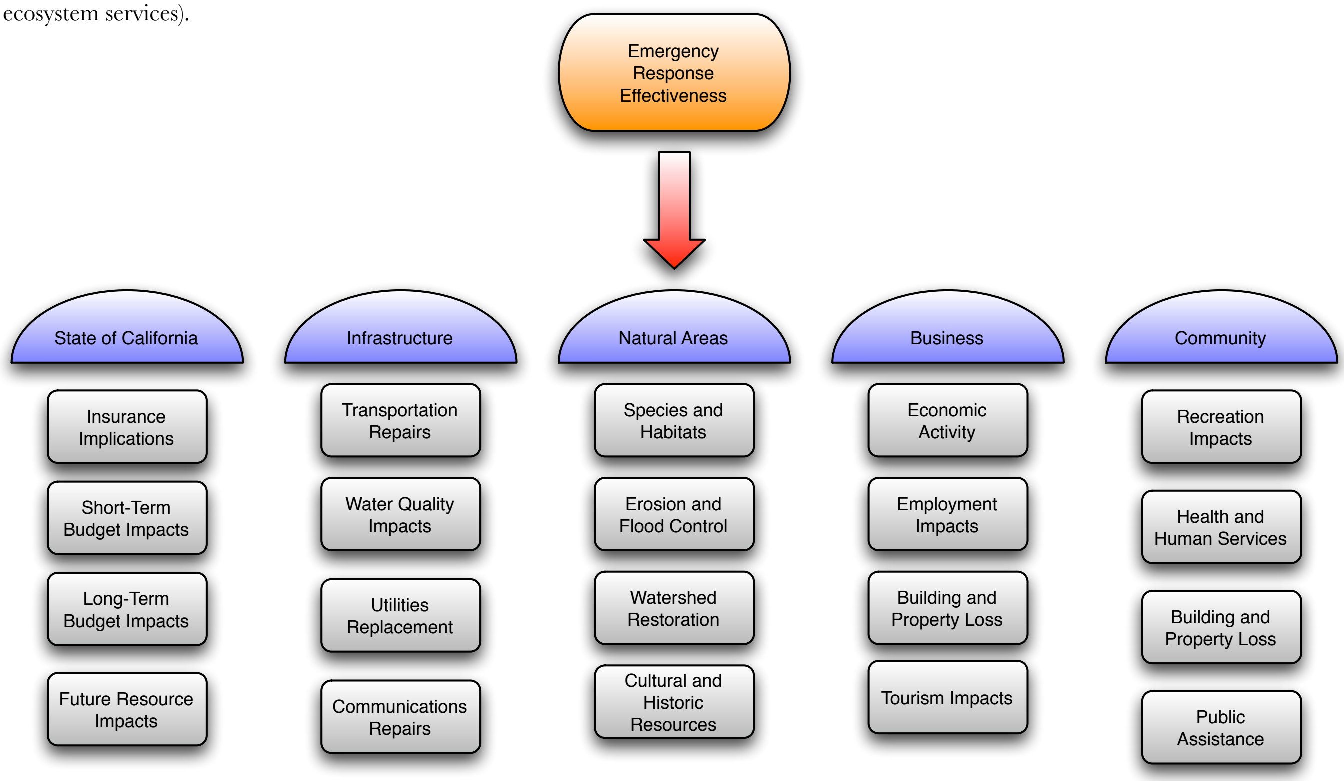
Framework for Data Collection

The first step in developing an economic impact analysis is selecting suitable indicators. These indicators will identify the chief categories of overall economic loss. We focused on five main areas of economic losses: state/agency, infrastructure, natural areas, businesses, and community. These five categories include both tangible items (loss of buildings) and intangible items (loss of ecosystem services).

Case Study of Economic Loss from Wildfires

San Diego County

Based on its recent history of severe and intense wildfires, it made immediate sense to conduct this economic analysis on the 2003 wildfires in San Diego County, with supplemental supporting information from the 2007 fire season. This report assesses data from federal, state, and local jurisdictions. The majority of the analysis is based on actual recorded economic losses published by the agencies and authorities within the region. However, a significant limitation to an economic analysis of this scale is access to suitable information and a lack of concrete data. Consequently, conservative estimates are provided for categories lacking actual data. While this report is comprehensive we recognize that not all information could be captured in this analysis. We ultimately provide recommendations for future wildfires to support the collection of adequate comprehensive information for improved economic impact analyses.



SAN DIEGO COUNTY

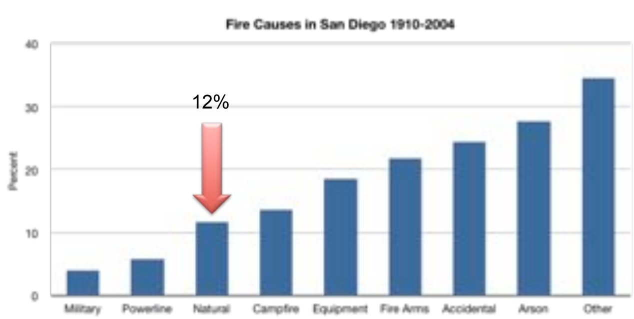
WILDFIRE HISTORY

Wildfires have been a significant part of the southern California landscape, helping shape our ecosystems.

The San Diego region is located in one of the top twenty biodiversity hotspots in the world, hosting many endemic and rare species. The County also hosts the highest number of federally listed endangered species in the United States.

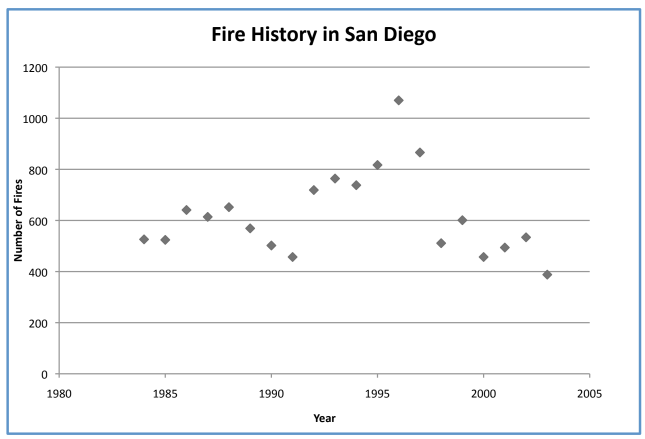
The uniqueness of the region poses a significant challenge in balancing urban growth and habitat conservation. This conflict is intensified by the urban-wildland interface, and increases in fire frequency and intensity.

Although San Diego County has experienced extraordinary urban growth, vast areas of land still contain native habitat, including grasslands, coastal sage scrub, chaparral, and forests. Much of this area is protected under regional multi-species habitat conservation plans, harboring some of the most sensitive and endangered species in the country. Historically, these ecosystems experienced periodic fires, likely caused by natural events (like lightening strikes). However, recent fire events have been intensified by human activity and growth. San Diego now experiences severe fire events caused by human vagary, accidents, and mismanagement. Only 12 percent of our fires in the past century were started by natural causes.



Causes of wildfires in San Diego County since 1910

While the total number of annual fires has fluctuated in the past 20 years, the San Diego region has been experiencing larger and more intense wildfires as evidenced by the fire events from 2003 and 2007. Predictions of climate change suggest that future temperatures, precipitation, and El Niño events may likely intensify the wildfire risk. Wildfire responders and land managers must be able to anticipate these changes and modify existing protocols and procedures accordingly.



Chaparral and coastal sage scrublands dominate much of the region. There is continuing debate whether such massive fires are natural but infrequent events or are a result of modern fire suppression and land management practices[4]. While the 2003 fires were unprecedented in their scale, they were not necessarily unique, and they were predicted to occur again. Unfortunately, consistent with the risk, just four years later and under similar conditions, San Diego experienced another devastating fire event in 2007. Many lessons were learned between these two fire seasons, and our understanding and response to wildfires in this environment has drastically improved.

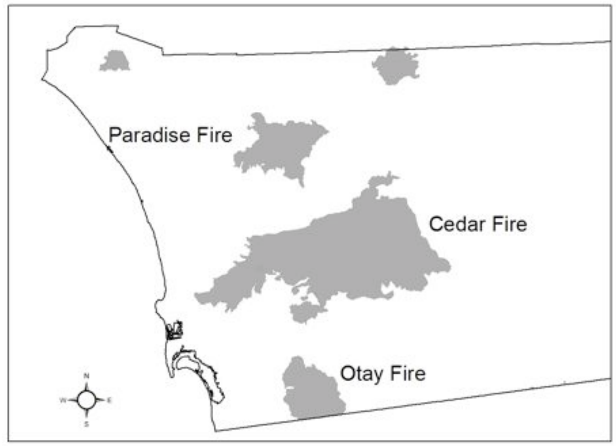
2003 WILDFIRES

SUMMARY REPORT

In late October of 2003, a series of wildfires began burning through the dense, dry brush and forest ecosystems of southern California. Fueled by drought conditions and Santa-Ana winds, the 2003 firestorm devastated southern California, becoming the largest fire in California's recorded history.

> *"Never in California's history were so many homes and lives in danger by fire at one moment. By the time the 14 major fires were extinguished; 24 lives were lost, 3,710 homes were destroyed and 750,043 acres were blackened."*
>
> *"California Fire Siege 2003: The Story"*

2003 San Diego Fire Map



Historically, the response to wildfires focused on establishing and defending a perimeter to control the fire. As the urban-wildland interface has increased, modern efforts are now focused on protecting our residential communities. In 2003, the unprecedented fire season pushed the limits of our capabilities, and showed us how vulnerable we really are. Three main fires were concurrently burning in San Diego County: Cedar, Paradise, and Otay.

Total Fire Impact

A total of 375, 917 acres were burned in San Diego County, 3,241 homes were lost, and sadly 16 people lost their lives, including one firefighter. At the peak of the fires, 6,635 crew were fighting the blazes.

Cedar Fire: October 25 - November 4

The Cedar Fire began at dusk on October 25th. It became the largest fire in California's history.

- Total Acres: **273,246**
- Suppression Cost: **$29,880,826**
- Firefighters at Peak: **4,275**
- Homes Lost: **2,232**
- Commercial Buildings Lost: **22**
- Other Buildings Lost: **566**
- Lives Lost: **14**
- Cause: **Human**

Paradise Fire: October 26 - November 4

The Paradise fire began on October 26. It was listed as the third highest priority during the fire siege.

- Total Acres: **56,700**
- Suppression Cost: **$13,000,000**
- Firefighters at Peak: **2,222**
- Homes Lost: **221**
- Commercial Buildings Lost: **2**
- Other Buildings Lost: **192**
- Lives Lost: **2**
- Cause: **Human**

Otay Fire: October 26 - October 28

The Otay Fire started the same day as the Paradise fire. Although this fire burned a substantial area, the total suppression cost and structures lost was minimal.

- Total Acres: **45,971**
- Suppression Cost: **$350,000**
- Firefighters at Peak: **138**
- Homes Lost: **1**
- Commercial Buildings Lost: **0**
- Other Buildings Lost: **5**
- Lives Lost: **0**
- Cause: **Undetermined**

ECONOMIC IMPACT ANALYSIS

FIVE INDICATORS OF FIRE IMPACTS:

As described by the figure on page 2, we selected five indicators of economic impact from wildfires:

- **state/agency**
- **infrastructure**
- **natural areas**
- **businesses**
- **community**

The impact analysis is based on actual data obtained from various agencies and conservative estimates from economic experts and organizations.

Economic Impact Analysis

Following major wildfire events, considerable scrutiny is placed on the agencies responsible for control and suppression. The focus is usually on the number of acres burned and homes lost. Often there is a rush to blame existing policy and procedures, and recommend changes to response protocol. Sadly, these hyper-critical, post-fire analyses focus on the wrong factors. To truly understand a fire event, it is crucial to provide a thorough review of the overall economic loss and the benefits and "saves" associated with fire protection.

An economic loss analysis for natural disasters is only as good as the quality and quantity of data used. The results are strongly influenced by the scope of the categories used in the evaluation, with a specific sensitivity to the spatial scale (geographic area), temporal scale (time span used to assess impacts), and sectoral scale (economic sectors included)[5].

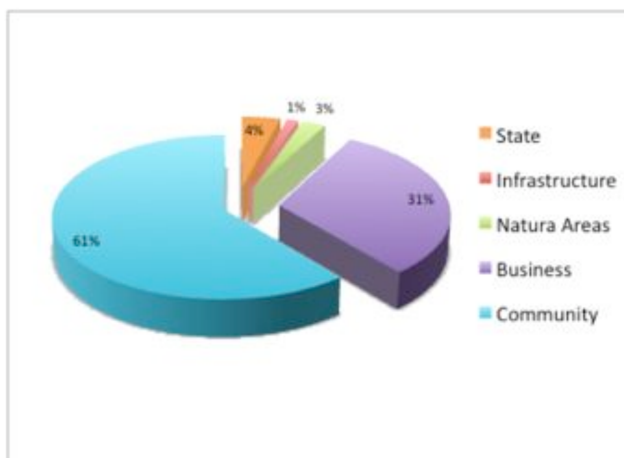
Certain losses caused by wildfires require additional research to ensure a consistent and reliable estimation of loss. Often, the types of data available are severely limited, and many key agencies and organizations have not yet considered undertaking a post-fire economic assessment. Also, many of the losses and impacts from certain sources take significant time to estimate, and may not be fully understood in a reasonable timeframe (e.g. water quality impacts and habitat restoration costs).

This assessment follows a global method of calculating the total costs, losses, and impacts of wildfires. The purpose of the assessment is to use the 2003 San Diego wildfires as a case study to provide a framework for developing a consistent and reliable method for assessing the economic impact from these disasters.

Summary Results

In the following sections, we discuss the indicators of costs and losses detailing the economic analysis conducted for each category, and the source of data and information used. This assessment corroborates other estimates provided in the media, agency reports, and at subsequent meetings and conferences[6,7]. However, this report is based on actual data and information to provide a more accurate, and justified estimate of the economic loss.

The total economic impact of the 2003 wildfires in San Diego County is estimated at **$2,450,016,476**. This equates to a cost of over **$6,500 per acre**. The total suppression costs amount to *less than* **2 percent** of the entire economic impact; a relatively negligible cost in contrast to the overall loss. A complete description of the economic loss is provided in subsequent sections, and summary table provided in Appendix A



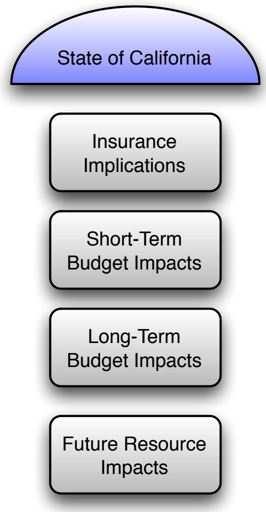
CALIFORNIA'S ECONOMIC IMPACT

AGENCY EXPENDITURES

The State of California is feeling the lingering impacts of a serious financial crisis that could be a decade long. However, our obligation to ensure public safety and land stewardship cannot be neglected. The social and economic losses would only exacerbate the problem

According to budget reports and committee analysis, CAL FIRE is threatened each year with cuts that will result in losses in personnel and infrastructure, spreading the remaining resources thin. For example, in 2008, the State cut $10 million from its fire service budget in Southern California. This forced the San Diego Unit Chief to cut 16 jobs, spreading the remaining resources even thinner.

> *"If we don't have resources ready to jump on these fires when they are small, we will have another major wildfire in the county,"*
> ***Supervisor Dianne Jacob***



Short-Term Budget Impacts

The short-term budget impact to the State includes the costs for fire suppression, staff, overtime, equipment, and supplies. This also incorporates the considerable costs of transportation and mobilization. The total cost of fire suppression was over $43 million, roughly 1.8% of the total economic loss estimated. The suppression estimates are typically very accurate in capturing the actual costs of this activity. In an economic analysis, this information is critical because it provides a perspective of how much is invested in staffing and equipment, and how even moderate increases in resources (in comparison to the total loss) can have a positive impact on the outcome of a fire event. Fortunately, this data is relatively easy to collect and has a high degree of consistency and reliability between fire events.

Long-Term Budget Impacts

Depending on the severity and location of a wildfire, post-disaster recovery can come with a considerable price. Factors that impact the budget in the long-term include watershed and water quality mitigation, sensitive species and habitat restoration, and loss of facilities and concomitant infrastructure. These data are typically not easily calculated or readily available.

Insurance Implications

The state often covers losses to infrastructure, facilities, and other resource obligations after a fire event. After the 2003 San Diego fires, the California Department of Transportation estimated their total loss at roughly $15 million. Furthermore, the total loss to San Diego Gas and Electric was a staggering $71.1 million loss in infrastructure. State tax-payers reimbursed the utility company more than half its total loss in a Catastrophic Event Memorandum Account (wildfire account), totaling $39.5 million.

Additional costs may be incurred by the state under unemployment insurance claims. While no report was provided for 2003, a comparative assessment was provided from the 2007 wildfires. The County of San Diego experienced 4,692 "fire-related" unemployment insurance claims, including 479 disaster related unemployment claims[8]. This loss is covered in greater detail below.

Future Resource Impacts

In response to large wildfires, the state often incurs additional costs in bond measures, local assistance grants, and investments in additional equipment or fire response staff. These costs are not well understood or estimated, but they are undoubtedly in the millions of dollars, and are felt in budgets as varied as our transportation and watershed protection funds. There's an old firefighters chestnut: "no matter where the fires are burning, all fires are local."

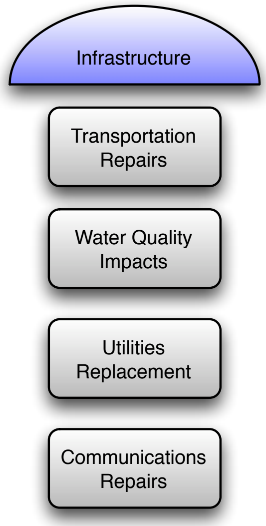
Total Economic Loss

The total economic loss to the State of California was estimated at nearly **$100 million**. This estimate is substantially lower than the total experienced by the state. For example, there were additional losses experienced by resource agencies (California Department of Fish and Game), local Universities (San Diego State University and UC San Diego), and other state agencies when they were closed during the peak fire event. Also, unemployment insurance costs (discussed below) could also be included in this section.

INFRASTRUCTURE ECONOMIC IMPACT

REPLACEMENT COSTS

Wildfires frequently damage our fragile infrastructure, including highways, communication facilities, power lines, and water delivery systems. Restoring basic services is a top priority, with many agencies and organizations incurring significant costs.



The 2003 wildfires resulted in daunting impacts to San Diego's infrastructure. Restoring these services post fire was critical to the recovery and restoration efforts. Fortunately, many of these costs have been well documented. The total economic loss to infrastructure was approximately **$147.3 million**. Some of these costs were included under the economic impact to the State of California (discussed above), and the economic impact to natural areas (discussed below).

Transportation Repairs

The California Department of Transportation incurred approximately $15 million in damage to existing infrastructure. This was the total cost of repair and rebuilding of the road and highway infrastructure under the purview of CalTrans. This effort included the cost of maintenance and damage assessment teams, field data collection, and replacement or repair of roads, guardrails, signage, electrical supply, culverts, landscaping, etc. This value tracks closely with the $17 million costs projected for the 2007 San Diego wildfire impacts.

The initial effort is focused primarily on safety concerns. Therefore, this cost estimate is fairly conservative, since it does not consider the long-term costs associated with restoring transportation to pre-fire conditions. For example, the long-term costs of habitat or landscaping restoration, erosion control, and maintenance of culverts (in response to inevitable mud slides and debris buildup).

Water Quality Impacts

Assessing water quality impacts is one of the most difficult components to calculate. Direct impacts to our municipal water supply occurred through contamination of ash and debris, and the flooding/mud slides that follow in the rainy season. Municipal water managers must address water supply impacts, and the potential substantial costs associated with changes in quantity and quality. Currently, data are not available to estimate this accurately.

However, while not exclusively used for water quality and infrastructure recovery, FEMA contributed $14 million in hazard mitigation efforts. Part of these funds were used to restore and protect sensitive habitat and watershed functioning (discussed below).

Utilities Replacement

Approximately 3,200 power poles, 400 miles of wire, 400 transformers and more than 100 other pieces of related equipment were damaged by the fire and needed to be replaced by San Diego Gas and Electric. In total, SDG&E spent $71.1 million to replace lost equipment and restore services. Every tax payer felt the squeeze, since approximately 55.6 percent of this loss was reimbursed by the State of California.

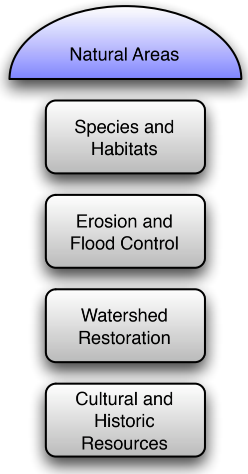
Communications Repairs

Given the diversity of communication carriers, and vast infrastructure associated with digital, wireless, and hard-line communication, estimates were difficult to obtain. This estimate does not include the total loss associated with communication infrastructure losses, including cell phone towers, communication relay stations, cable lines, phone lines, and poles. This loss was not adequately measured in 2003, but based on discussions with several prominent companies we can conservatively estimate the loss at several million dollars county-wide.

NATURAL AREAS ECONOMIC IMPACT

SPECIES, HABITATS, AND ECOSYSTEM SERVICES

A considerable ongoing research effort has been focused on appropriate and effective fire management practices, balancing the multitude of concerns such as endangered species, invasive species, defensible space, and fuel reductions. Despite our best intentions to manage our ecosystems, current and historic practices may both improve and worsen the risk of fire and the economic impacts.



Southern California's fire-adapted ecosystem has a well-documented history of large, catastrophic fires, yet integrating this risk into regional management strategies had not generally occurred prior to the fires in 2003. Pre- and post-disaster planning should aim to decrease the chances of catastrophes occurring while increasing the chances of maintaining the environment and enhancing post-catastrophe recovery.

The San Diego fires and their aftermath dramatically illustrate the need for change in natural lands management. Management must explicitly take into account the probability, direct and indirect impacts, and potential cumulative effects of stochastic (random) environmental events, anthropogenic (man-made) disasters, non-native species, disease, and other threats. Exotic invasive plants represent the main threat to post-fire succession; many non-native grasses, such as rye grass, reduce native species diversity and biomass. Furthermore, rapid establishment of exotic species promotes more frequent fires, resulting in conversion of chaparral shrublands into exotic grasslands.

Just as emergency services have learned how to better protect human life and resources with well-planned responses, land managers can also plan ahead to better conserve natural resources in the face of catastrophes. In general, disaster planning for natural systems should include strategies that: 1) minimize the risk of catastrophic events; 2) increase the chance of surviving a catastrophe; and 3) enhancing post-catastrophe recovery. Responses to catastrophes should focus on maintaining population viability, community structure, and ecological processes.

Unfortunately, this is probably the poorest documented economic impact, but it may actually represent one of the largest economic losses in wildfire events. Including these damage and restoration estimates is problematic due to questionable methods in creating models and high variability in their assumptions. A thorough assessment requires both estimates of the impacts on ecosystem structure and function, an estimate of the loss in ecosystem services, and the cost for restoration.

Species and Habitats

The question of who is responsible for financing and implementing post-catastrophe management was uncertain. The two multiple species habitat conservation plans include take permits for approximately 100 species. This makes the San Diego fires perhaps one of the most complex financial and legal issues for a conservation program to address after a catastrophe. No suitable estimates were available for this category.

Erosion and Flood Control

FEMA provided $47,183,333 in watershed restoration funding, and $14 million in hazard mitigation efforts. Portions of these funds were used to restore habitat and control the potential impact of erosion and floods in the following winter. It will never be clear how much funding private landowners, tribes, and municipal entities spent on erosion and flood control measures, but we know this expenditure is extraordinary.

Watershed Restoration

The County of San Diego reported the estimated total cost for fuels treatment in the three most impacted areas at $1.1 billion, with $250 million needed to reduce fuels along roads and in parks alone[9]. To date, we have confirmed only $47,183,333 allocated, coming from three US Department of Agriculture Programs providing the County with $39.575 million, with matching funds from the County ($5 million) and SDG&E ($2,608,333). These funds have been used for restoration and post-fire fuel treatment.

While not adequately understood or supported, a loss of ecosystem services could potentially be included in the total economic loss (though not included in this report). An estimate of increased storm water runoff containment and air pollution reductions by vegetation (formerly taken care of through natural processes) were $25,349,000 and $798,000 respectively[10].

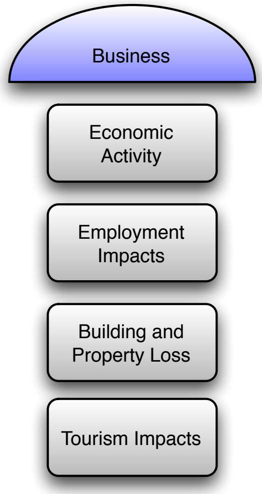
Cultural and Historic Resources

The San Diego region is rich in diverse cultural and historic resources. Unfortunately, no records or an assessment of economic losses associated with these resources has been completed.

BUSINESS ECONOMIC IMPACT

DELAY, PRODUCTIVITY, AND LOSS

San Diego's economy was once dominated by the military (now the city's second largest economic sector). Manufacturing, technology and trade are now the major industries. In 2002, manufacturing contributed $25 billion to the county's economy, with international trade accounting for 37 percent this value. In 2001, goods moving through San Diego customs totaled $33.6 billion, with the border between San Diego and Tijuana being the busiest in the world.



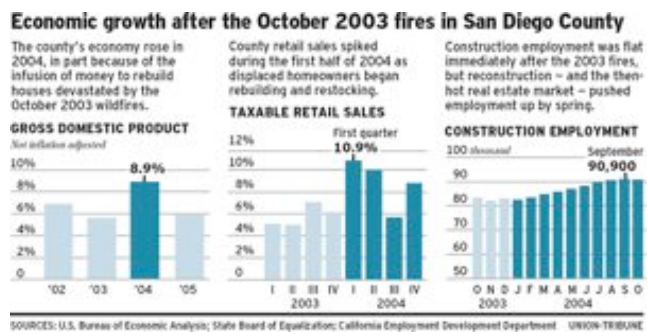
Determining the total economic loss and impact of the wildfires to the region is challenging. While many of the local businesses experienced impacts to facilities, shipping delays, and employee productivity, few of them actually estimated this loss. Without this information, we relied on economic indicators and estimations. For example, Qualcomm, a leader in San Diego's high tech industry, remained open for business during the wildfires, but incurred costs from replacing air filters, and maintaining equipment. Similarly, the military experienced not only a loss in activity, but also a loss of habitat and infrastructure at Miramar. Although this value was not tracked during the 2003 wildfires, the Navy estimated a total economic loss of $1.5 million during the 2007 wildfires.

Economic Activity

The lost economic activity in the San Diego Region was calculated by dividing San Diego's estimates 2003 Gross Metropolitan Product (GMP) of $133.4 billion by one day or $365.5 million. This loss is based on a ten-day long fire siege, and a conservative estimated loss of 10% in gross productivity, manufacturing, employees not working, and curtailed spending. Other losses captured by this estimate include impacts to shipping and distribution, tax revenue, and air transportation (Greater San Diego Chamber of Commerce).

For example, the wildfires led to nine separate airlines experiencing significant economic and operational impacts: 47 cancelled flights and 37 flight delays occurred as a result of decreased visibility on October 26, 2003. As a comparison, the San Diego Institute for Policy Research used similar (but more liberal) methods in estimating the loss in economic productivity during the 2007 wildfires ($893 million). While some of this economic loss can be (and probably was) recouped in later months, lost productivity and missed opportunity costs cannot be recovered.

Even though there may be economic growth after large wildfire events, this is still considered an overall loss; the boost in the economy is not a result of true economic growth, but rather a response to large-scale economic and infrastructure losses.



Employment Impacts

As stated above, business and the State may incur additional losses under unemployment insurance claims. While no report was provided for 2003, in 2007, the County of San Diego experienced 4,692 "fire-related" unemployment insurance claims. The 2007 "preliminary potential fire-affected loss of employment and wages" for San Diego County exceeded $400 million[11]. Equivalent losses are expected from the more devastating fires in 2003. In the future, it is vital to capture accurate data for this economic loss.

Building and Property Loss

A total of 24 commercial buildings were lost during the fire events, along with significant stocks of materials, merchandise, and equipment. Unfortunately, this total economic loss was not directly calculated for the 2003 events, but was likely in the millions of dollars.

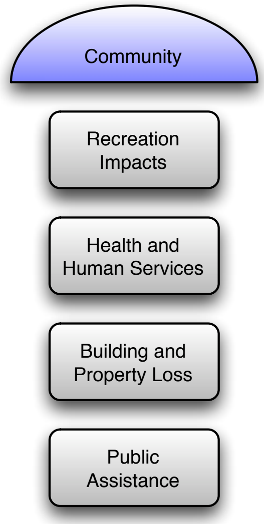
Tourism Impacts

According to the San Diego Convention and Visitors Bureau, visitor spending dropped by $32.5 million in comparison to the month of November, and decreased by 1.3% in comparison to 2002 statistics (or a decrease in approximately $4.4 million). While neither of these values accurately captures the true decrease in visitor spending, there is no doubt that the wildfires had an economic impact. Similarly, the San Diego County "Index of Visitor Activity" showed a 1.4% decrease in October 2003, and a total decrease of 8.7% when compared to the same period for 2002.

COMMUNITY ECONOMIC IMPACT

LIVES, HEALTH, HOMES, AND QUALITY OF LIFE

The San Diego region was devastated by the 2003 wildfires. The extreme loss of homes and employment is the largest loss of the five economic indicators.



Recreation Impacts

Short- and long-term impacts netted by recreational activity are challenging to quantify. Closures of areas often eliminate recreational activity, while interest in post-fire impacts on the wildlands may actually attract new visitors. Mission Trails Regional Park lost 2,800 acres to the wildfires. Large portions of the Park were closed to the public, to minimize further disturbance, and allow natural succession and species responses to occur. During that time, Park staff and volunteers worked on clearing the park of dead animals, hazardous debris, and installing erosion control measures. By April, 2004, majority of the Park was open to the public, but some areas are still considered extremely sensitive, even six years later. Similar stories can be told for many of the other recreational areas impacted by the fires.

Health and Human Services

It is impossible to place a value on the loss of human life. Tragically 16 lives were lost in the wildfires, including one firefighter. It is however possible to calculate the economic impact from injuries and health impacts from the wildfires.

Donations received by the Red Cross increased by 200% over the previous year's activity, receiving $7.5 million earmarked for post-disaster support. A force of 4,500 volunteers and 100 paid staff established 12 shelters across San Diego and Imperial Counties to care for over 6,000 people displaced by the wildfires. The Red Cross provided 122,034 meals, cots and blankets, comfort kits, baby supplies, and counseling.

Concrete data are not available for estimating total health impacts from wildfire programs, but it has been estimated at over $10 million. The Council of Community Clinics reported that clinics outside the fire area experienced losses up to $20,000, while those providing more extensive services reported losses up to $35,000. Those clinics directly impacted by the fires reported maximum losses of over $80,000. These losses included personnel, overtime, supplies, equipment, and lost revenue from regular patient visits[12]. A similar report was provided for the 2007 wildfires, estimating the total loss at $1.5 million.

During the Cedar Fire in 2003, hospitals experienced significantly higher than average numbers of complaints for illnesses plausibly associated with exposure to fire or smoke such as asthma, burns, and respiratory distress. There was also an increase in potentially related complaints such as altered neurological function, cardiac-related chest pain, and palpitations (County of San Diego HHSA, EMS QA Net MICN records, 2003).

Buildings and Property Loss

The Insurance Service Organization (ISO) gathers data from all insurance companies. The ISO estimated the total insurance settlements for the Cedar Fire at $1.06 billion. This single fire destroyed 2,232 residential buildings. Using the same formula for the Paradise fire (average settlements of $474,910), San Diego County experienced a potential total insurance settlement of $1.165 billion. This estimate correlates with similar loss estimates from late 2003 as reported by city and county officials (before all insurance settlements were settled), and the estimates from the losses in 2007 (projected at $1.1 billion; San Diego Institute for Policy Research).

Private Assistance

In response to the 2003 wildfires, charity donations and grant funding surged. The San Diego Foundation is San Diego's leading resource for information on charitable giving and community needs, managing $3,273,560 in donations and grants. FEMA assistance provided financial relief for individuals and households ($32.9 million), supplemental assistance ($1.4 million), disaster loans ($170 million), and public assistance ($103.2 million).

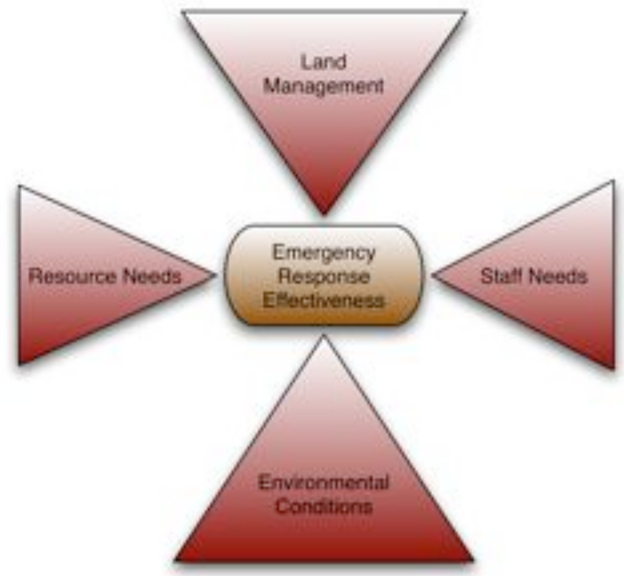
CONCLUSIONS

MAKING A DIFFERENCE

The focus of this study has been on documenting the staggering losses that occur in California every year due to major wildfire events.

The 2003 San Diego wildfire event was a staggering $2.45 billion economic loss. Suppression costs were only 1.8%, with the vast majority of the loss borne by the taxpayers and citizens of California.

"The term 'wildland fire' has become a misnomer for most of California... Top priority has been shifted to the protection of the millions of citizens who have moved to the wildland/urban interface"[13]



As increasing development, urbanization, climate change, and invasive species alter the landscape of California, we will certainly experience more extreme fire events. A true accounting of the economic impact and loss due to wildfires is an important tool for resource and regulatory agencies. This can help plan for future fire events, identify key areas for protection, and highlight areas for reducing economic impacts.

There are four main factors that influence the outcome of a wildfire: land management, environmental conditions, resource needs, and staff needs. Emergency response effectiveness is influenced by the existing land management practices. Stewardship and sustainable management of our natural areas requires a delicate balance between protecting our community and the natural ecosystems in our backyards. It was estimated that the total cost of fuel reduction for San Diego County is $1.1 billion. This is a significant and potentially insurmountable investment. The second factor involved in emergency response effectiveness is environmental conditions. Unfortunately, there is not much that can be done to manage drought conditions, electrical storms, or Santa-Ana winds. Under extreme weather events, these factors can significantly influence the outcome of a wildfire.

Finally, emergency response effectiveness is strongly influenced by the availability of adequate resources (engines, aircraft, equipment, and supplies). It is also influenced by adequate staffing levels and the number (and location) of fire stations.

Reducing the total acreage lost in a wildfire is strongly correlated with reducing the overall economic loss. Increasing resources and staffing can successfully accomplish this objective. For example, CAL FIRE has done comparative studies on staffing, measuring efficiency and effectiveness[14]. By increasing an engine crew from 3 to 4 staff, the efficiency in laying 1,200 feet of hose increased by 41% (or 8.5 minutes). Likewise, increasing staffing to 4 persons per engine resulted in substantial savings in the state's emergency fund (estimated at $41 million per year as compared to previous staffing levels of 3 persons). These same staffing levels also accounted for an increase in the total number of fires that were held to less then ten acres (1.7% and 3.9% increase in 2001 and 2002 respectively).

The benefits of increasing the number of firefighters on a single engine cannot be overstated. For example, if a fire takes 12 personnel to fight it, this can be achieved by only sending three engines to the scene, rather than four, leaving behind one engine and enough resources to stay and protect the local area. During the 2003 wildfire events, 100% of the CAL FIRE staff for San Diego County were committed to the incident. However, over two-thirds of **all** statewide CAL FIRE resources were pulled into southern California, leaving some regions at risk. For example, the Humboldt-Del Norte and Lassen-Modoc districts committed 100% of their resources to assist southern California, leaving their areas at risk. On average, only one third of the state had any remaining staff during the 2003 fire siege. This is a necessary, yet risky solution to responding to large wildfire events. Increasing staffing and resources would significantly decrease this risk.

Emergency Response Effectiveness

The proposed annual budget for fire protection by CAL FIRE for the 2009-2010 fiscal year is $103,484,500, which is less than **1 percent** of the total state budget (and only **4% of the total economic loss of the 2003 San Diego County wildfires**). The benefits of a well-funded and staffed fire agency cannot be overstated. The ability to control wildfires can significantly reduce the resulting financial burden to the state of California. Additional staffing, training, and equipment, can lead to significant reductions in the total fire perimeter, resulting in dramatic reductions in the overall economic impact.

If the emergency response effectiveness was aided by additional staffing, even moderate reductions in the total fire perimeters of **1%** would have led to a predicted savings of **$24.6 million**, while a reduction of **10%** would have saved **$245 million**.

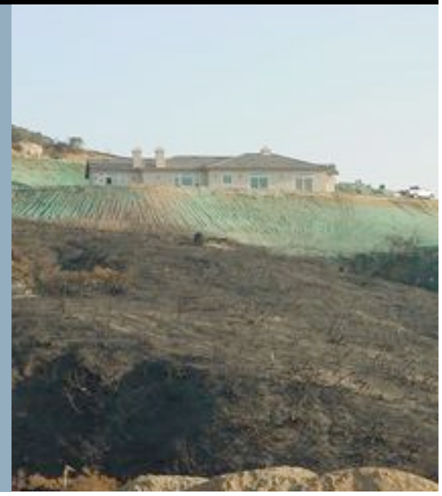
Percent Reduction	Revised Costs	Costs Savings
1%	$2,425,352,578	$24,663,898
5%	$2,327,358,535	$122,657,941
10%	$2,204,865,980	$245,150,496
25%	$1,837,388,317	$612,628,159
50%	$1,224,925,545	$1,225,090,932
75%	$612,462,772	$1,837,553,704

The unfortunate reduction in staffing levels due to the budget crisis will be the first since CAL FIRE began funding 10 three-person fire engines year-round in San Diego County following the devastating 2003 wildfires. Alarmingly, the County is still experiencing a severe drought conditions, increasing the risk of future wildfires, as evidenced by the 2009 Santa Barbara fires.

RECOMMENDATIONS

IMPROVING THE FUTURE

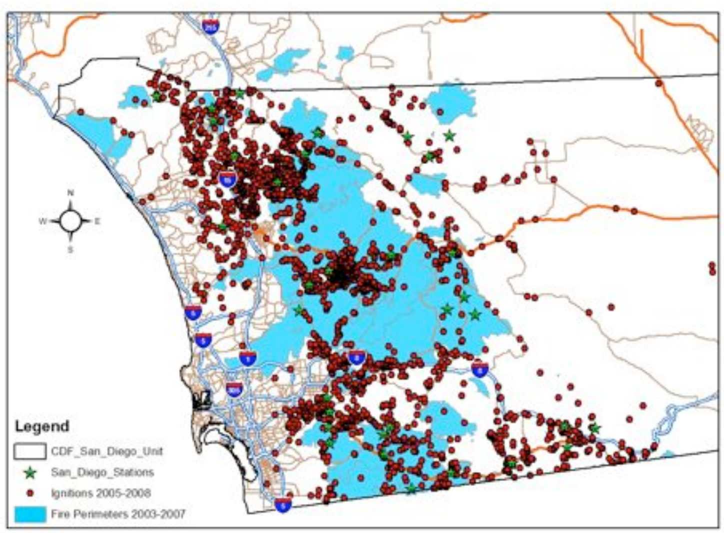
The focus on economic losses highlights the regional impact that wildfires can have. The impacts can span vast temporal and spatial scales, and the estimate provided may have still grossly underestimated the actual impact. Standardizing data collection, improving cooperation, and communication can lead to improved assessments in the future.



The focus on economic losses highlights the statewide impact that wildfires can have. The impacts can span vast temporal and spatial scales, and the estimates provided may have still grossly underestimated the actual economic impact. By standardizing data collection, improving cooperation, and increasing communication, we can improve assessments and effectiveness in the future. This report is limited to the data available, and our ability to create conservative and valid estimates of loss (in the absence of actual data). As we begin to ponder the future of data collection and economic impact analyses, we acknowledge that there are many more categories that we have not included, instead focusing on the largest and most obvious impacted areas. The following recommendations are intended to improve this process in the future:

- Conduct future economic assessments promptly, to avoid loss of data or institutional memory
- Develop a rigorous, statistically valid, and standardized protocol for future assessments
- Create a GIS based platform for data collection in the field, with an integrated GIS platform and mobile capabilities
- Establish a coordinator during and after major wildfires, to oversee reliable and accurate data collection
- Develop a protocol for estimating the economic "saves" associated with fire suppression, to document the annual value and benefit of firefighting services statewide
- Establish communication and data sharing with insurance companies, to insure accurate data collection
- Conduct research on the impacts associated with wildfires on natural areas, sensitive species/habitats, watersheds and losses in ecosystem services
- Review location of stations in relation to ignition points and fire perimeter maps to ensure adequate placement and volume of fire stations.
- Develop a strategy for assessing impacts to cultural and historic resources
- Review and improve reserve design and management strategies to effectively prepare natural systems for a catastrophe
- Ensure proper staffing and resource needs to ensure effective response and control for wildfires
- Evaluate the number and location of fire stations in relation to existing wildlands, ignition sites, and fire risk.

San Diego Fire Map



APPENDIX A.

Economic Impact Analysis Preliminary Results

Cost Type	Total Estimated Cost	Cost Per acre	Percent of Total
Fire Supression and Emergency Response	$43,230,826	$115	1.8%
CalTrans	$15,000,000	$40	0.6%
San Diego Gas and Electric	$71,100,000	$189	2.9%
FEMA - Hazard Mitigation	$14,000,000	$37	0.6%
Watershed Protection	$47,183,333	$126	1.9%
Estimate of Lost Business Economic Activity	$365,500,000	$972	14.9%
Unenployment Insurance	$400,000,000	$1,064	16.3%
FEMA - Disaster Loans	$170,000,000	$452	6.9%
FEMA - Individuals and Households Program	$32,900,000	$88	1.3%
FEMA - Supplemental Assistance	$1,400,000	$4	0.1%
FEMA - Public Assistance	$103,200,000	$275	4.2%
Foundation/Grant Programs	$3,273,560	$9	0.1%
American Red Cross	$7,500,000	$20	0.3%
Home, Business and Property Loss	$1,164,955,197	$3,099	47.5%
Medical Costs	$10,773,560	$29	0.4%
TOTAL	**$2,450,016,476**		

Appendix B

Literature Cited

1) Davis et al. 1998. The California Gap Analysis Project, final report. University of California, Santa Barbara, California.

2) Holland, V. and D. Keil. 1995. California vegetation. Hendall/Hunt, Dubuque, Iowa.

3) National Interagency Fire Center. 2007. Fire information: Wildland fire statistics, 1960-2006). Boise, ID.

4) Keeley, J.E., C.J. Fotheringham, and M.A. Moritz. 2004. Lessons from the October 2003 wildfires in southern California. Journal of Forestry. Oct/Nov 2004.

5) Thomas P. Holmes, T.P., J. P. Prestemon, and K. L. Abt. 2008. *in T. P. Holmes et al. (eds.), The economics of forest disturbances: Wildfires, storms, and invasive species, pg.* 151–166. Springer Science, Netherlands.

6) Dunn, A.E. 2003. The Old, Grand Prix, and Padua Wildfires; How much did these fires really cost? USDA Forest Service, Pacific Southwest Research Station, Riverside, CA.

7) California Board of Forestry and Fire Protection. 2008. California wildfires: Policy implications of research findings. Workshop May 8, Sacramento, CA.

8) California Employment Development Department. 2007. The economic impact of the October 2007 southern California wildfires. Employment Development Department, Labor Market Information Division.

9) County of San Diego. 2004. Fire safety and fuels reduction program. June 22.

10) American Forests (2006). San Diego urban ecosystem analysis after the Cedar Fire. American Forest, P. O. Box 2000, Washington, DC 20013.

11) California Office of Emergency Services. 2007. The economic impact of the October 2007 southern California wildfires. California Employment Development Department, Labor Market Information Division. December 2007.

12) Council of Community Clinics. 2003. Community health center services and needs related to the October 2003 San Diego County firestorm. November 10, 2003.

13) California Fire Seige 2003: The Story. October 21-November 4, 2003.

14)Hale, Ken, and O'Meara, Kevin. CDF Firefighters. 2004. Engine Staffing Analysis for California Department of Forestry and Fire Protection.

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I would like to thank Curtis Brown and Tom O'Keefe of CDF Firefighters for their valuable information and insights provided for this project. I would also like to thank Terry McHale and Tom D'Agostino of Aaron Read and Associates for the information and advise on this project.

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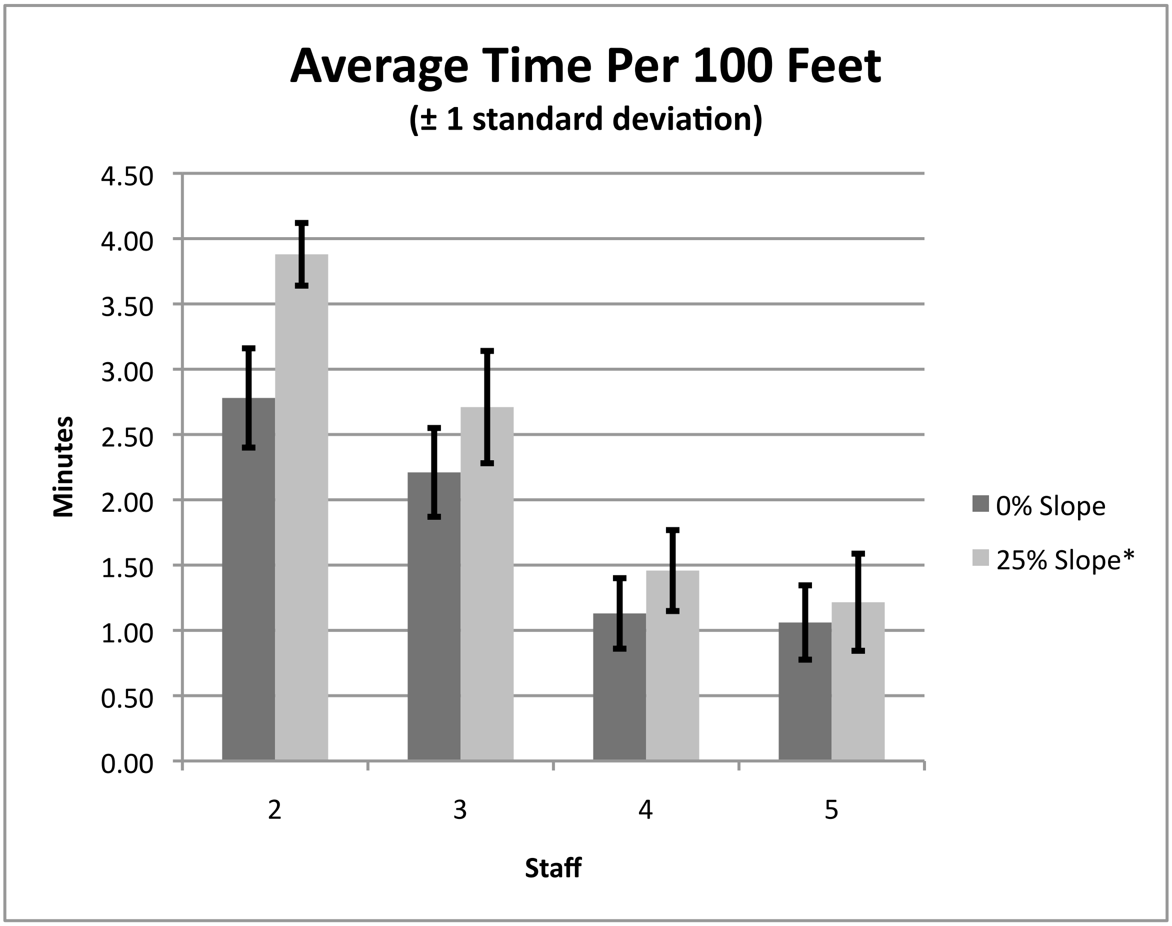
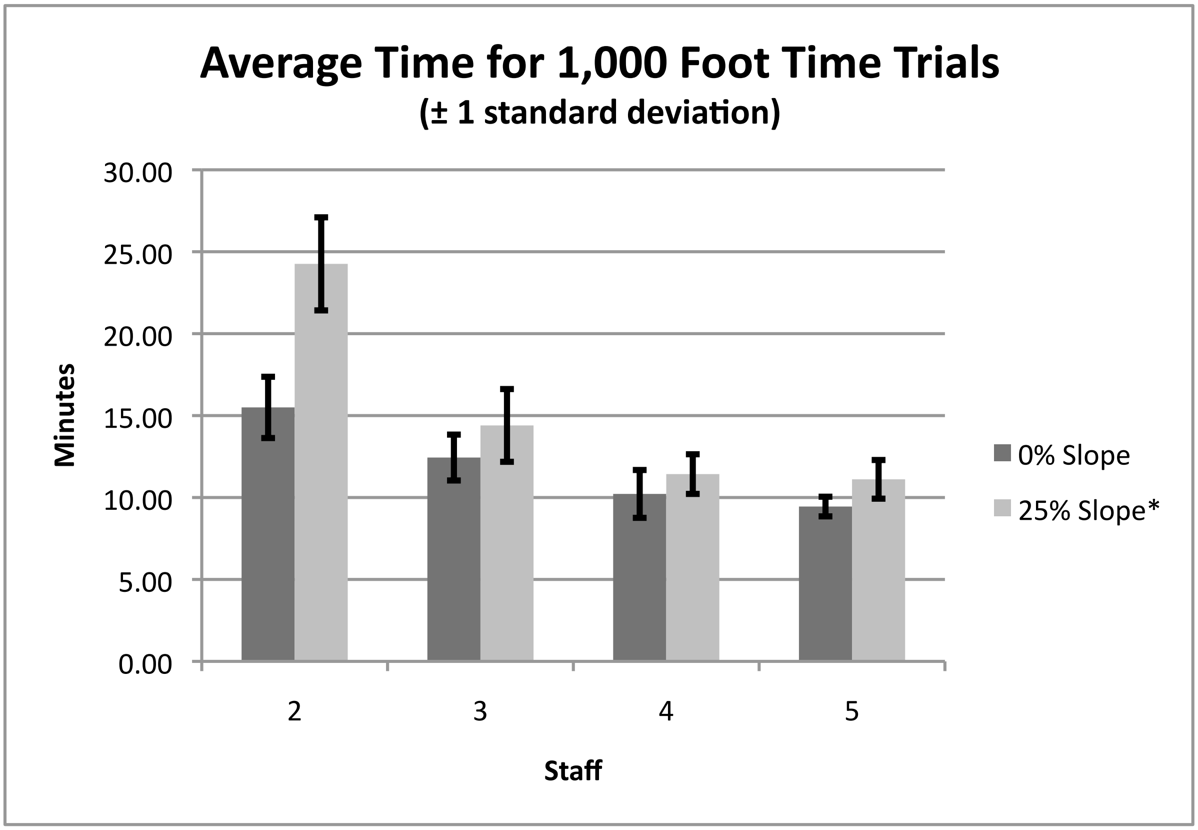
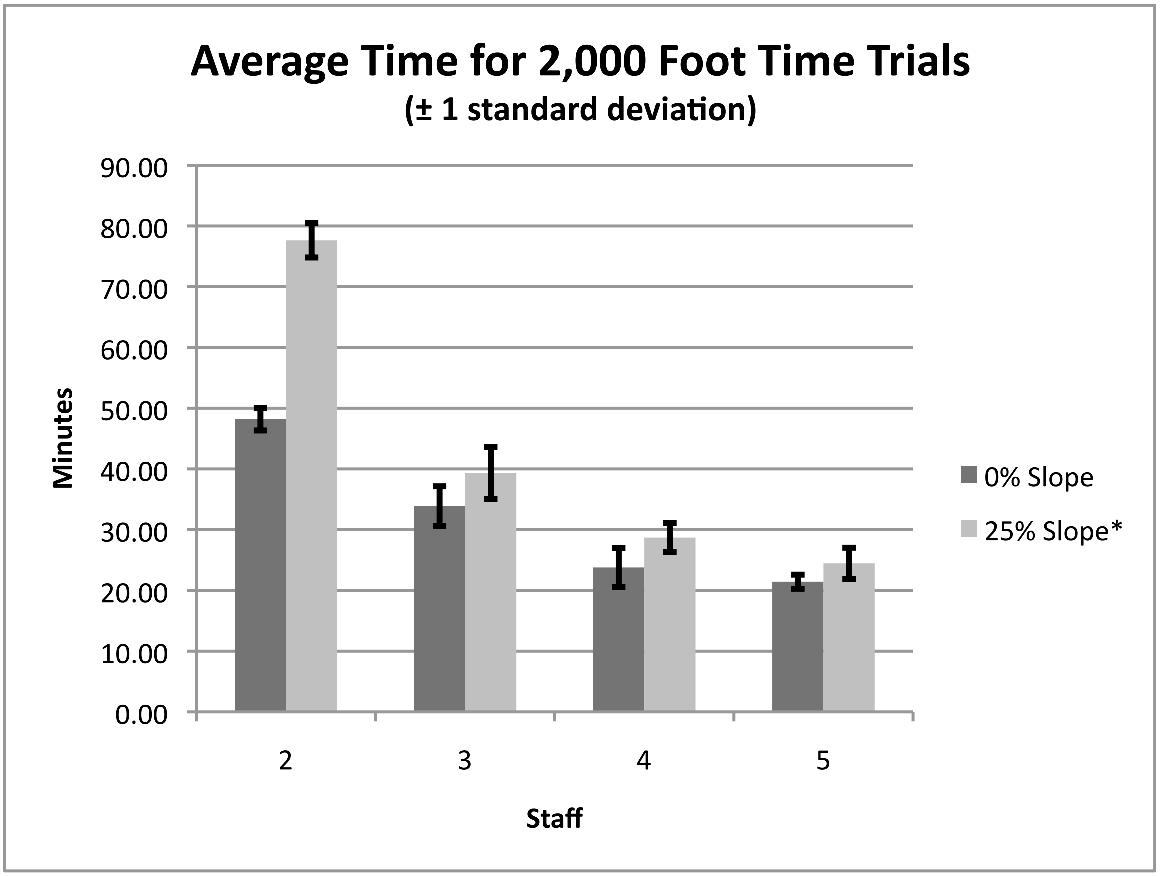
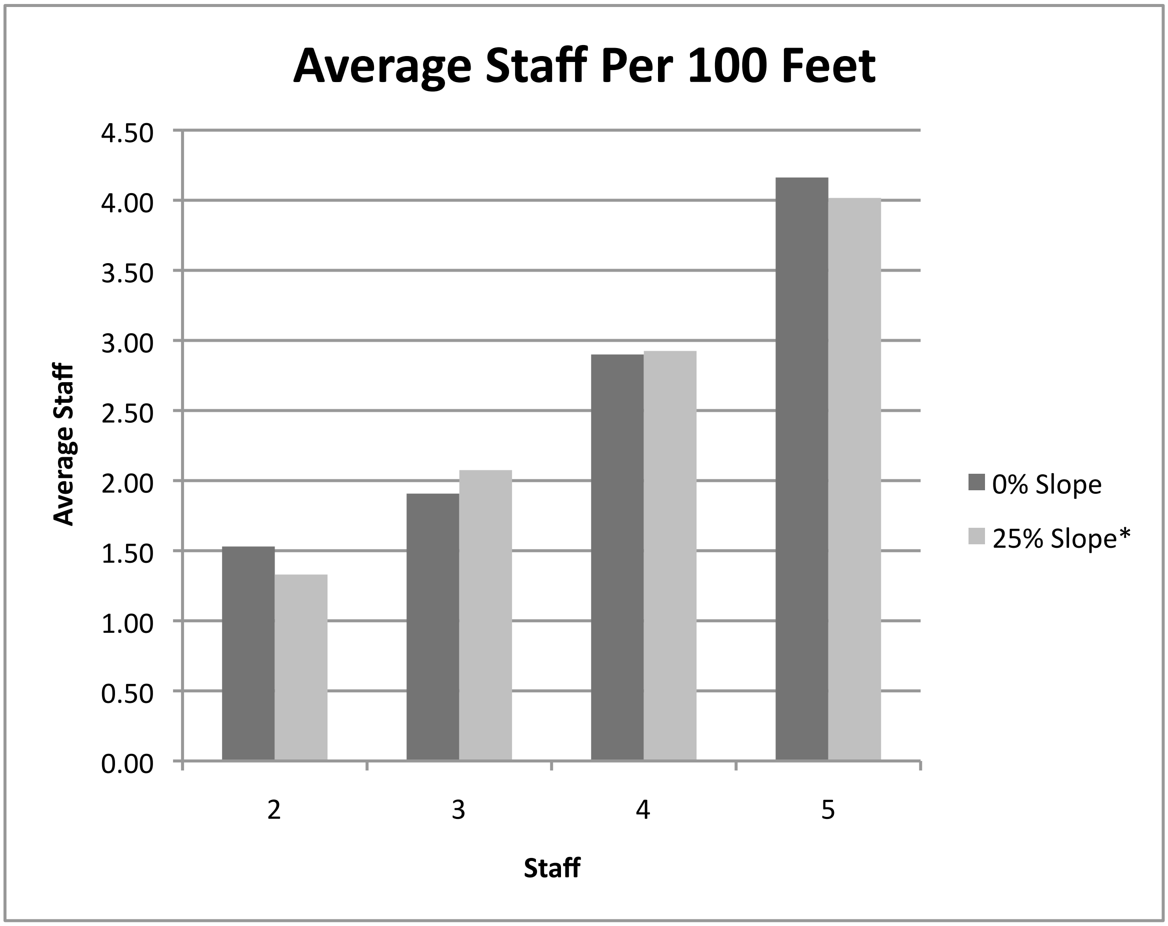
FIGURES AND TABLES

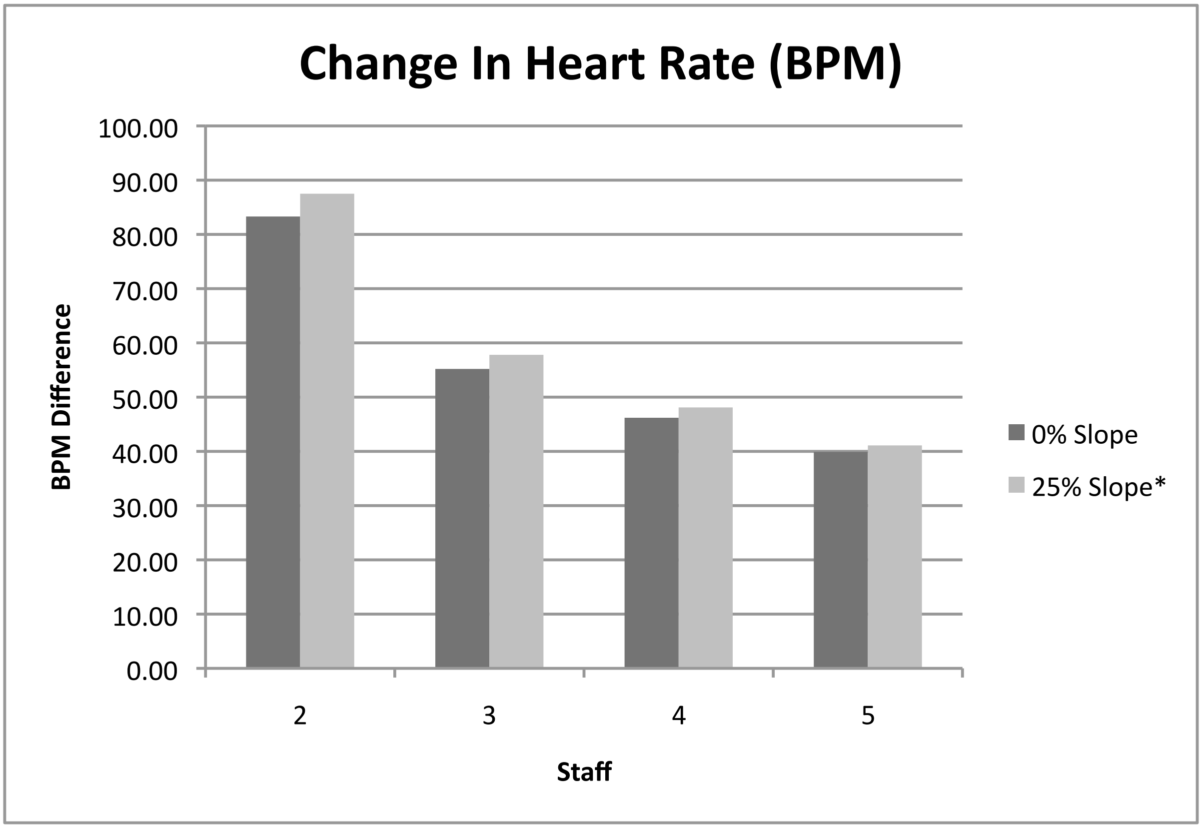

Average Time Per 100 Feet
(± 1 standard deviation)
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Minutes
2
3
4
5
Staff
0% Slope
25% Slope*

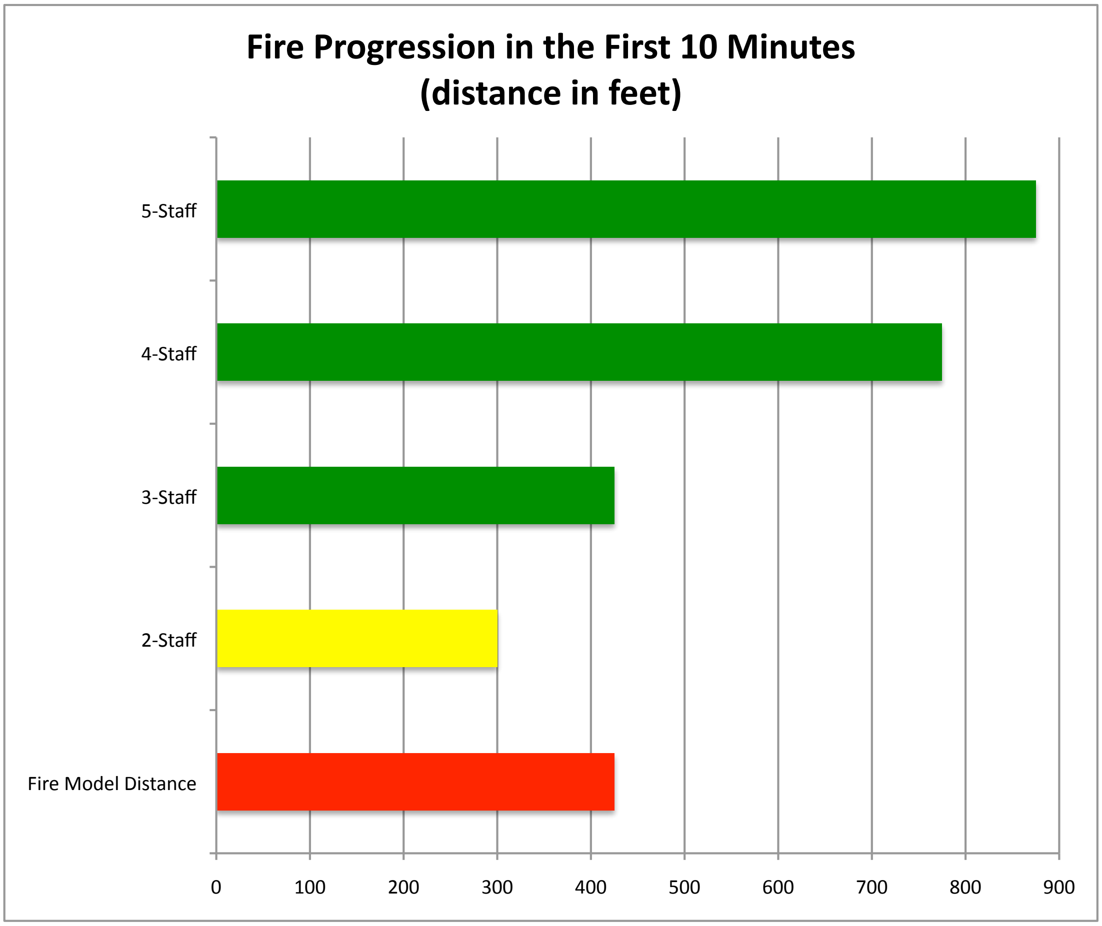

Average Time for 1,000 Foot Time Trials
(± 1 standard deviation)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Minutes
2
3
4
5
Staff
0% Slope
25% Slope*

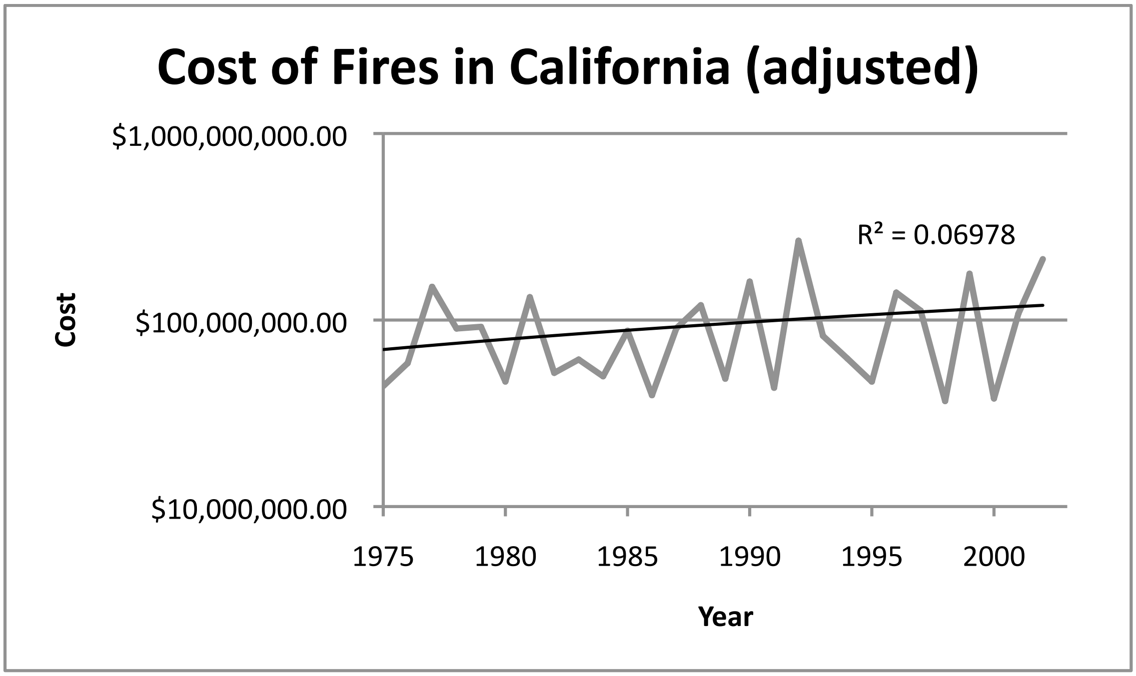

Average Time for 2,000 Foot Time Trials
(± 1 standard deviation)
Minutes
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
3
4
5
Staff
0% Slope
25% Slope*


Average Staff Per 100 Feet
Average Staff
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2
3
4
5
Staff
0% Slope
25% Slope*

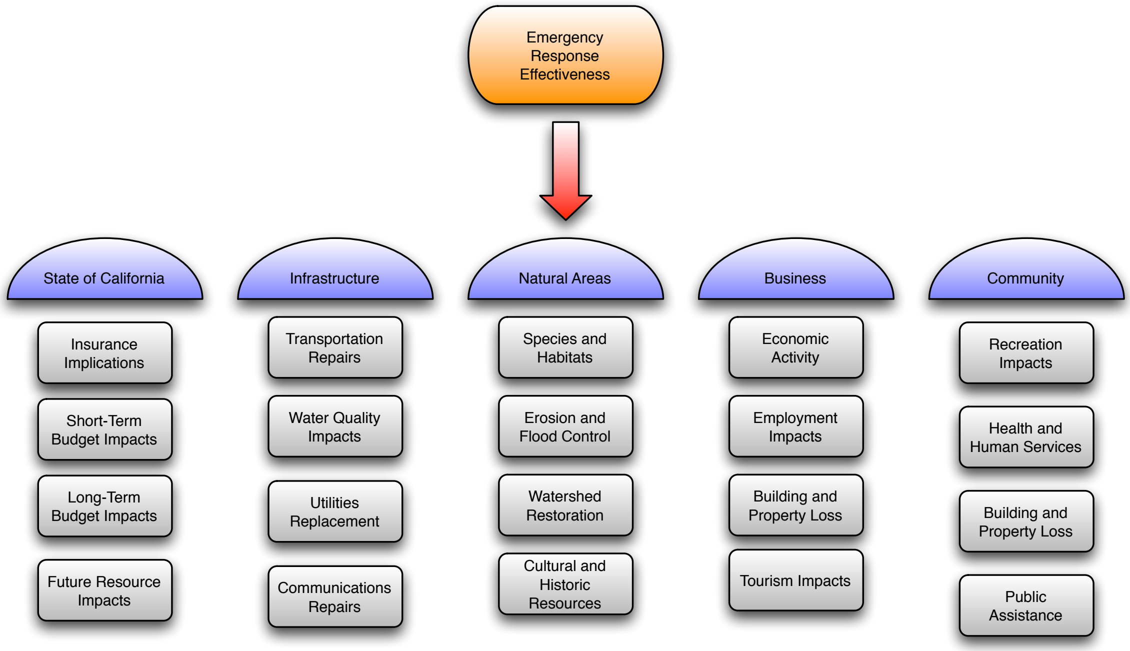

Average Errors
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Number of Errors
2
3
4
5
Staff
0% Slope
25% Slope*

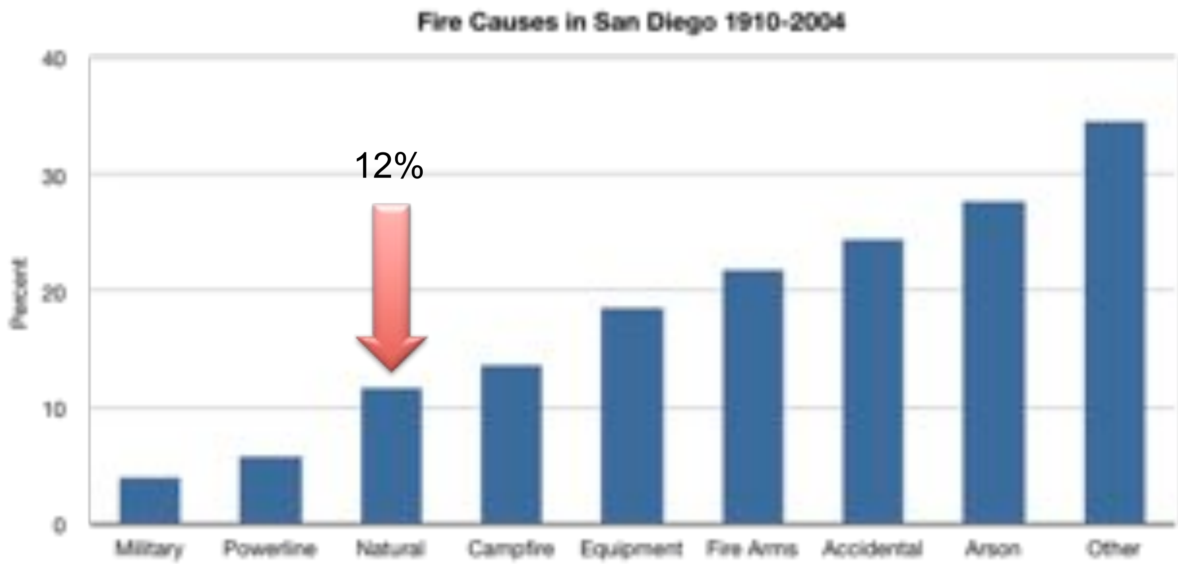

Change In Heart Rate (BPM)
BPM Difference
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2
3
4
5
Staff
0% Slope
25% Slope*

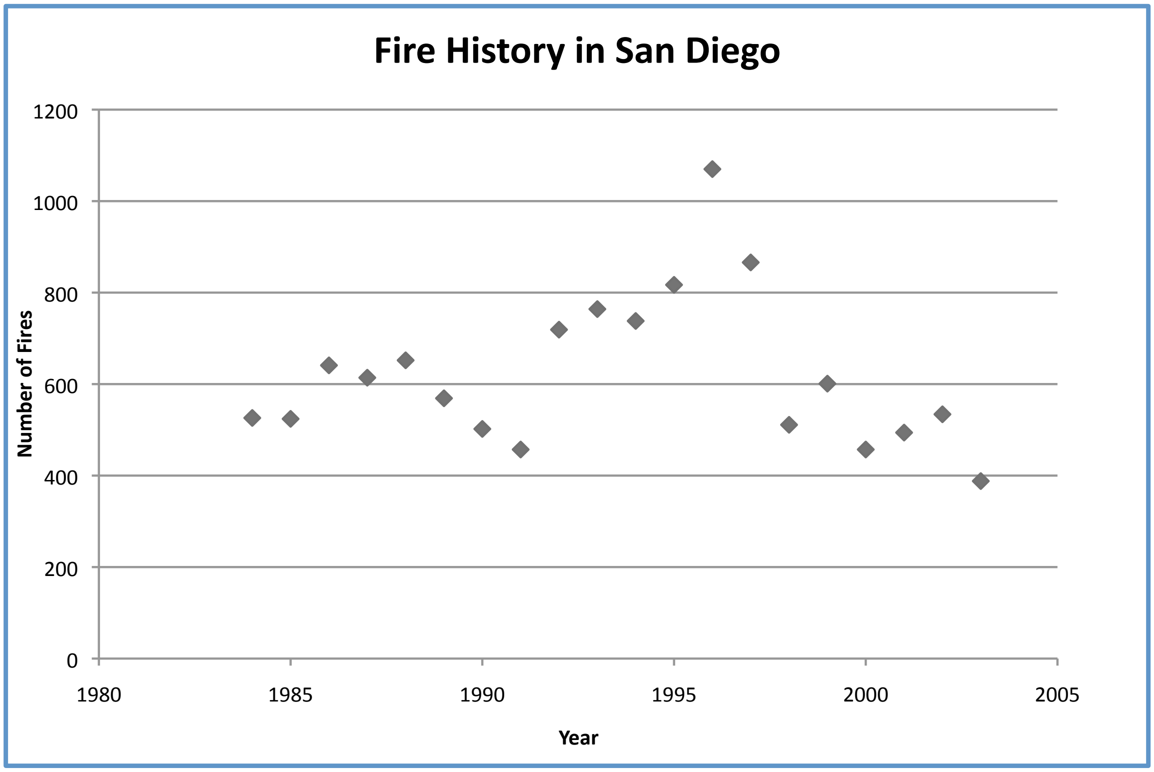

Fire Progression in the First 10 Minutes
(distance in feet)
5-Staff
4-Staff
3-Staff
2-Staff
Fire Model Distance
0
100
200
300
400
500
600
700
800
900



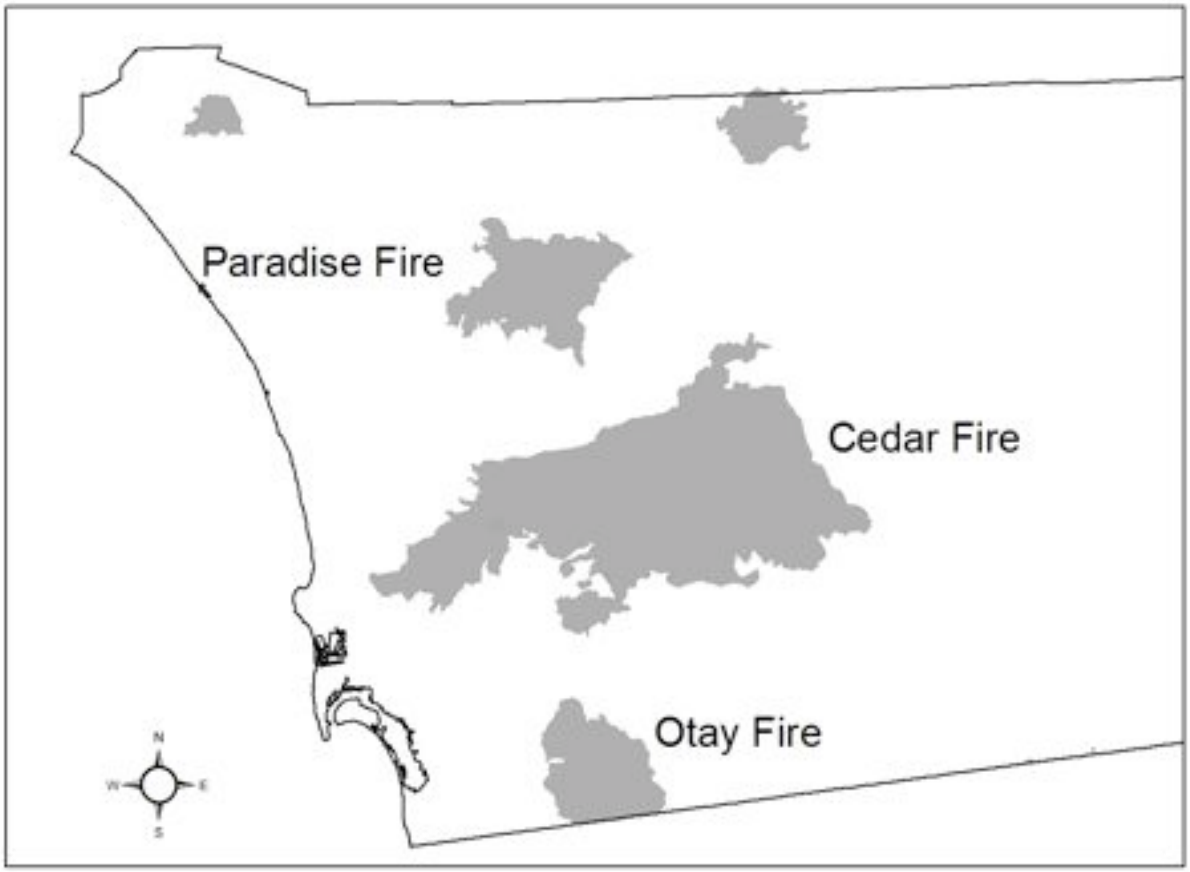
Cost of Fires in California (adjusted)
$1,000,000,000.00
$100,000,000.00
$10,000,000.00
Cost
R² = 0.06978
1975
1980
1985
1990
1995
2000
Year

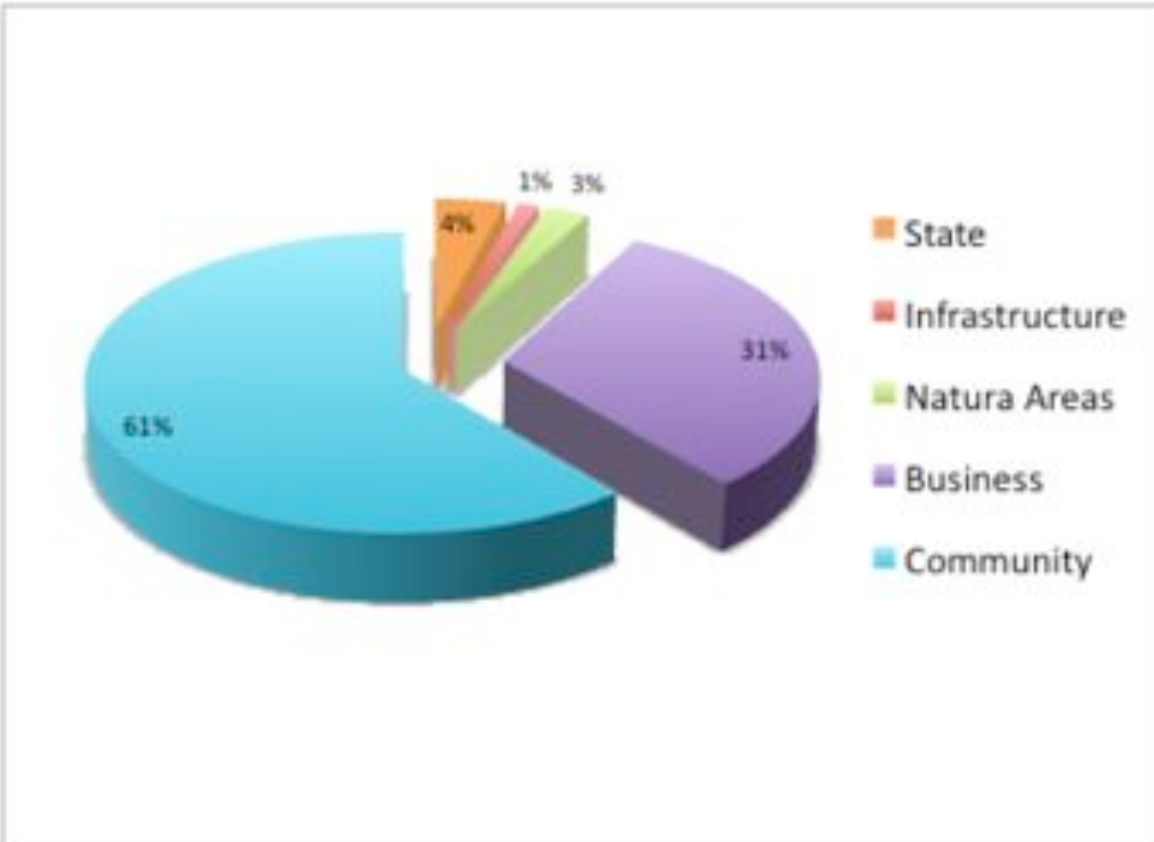

Emergency Response Effectiveness
State of California
Insurance Implications
Short-Term Budget Impacts
Long-Term Budget Impacts
Future Resource Impacts
Infrastructure
Transportation Repairs
Water Quality Impacts
Utilities Replacement
Communications Repairs
Natural Areas
Species and Habitats
Erosion and Flood Control
Watershed Restoration
Cultural and Historic Resources
Business
Economic Activity
Employment Impacts
Building and Property Loss
Tourism Impacts
Community
Recreation Impacts
Health and Human Services
Building and Property Loss
Public Assistance


Fire Causes in San Diego 1910-2004
Percent
0
10
20
30
40
12%
Military
Powerline
Natural
Campfire
Equipment
Fire Arms
Accidental
Arson
Other

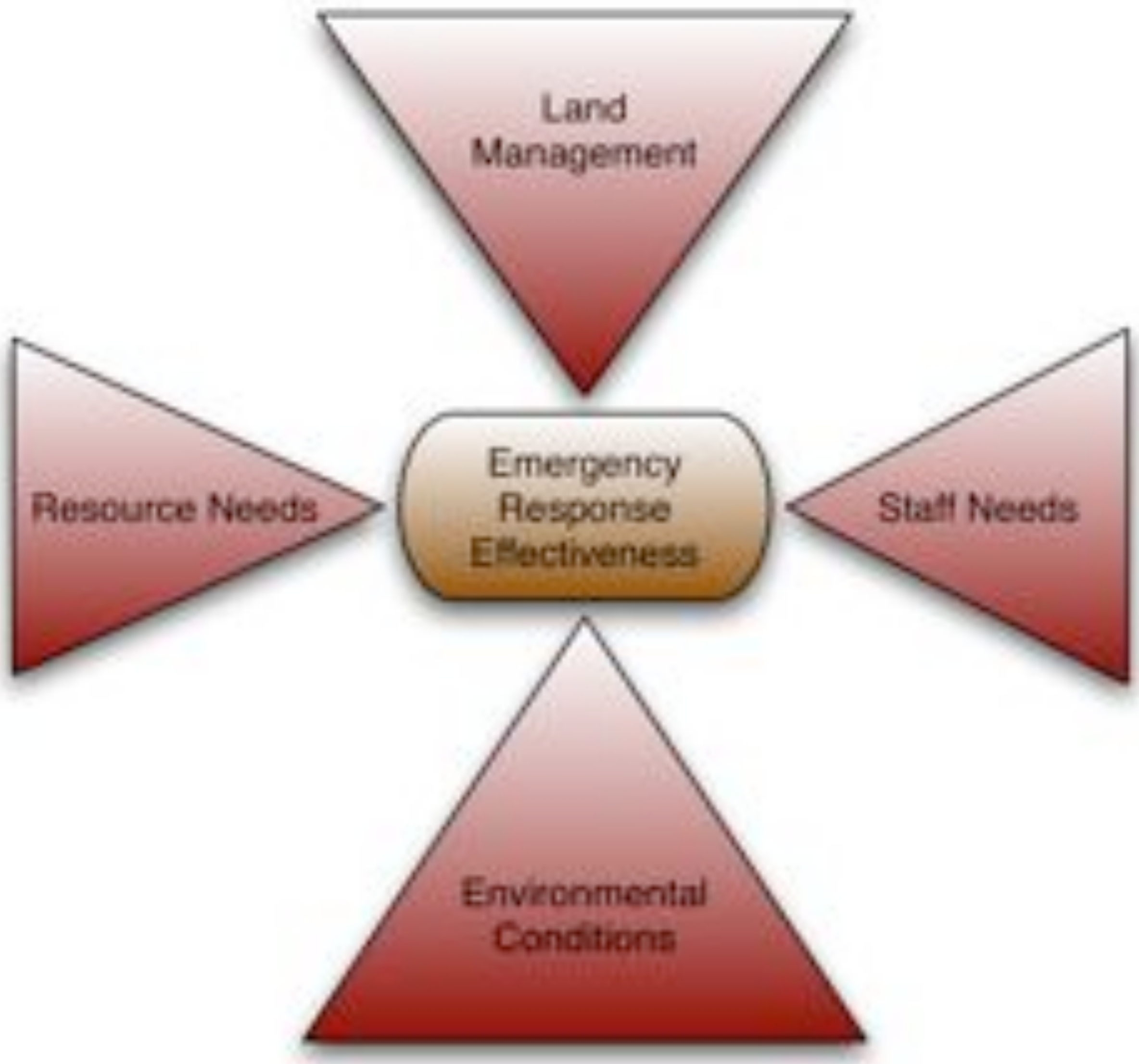

Fire History in San Diego
Number of Fires
1200
1000
800
600
400
200
0
1980
1985
1990
1995
2000
2005
Year

2003 San Diego Fire Map

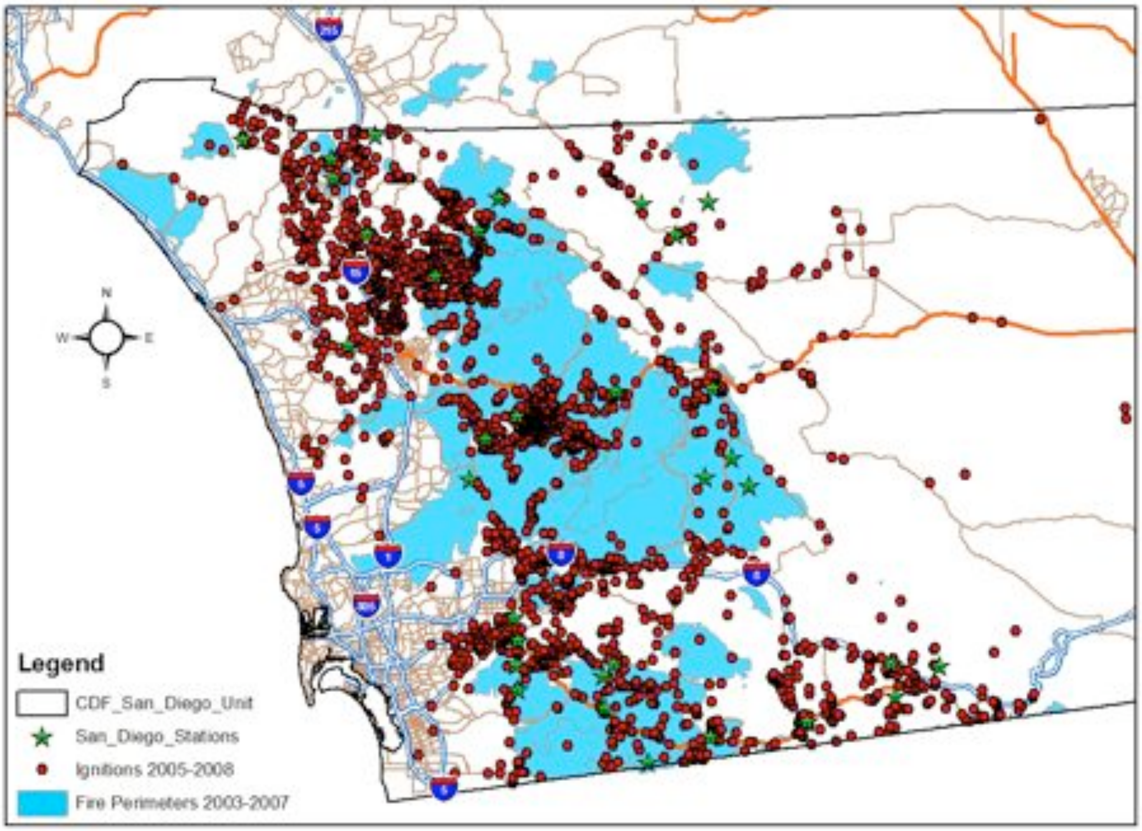




4%
1%
3%
31%
61%
State
Infrastructure
Natura Areas
Business
Community


Land
Management
Resource Needs
Emergency
Response
Effectiveness
Staff Needs
Environmental
Conditions

San Diego Fire Map



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