Assessing the Effectiveness of Fire Management Strategies in the Wildland Urban Interface: A City of Santa Barbara Case Study

A Group Project submitted in partial satisfaction of the requirements for the degree of Master of Environmental Science and Management for the Bren School of Environmental Science & Management

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The Group Project is required of all students in the Master of Environmental Science and Management (MESM) Program. The project is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management, and policy dimensions of a specific environmental issue. This Group Project Final Report is authored by MESM students and has been reviewed and approved by:

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Abstract

Fire in the wildland urban interface (WUI) is a growing problem – causing destruction of property, water supply issues, and landslides. In areas, like Southern California, where vegetation is conducive to frequent high severity wildfires and where there is a high level of WUI development, implementing initiatives for fire management is critical. Still, cities have very few policy tools for managing fuels and fire. Santa Barbara City has a unique Wildland Fire Suppression Assessment District with the primary goal of raising funds to manage fuels and fire risk on both public and private lands in the WUI. Now, ten years after the District's inception, Santa Barbara City Fire Department desires a cumulative review of the District. This project examined the attitudes of residents within the District towards the program and their use of the fire reduction services provided to them (chipping, defensible space inspections, etc.). The project also assessed the effectiveness of the Santa Barbara City Fire Department's vegetation management strategies at altering fire behavior and reducing risk from wildfire. We found that there was some underutilization of certain district services, but overall 80% of residents approve of the District. Vegetation management was effective at reducing fire risk under standard conditions, but during times of extreme fire weather, heightened awareness is essential for the benefits of management to come to fruition. Additionally, using a multi-decision criteria analysis the project identified 80 cities in California that would be suitable for a similar program based on landscape and socioeconomic factors.

Executive Summary

Fire in the Wildland Urban Interface

California has an increasingly large extent of wildland urban interface (WUI), the area where homes and associated structures are built among forests, shrubs, or grasslands (Stewart et al., 2006). The combination of human activity and wildland vegetation exacerbate wildfire potential. In Santa Barbara County in particular, there is a substantial amount of highly flammable vegetation along with WUI development, making it imperative that fire management initiatives be implemented. Along with identifying proper management strategies, understanding the sociopolitical and landscape conditions that contribute to the success and effectiveness of fire-mitigation programs is a task of equally critical importance.

To mitigate the risks from wildland fire, the City of Santa Barbara Fire Department created a Wildland Fire Suppression Assessment District (District). The District is funded by a yearly fee of approximately $75 from residents within the District boundaries. In exchange for the yearly fee, residents receive additional fire protection services, such as: debris chipping, defensible space inspections, roadside clearance, and vegetation management. Homes benefitting from the District fall within areas of high fire hazard.

Project Analysis

Ten years after the District's inception, the Fire Department is interested in a comprehensive evaluation of the effectiveness of the District in reducing threat from wildfire. In response, this thesis project looked at several aspects of the District to determine its effectiveness.

First, a 16 question survey was designed and distributed to over 3300 residents to gauge their perspectives on the District. Responses showed that they generally approve of it, with 80% of respondents noting that they think the District is beneficial to them. We conducted a spatial interpolation to explore how perceived fire risk changed across the landscape. Residents closer to Los Padres Forest accurately perceived a high fire threat while residents closer to urban centers had lower perceptions. This discrepancy indicates there is potential for increased fire awareness, as the entire district is designated as a high fire hazard zone. The Fire Department was also interested in the residents' use of the special homeowner vegetation management services provided by the District. We found that 50% of residents use the free-chipping services but only about 40% used the defensible space inspections. While some of the services are underutilized, the use of strategic communication could help target those residents who are not reaping all the benefits of the services offered to them. These communication efforts range from creating a strong social media portfolio and regular

email updates to switching “inspections” to consultations” to remove its negative connotation.

The second phase of this project evaluated the effectiveness of vegetation management at reducing fire risk. The Fire Department’s current vegetation management operates within a range of 1/2 to 2/3 fuel reduction treatments. A common software used by the U.S Forest and fire managers across the country known as BehavePlus was utilized to measure potential reductions from management. Fire risk was modeled under two different wind conditions, standard (6 mph) and Sundowner (60 mph) weather conditions, to analyze if and how fire behavior is affected by the vegetation treatments. Outputs of the model included fireline intensity, flame length and rate of spread. Scenarios were run to compare pre- and post-treatment fuel loads. Management under standard conditions notably reduced fire risk. Fireline intensity saw reductions ranging from 60% to 80%. Similarly flame length was reduced from 30% to 50%. Reductions were comparable or even greater under sundowner conditions. It should be noted however, that with the fast, dry winds during a sundowner event, fire risk is still extremely high, making fire awareness evermore paramount. We recommend the Fire Department conducts 2/3 fuel treatments whenever possible to maximize efforts and development a volunteer biological monitoring program to continually assess the ecological impacts of management.

Once it was found that the residents approve of the District and that the vegetation management efforts are largely effective at reducing fire risk, the last part of this project aimed to identify other cities that may benefit from a similar fire suppression district. We conducted a multi-criteria decision analysis to first find a city’s landscape suitability and then its socio-economic feasibility of passing a similar special assessment district. Landscape suitability factors included fire frequency, topography, vegetation, and wildland urban interface. These factors were weighted using an analytical hierarchy process where members of the Santa Barbara Fire Safe Council and of this project ranked these factors using pairwise comparisons. Next, the model filtered cities by local responsibility area, income and political party affiliation to determine their feasibility of passing a similar district. This project identified 80 cities in California that would be suitable for a similar program based on landscape and socioeconomic factors. This report will not only inform Santa Barbara residents and the fire department, but other cities in California that may be interested in implementing a special assessment district of their own. The more cities that develop a similar program, the safer California’s citizens, and ecosystems will be as a whole.

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Abbreviations and Acronyms

CFTN: Community Fuels Treatment Network

VMU: Vegetation Management Unit

WAF: Wind Adjustment Factor

WFSAD: Wildland Fire Suppression Assessment District

WUI: Wildland Urban Interface

1. Introduction

The escalation in the frequency and intensity of wildfires with global climate change increases the dangers of living in the wildland urban interface (WUI) (Radcliff et al., 2005). Extrapolating from past trends, one can predict that more homes will be built extending into wildland areas, where fire risk is higher than usual. Between 1970 and 2000, development in the WUI has increased as much as 52%, or 12.5 million homes, making fire management increasingly difficult (Theobald and Romme, 2007).

The close proximity of homes with wildland vegetation allows for the rapid transfer of fire across a landscape, causing large monetary losses as structures are burned. This increasing fire risk is magnified by the difficulty of transporting firefighting resources to the secluded homes found in the foothill and mountainous zones of the WUI. Winding roads and increasing distance between homes characterize the foothill and extreme foothill zones. The farther into the depths of the interface, the lower the ability for fire trucks to quickly arrive to structures on fire; this makes it difficult to protect more than one home at a time. Additionally, there is a growing belief that California's fire season will soon be year-long, meaning that resources must be paid for and on-reserve longer than before, increasing the costs of fire prevention (Park, 2015). The federal government spends over $1 billion annually on fire suppression alone, with additional expenditures on post-fire rehabilitation and fuel removal treatments (Federal Firefighting Costs (Suppression Only), 2015).

With its Mediterranean climate and chaparral vegetation community, Santa Barbara is a community with the potential for yearly fires. Those fires may ignite in the Los Padres National Forest and spread to the city, where management becomes more difficult as the wildland mixes with development. Like much of California, Santa Barbara has a large area where homes are entwined with the natural vegetation. This mix of wild vegetation and homes not only complicates the natural fire regime, but also complicates wildfire management and prevention. The City of Santa Barbara created the Wildland Fire Suppression Assessment District to handle the difficult task of managing fire in these areas. The District seems successful on its face, but after ten years, the City has not conducted any sort of large-scale evaluation of it.

As the pioneering district of this kind, there are significant lessons to be learned. The Fire Department needs to identify if the residents within the District know about the services offered, if they are using them, and which ones are most popular. This project also aims to determine the perceived fire threat of each resident, as well as the actions taken to prepare for wildfires. Input like this helps determine if more of the District funds should be appropriated to outreach and communication, and whether or not the same set of fire prevention services should be offered.

Lastly, this project intends to understand where such lessons could be best applied outside of the City of Santa Barbara, since most cities do not have a similar fire-related special assessment district.

Fire in Santa Barbara

Since 2002, six large wildfires have burned through the City of Santa Barbara, leading to a loss of 291 homes (Bliss, 2014). Fortunately for Santa Barbara residents, successful evacuation procedures were in place that saved countless lives. If additional preventative measures, like those from the District, were in place throughout the entire high fire hazard areas, there would have been a reduced loss of homes.

The fire season in Santa Barbara occurs from May to October, during which time there is little rainfall and higher mean monthly temperatures. Additionally, it is not uncommon for Santa Barbara to face a phenomenon called "sundowners" during these months. Sundowners are the local version of the Santa Ana Winds that often occur in the late afternoon or evening hours. Strong sundowners can occur two to three times per year, and result in sharp temperature rises, local gale force winds, and significant increases in fire risk (Ryan, 1991). During these events, super-heated air rushes down the Santa Ynez Mountains and onto the coastal plain, making it easy for fire to spread to and through the WUI. The Painted Cave Fire of 1990 burned under sundowner conditions and resulted in the loss of 524 homes, making it the most destructive fire of the last 40 years (City of Santa Barbara Fire Department, 2004). Under sundowner or Santa Ana conditions, things change rapidly and there is sometimes little time to react. This increases the need for effective preventative measures in place year-round.

The mosaic of homes and wildland vegetation in the foothill region makes for difficult fire management strategy and decisions. Santa Barbara's foothill and extreme foothill zones, between the southern boundary of the Los Padres National Forest and the northern city boundary, face the greatest risk from wildfire. The increased fire risk for this region is due to: climate, topography, vegetation type, road system layout, water supply limitations, fire response time, and its proximity to the Los Padres National Forest (Bliss, 2014). Homes outside of the WUI are typically clustered together with well-established roadways, enabling fire engines to quickly access a great number of homes in an emergency. On the other hand, homes in the WUI are often spread out with narrow and winding access roads and overgrown tree canopies, making access difficult for fire engines.

The Wildland Urban Interface

The increased construction of homes in the WUI is a growing concern for fire managers who are facing challenges in managing and preventing wildfires. The WUI is increasing by approximately

2 million acres per year as wildlands are converted from wildlands to wildland urban interface (International Association of Wildland Fire, 2013). The increase in WUI results in an increase of risk from wildfires, which can cause destruction of property, water supply issues, and landslides (Marx, 2014). Although this is a growing problem, cities have very few policy tools available for managing fuels and fire in the WUI.

District History

In 2006, the City of Santa Barbara Fire Department created a Proposition 218-compliant and voter-approved Wildland Fire Suppression Assessment District. Special districts are typically created to provide a particular public service to a specific set of residents; examples of such services are water, sanitation, fire protection, and parks and recreation (Salt, 2013). Funds for these services can come from several sources, such as property taxes, fees, and special assessments (Salt, 2013). In this case, the District is offering extended fire protection for a yearly special assessment fee, proportional to the property size, which is around $65 on average. The fee is adjusted annually and reported in the engineer's report at the City Council renewal meeting. With Santa Barbara City Fire Department's limited annual budget, it is important to have the extra funding provided by the District to help with the complicated fire management in the WUI. These extra funds pay for a full-time staff member dedicated to administering the services offered to residents to aid in their fire prevention and preparedness efforts.

Services Provided

The District covers roughly 3,300 homes in the foothill and extreme foothill high fire hazard areas. An annual fee is levied to residents in the District to fund vegetation road clearance for fire response and public evacuation safety, defensible space inspections, community vegetation chipping, and fuel management projects. Over the past eight years, fire department personnel have cleared 143 miles of roads, performed over 300 voluntary defensible space inspections, chipped over 3,200 tons of brush, and completed 126 acres of fuel management projects. All of these services would not be possible without funds raised from the District.

Yearly Review/Renewal

After the initial vote that created the District in 2006, the Santa Barbara City Council votes yearly on whether or not to extend the program for another year. The City Council must examine the budget for the upcoming fiscal year's costs and services, an updated annual Engineer's Report, and an updated assessment roll listing all parcels and their proposed assessments for the upcoming fiscal year (Bliss, 2014). Prior to their final decision, there is an annual public hearing held so that members of the public can provide input to the Council (Bliss, 2014). To date, the City Council has renewed the District each year, deeming it a successful program based on the yearly engineer's report. However, there has not been a formal aggregate assessment of the

District to determine if it is successful at mitigating fire risks and whether or not the funds are being used efficiently.

Objectives

The City of Santa Barbara is the only city in California to have an active fire mitigation district. Although there is a yearly engineer's report that assesses the fee allocation and takes inventory on the tasks and services conducted that year, there is no cumulative assessment of the District. As part of the assessment, this project aimed to determine how many residents are using the fire prevention services they are paying for, and for those residents that are not using the services, why not? To address this objective we designed and circulated a survey to all residents within the District boundary, including questions that would elicit the general attitudes of the WUI residents towards the District. As a means for comparison, we also surveyed residents of the coastal high fire hazard areas to determine their fire risk perception and overall preparedness for wildfires.

For the cumulative review, this research assessed how effective the District's fuel treatment programs are at reducing fire risk and potential. To do this, we used a fire behavior modeling software called BehavePlus to model fire progression under various wind scenarios and vegetation treatment levels.

From these first two objectives, this project aimed to identify opportunities to change services of the assessment district within the confines of the plan to better serve the community. We used surveys and fire behavior modeling results to determine what services are helping to reach the mission of the District and what services need to be reevaluated.

After the District's comprehensive assessment, this project aimed to identify what other cities might benefit from a similar special assessment district. For this objective, a statewide spatial analysis of cities in ArcGIS was performed to determine the suitability of other areas for such a program.

2. Evaluating Residents' Attitudes and Perceptions

Survey Design

The District has been generally well received; gaining support at public meetings and homeowner groups, but little is known about the specific attitudes of residents toward the District. While the City Council has the final decision on renewing the District, it would be helpful to hear from residents of the District as to why they do or do not use the services offered to them. Knowing this and the other thoughts of the residents on the District could help determine if more

communication is needed or if there are other, more effective, fire prevention measures that should be undertaken. The yearly services provided to the residents are costly, so if they are not being used, the fire department may want to implement other methods of fire prevention.

To evaluate the residents' level of perceived fire threat, levels of fire preparedness, use of District services, and more, we surveyed residents within the District. As a means for comparison, we conducted a separate survey for the residents of the coastal and coastal interior high fire hazard areas. The only contact information available for a majority of the residents was home addresses so we chose to mail out hard copies of the surveys. The survey package that we mailed out included an outer envelope with a cover letter, survey, and return envelope inside. Postage was provided on the return envelopes to make it easier and cheaper for residents to return their surveys via mail. For statistical power, we aimed for a ten percent or greater rate of return on the 4,175 surveys. The surveys consisted of 16 questions for residents in the District and 17 questions for coastal residents with an additional 4 optional demographic questions for each. We gave each survey a four-digit code that corresponded to their address so that the geographical area of responses could be tracked. Appendix A shows an example cover letter that was attached to the survey sent to residents. Appendix B.1 shows an example survey that was sent to residents of the District, and Appendix B.2 shows an example survey that was sent to Coastal and Coastal Interior zones of the City of Santa Barbara.

Surveys to Wildland Fire Suppression Assessment District Residents

We sent out a total of 3,323 surveys to residents of the District, which included all single-family homes. We did not mail surveys to parcels within the District boundaries that were not residences, since we were only interested in households that either owned or rented homes on parcels of land that are charged the yearly District fee. Only one survey was sent per parcel, so homes with two voting-age owners were surveyed as one.

Surveys to Coastal High-Fire Hazard Zone Residents

We surveyed all single-family homes and certain multi-unit homes in the coastal and coastal-interior high fire hazard areas for a total of 852 surveys. This region had several apartment complexes that were largely full of rentals and lacked common grounds for vegetation, so those units were removed. While residents in the coastal zone are not part of the District, they are still in the WUI and at high risk from fires. A preliminary survey prior to the creation of the District in 2006 showed that these residents would not vote in favor of a special assessment district, so they were not included in the creation of the District. However, things have changed since then – there have been a few large wildfires in the city, old residents have moved out and new ones have moved in, and there has possibly been a change in attitudes and opinions of fire risk and fire prevention.

Data Collection

The survey cover letters instructed the recipients to return their surveys by September 30, 2015; two weeks from the date they received the surveys. While some surveys trickled in past the due date, a majority of the returned surveys did arrive during those two weeks. To make entering the survey data easier, the surveys were post-coded so that each response corresponded to a particular number. This way, the survey reader could easily read out the postcode number to the person doing the data entry. This also made it easier to recode the responses for entering into RStudio for statistical analyses. All survey codes were matched with their addresses.

Statistical Analyses and Results

Of the 3,323 surveys mailed to the District residents, 480 surveys were returned (14%), and of the 852 surveys mailed to the coastal residents, 92 surveys were returned (10%). Figure 1 shows the distribution of the returned surveys (see Appendix C for survey representativeness).

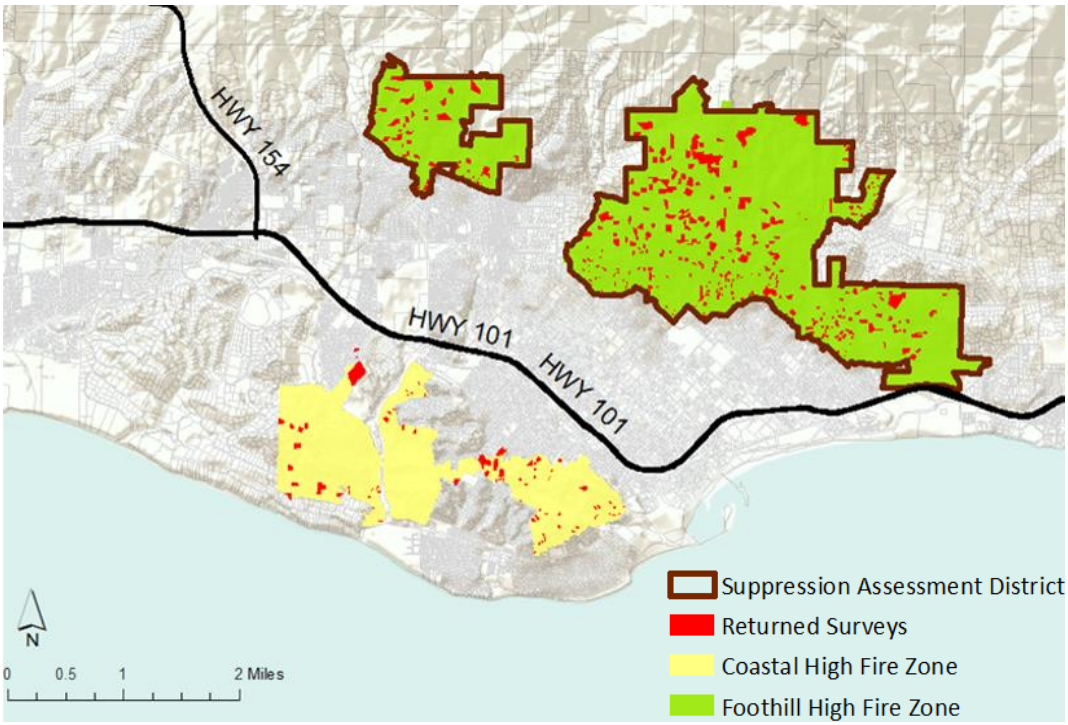

Figure 1. Map of returned surveys. Homes within the District that responded are in yellow. Homes within the Coastal and Coastal Interior zones that responded are in purple.

Survey responses from the District residents show that 80% of the residents believe that the District is beneficial to the community, and only 5% disagreed (Figure 2).

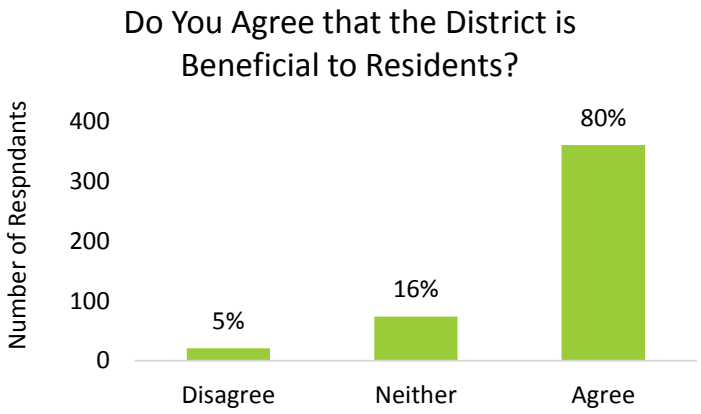

Figure 2. Bar graph of whether or not residents believe the District is beneficial.

In response to the question, "What do you think is the level of fire risk at your residence?" a chi-squared test showed that the responses between the coastal and the District residents were significantly different ($x^2 = 194.19$, $p < 0.001$, $df = 2$). While both the District and the Coastal and Coastal Interior regions are considered high fire hazard regions, only 28% of coastal residents think they live with a high or very high risk from fire. This is compared to the 70% of District respondents that believed that they were at a high or very high risk of fire (Figure 3). It is important to keep in mind that both areas surveyed are classified as high fire risk zones by the Fire Department.

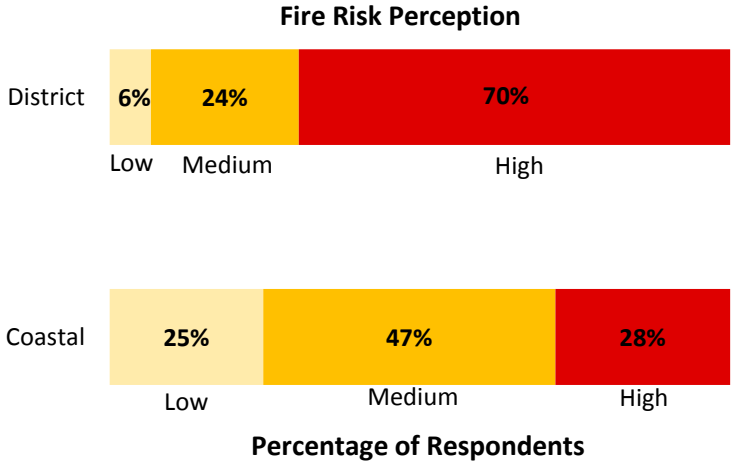

Figure 3. Perceived fire risk for survey respondents from the Coastal residents and Wildland Fire Suppression Assessment District residents.

To analyze how the distance of each home to the Los Padres National Forest boundary might affect a resident's perceived risk level, a spatial analysis was performed in ArcGIS and RStudio. All respondents that answered the perceived risk question were included on a GIS map in the

form of a point. Next, for each point, its distance (feet) to the Los Padres National Forest was determined using the "Near" function in ArcGIS. The "Near" function calculates the distance between an input feature (returned survey point) and the closest feature in another feature class (Los Padres National Forest Boundary). Once the distance of the points to the Los Padres National Forest was determined, the parcel points were matched up with their self-assigned risk level (1-5; 1=Very Low Risk, 5=Very High Risk). The combined distances were determined for each of the five risk level ranks.

Since the data were non-parametric, a Kruskall-Wallis test with post-hoc analysis was performed in RStudio to compare median values for distance to the Los Padres National Forest and risk level ranks 1-5 (1=Very Low Risk, 5=Very High Risk) (Figure 4). Median distances differed significantly (x^2=60.33, df=4, p <0.001). To determine which median distances associated with fire risks were the ones that specifically differed, post-hoc tests were conducted. Post-hoc tests revealed significant differences between those who answered with 'Low Risk' (M=8,997) and 'High Risk' (M=6,610), showing that those who believe they are at a high fire risk are significantly closer to the Los Padres National Forest boundary (Figure 4).

The same process was conducted for resident fire risk responses and their distance to the Tea Fire ignition location, as this point was within Santa Barbara City boundaries (Figure 5). Median distances differed significantly (x^2=39.07, df= 4, p <0.001). Post-hoc tests once again revealed significant differences between 'Low Risk' (M=9,602) and 'High Risk' (M=7,839), showing that residents who believe they are at high fire risk, compared to those who believe they are at low risk, reside significantly closer to the Tea Fire ignition point.

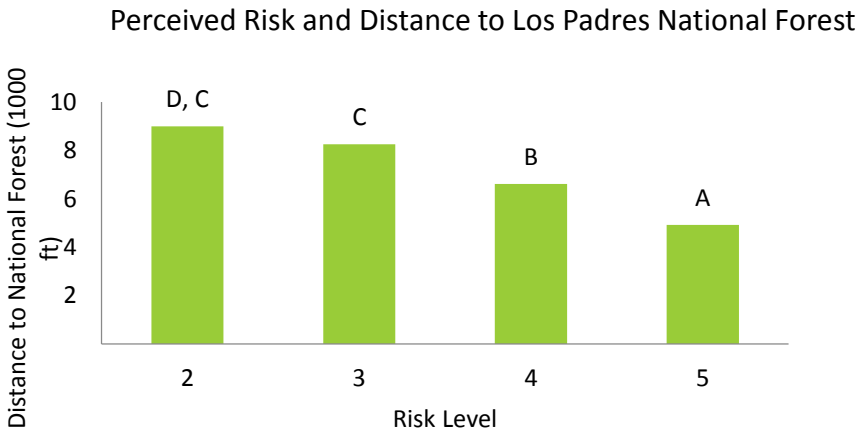

Figure 4. Effect of distance from Los Padres National Forest on perceived fire risk level. Distance from Los Padres National Forest for perceived risk levels 1 through 5. Like letters above error bars indicate values that are not significantly different by a Kruskall- Wallis test (x^2=60.33, df= 4, p <0.001) with post-hoc Tukey's HSD (α=0.05). (Note: Risk level 1 is omitted because it was selected for only 5 out of the 440 responses).

Figure 5. Effect of distance from Tea Fire on perceived risk level. Distance from Tea Fire ignition for perceived risk levels 1 through 5. Like letters above error bars indicate values that are not significantly different by a Kruskall- Wallis test (x^2=39.07, df= 4, p=<0.001) with post-hoc Tukey's HSD (α=0.05). (Note: Risk level 1 is omitted because it was only selected for 5 out of the 440 responses).

To determine the collective risk perception for geographic areas in the foothill and extreme foothill zones, as well as the coastal zones of the high fire hazard areas, we used interpolation of survey responses. To do this, we used the perceived fire risk responses, including non-respondents, to perform the Kriging method of interpolation in ArcGIS. A Kriging analysis is appropriate for this interpolation since there is a correlated distance or directional bias in our data. Based on the location of our data points and the nature of the data collected from each point, we chose to use a spherical semivariogram with ordinary kriging.

As one might expect, the Kriging analysis showed that areas near the Los Padres National Forest border, the Tea Fire ignition location, and areas near densely vegetated canyons all had higher perceived risk estimates (red shaded area on map) (Figure 6).

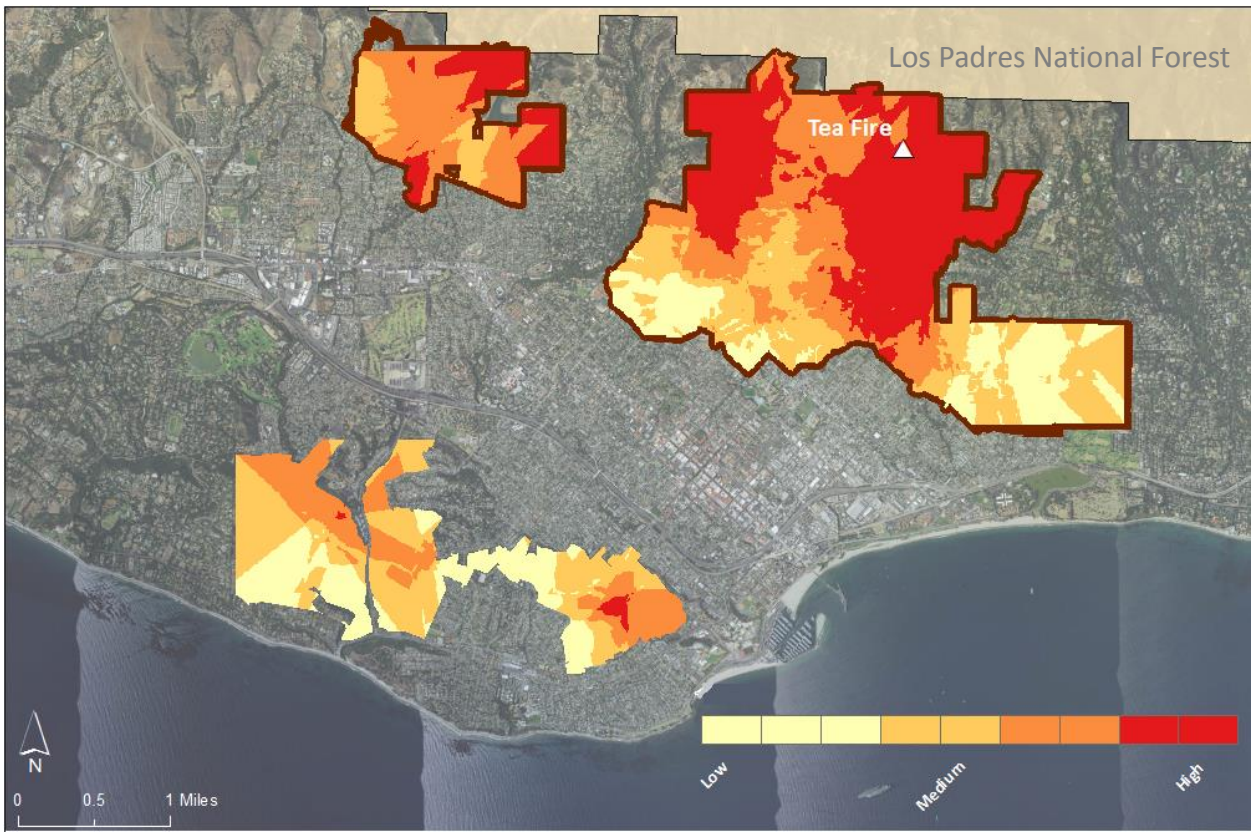

Figure 6. Perceived fire risk interpolation. A map of the Kriging method interpolation of perceived risk in the high fire hazard areas of the City.

After the Kriging analysis determined areas of low-to-high perceived fire risk, we identified statistically significant hot spots and cold spots. Using the "Hot Spot Analysis (Getis-Ord Gi*)" tool in ArcGIS. Points that were determined to be statistically significant hot spots were points that had a high risk value and were surrounded by other high risk value points. The same goes for the cold points and low risk values. The local sum for a point and its neighbors is compared proportionally to the sum of all features. If the local sum varies largely from the expected local sum, then the feature is a statistically significant hot (area of high risk perception) or cold spot (area of low risk perception).

The results found two large cold spots within the District, both of which fell in the Southern region - farthest from the Los Padres National Forest boundary line (Figure 7). The residents within these areas are clearly unaware of the actual fire risk in their neighborhoods, likely due to their homes being farther from the mountains and therefore appearing to be at less of a risk than those in the extreme foothill zones. The hotspot analysis identifies grouped neighborhoods within the community with low fire perceptions that the Fire Department should target for increased and enhanced communication efforts. Survey responses had address codes so the Fire Department has a clear understanding of where these areas are.

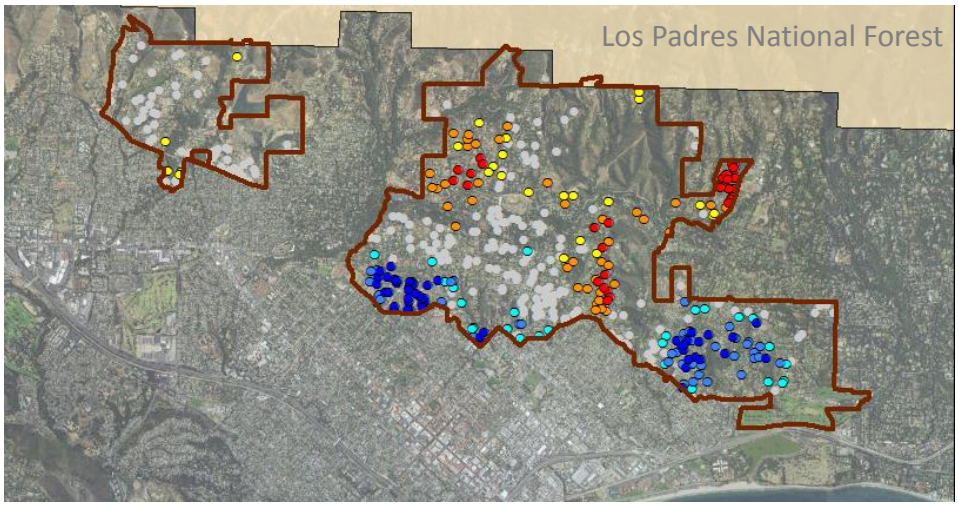

Figure 7. Hot spot analysis of fire risk perceptions within the District. Dots with shades of blue represent statistically significant cold spots. Dots with shades of red represent statistically significant hot spots.

A few questions in the survey to District residents were to determine the frequency of use of the District services by the residents. The survey found that 49.5% of residents have used the chipping service, while 50.5% have never used that service. To better understand why residents do not use this service, we evaluated their responses. The most common response was “Other” (39%). “Other” varied throughout responses, with the top three repeated reasons being “I do it myself”, “I hire a gardener/ tree service”, and “The timing doesn’t work for me”. The next top survey responses were, “It does not pertain to my property” (32%), “I have never heard of it” (17%), and “I do not think it would be useful” (7%) (Figure 8).

We aggregated some of these responses to get a clear idea of the true percentage of respondents who could be targeted through improved strategic communication to increase use of this service. To do this, it was assumed that at least half of respondents who answered “Does Not Pertain to My Property” are lacking awareness of the benefits they could reap from this service. Those respondents were combined with all those who said “I Have Never Heard of It” and those who answered “I Do Not Think It Would Be Useful”, resulting in a new target audience totaling 40% (Figure 8). Communication strategies focused on 40% of the District respondents could greatly increase the utilization of this service.

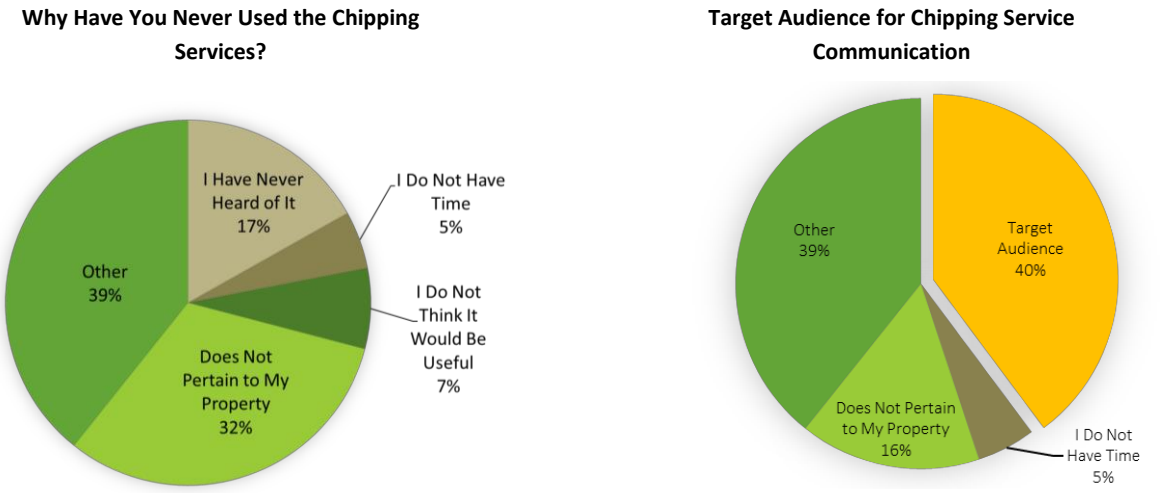

Figure 8. Distribution of responses for chipping services question. Left: distribution of original responses. Right: distribution of responses with target audience incorporated.

Results from the survey also showed that only 38% of residents have ever used the defensible space inspection offer. To better understand why residents do not use this service, we evaluated their responses. The most common response was once again "Other" (32%), with the top three repeated reasons being "Procrastinating", "Unclear scheduling", and "The word 'inspection' scares me". The next top survey responses were, "I do not think it would be useful" (25%), "It does not pertain to my property" (19%), and "I have never heard of it" (19%) (Figure 9).

Once again, we aggregated responses to come up with a target audience that could benefit from strategic communication outreach from the fire department to increase awareness of the service benefits. In this case, we included more responses to the target audience because of the critical importance of defensible space. It has been proven that defensible space is one of the top indicators determining whether or not a home will survive a fire. We assumed lack of understanding for half of those who responded "Does Not Pertain to My Property" and included all of the other respondents apart from those who answered "Other". This resulted in a new target audience of 59% that should be focused upon by the fire department to increase awareness of the critical importance of defensible space.

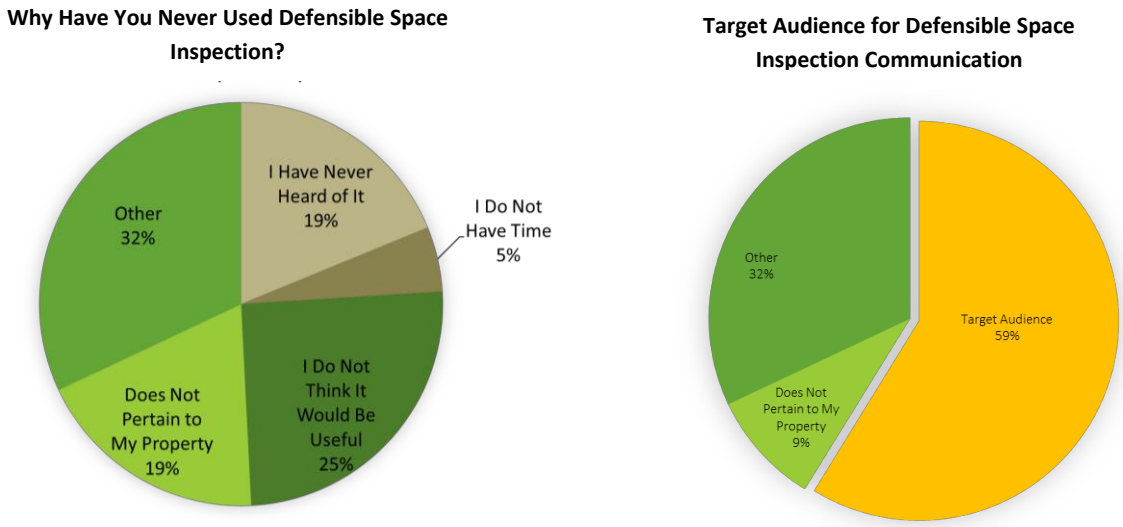

Figure 9. Distribution of responses for defensible space question. Left: distribution of original responses. Right: distribution of responses with target audience incorporated.

Discussion

About 50% of the residents have used the chipping service, and 38% of residents have used the defensible space inspections at some point. While those numbers are encouraging, there is still a large amount of room for improvement. Since a common response from residents was that the timing of the chipping service does not work for them, we suggest contacting those respondents to determine why the timing does not work for them. They may have suggestions for times that not only work better for them, but also for other residents. For the defensible space inspections, many people mentioned that the word “inspection” has a negative connotation and makes them think they will get in trouble. We suggest changing this word to “consultation” so that residents truly feel like the service is for their benefit, and this should increase the trust between them and the Fire Department.

A surprising number of residents have never heard of the chipping (17%) and defensible space inspections (19%). With these services being two of the three homeowner-level services provided, it is unacceptable to have that many residents unaware of the services that they are paying $65 a year to receive. In addition to that, many of the responses for why residents do not use the services were that they did not feel they would be useful and that the services did not pertain to their property. While residents may feel that way, the fact that they live in the high fire hazard regions makes this unlikely. This means that these residents are a large group who could be using the District's services if provided with the right information. For these reasons, we recommend increased strategic communication efforts to target District residents. Through the surveys, we were able to collect over 100 emails for residents in the District. These emails could

be used to increase communication to District residents. While we do not suggest sending an overwhelming number of emails just in hopes of keeping the residents informed, we do think that yearly or seasonal email updates may be beneficial, in addition to email "alerts" when the date of the services is approaching. We also conducted an audit of the Fire Department's social media accounts (Appendix D). From the audit, it appears that their accounts could be used more effectively to reach out and share information to residents. In particular, we believe that the Fire Department should follow the lead of other City of Santa Barbara departments and create a YouTube channel. This channel could feature tutorials and instructional videos on what residents can do around their home to best protect themselves from fire. Another recommendation is that the Fire Department use an Instagram account to tap into another social media outlet for sharing information.

The results of the Kriging showed that the higher perceived risk levels are found towards the Los Padres National Forest boundary and the Tea Fire ignition, which is to be expected. However, as you get further away from those areas, the perceived fire risk levels drop. Since these homes are still in the high fire hazard areas, this is a troubling trend to see. Due to this, we recommend that the Fire Department address this and the dangers of living inside the high fire hazard area to the residents in the annual District newsletter. The Fire Department should target the neighborhoods that were shown as "coldspots" in the hotspot analysis for the increased and enhanced communication efforts.

3. Vegetation Removal Effectiveness

Fire Behavior Modeling

To assess the effectiveness of the fire mitigation program for fuel management and fire risk, BehavePlus was used to model fire behavior for five selected Vegetation Management Units (VMU) under a pre- and post-treatment scenario and for two different wind conditions. BehavePlus was used due to its pervasiveness throughout the wildland management community. In fact, it was found to be the most commonly used fire behavior software program (Rauscher 2009). Pre-treatment modeling refers to assessing fire behavior under no vegetation management while post-treatment measures fire metrics based on recorded vegetation management by the fire department. BehavePlus is a computer program composed of a collection of mathematical models that describe fire behavior, fire effects, and the fire environment (Heinsch et al., 2010). This program has the options for more than 180 input and output variables, but the scope of this project allows for only a few of these to be examined. The inputs used in this project included fuel load type (the class of vegetation present in each VMU) and environmental details such as fuel moisture, wind speed, and slope. BehavePlus is intended to model fires in large landscape s so it is important to note that modeling results for smaller

areas have the potential to be artifacts of their resolution and therefore be misleading. To account for this, five large VMUs, Hillcrest (16 acres), Las Tunas (13.4 acres), Alston Place (11 acres), Las Canoas (10 acres), and St. Mary's (8 acres) were chosen for analysis due to their representativeness across all VMU vegetation types and treatment sizes. As measures of fire risk, we used the following outputs of interest based on Forest Service technical reports and client input: fireline intensity, heat per unit area, rate of spread, and flame length.

Understanding the Fuel Models

The fuel models used for BehavePlus are sourced from Scott and Burgan Fire Behavior Fuel Models. There are 40 fuel types, labeled by two letters and a number (i.e., SH7), and are grouped by grasses, shrubs, timber, and slash. Each fuel model has unique characteristics that result in variable fire behavior. This project focused on only the models reflective of Santa Barbara habitats. Santa Barbara Fire Department provided data on the fuel types found within the five VMUs: Las Canoas and St. Mary's with SH7 (Very High Load, Dry Climate Shrub), Las Tunas and Hillcrest with SH5 (High Load, Dry Climate Shrub), and Alston Place with TU5 (Very High Load, Dry Climate Timber-Shrub). BehavePlus has several selections for how the fuel types can be entered, but this project uses the option for a custom fuel. This option allows for detailed manipulation of the components of a given Scott and Burgan Fuel Model (SH7, TU5 etc.). By initializing a chosen fuel model, BehavePlus populates unique default values for the fuel inputs including, but not limited to: 1-, 10-, 100-hour fuel loads and live woody fuel load. The x-hour fuel loads represent the total tons per acre of dead-and-down vegetation of differing sizes. The 1-hr fuels refer to vegetation less than ¼'' in diameter (small sticks), 10-hr fuels are those between ¼ and 1'' in diameter (small branches), and 100-hr fuels are between 1 and 3'' in diameter (larger branches) (Maser et al., 1979).

Pre-Treatment Scenarios

For the pre-treatment scenario, the initialized fuel model values were used without manipulation. The remaining inputs included the fuel moisture, wind speed, and slope. Dead and live fuel moisture values were gathered from the literature and reflected the low moisture content of the vegetation due to local climate and drought. (See Appendix E Table 1 for exact values; Scott and Burgan, 2005). For each VMU, the fuel types were held constant and the two wind speed scenarios were run to determine the effectiveness of treatments under different wind conditions. The first wind scenario was 6 mph to represent standard conditions and the second scenario used 60 mph to represent Sundowner conditions. According to fire modeling completed by the City's Wildland Fire Specialist, Ann Marx, a wind adjustment factor (WAF) of 0.6 is appropriate for this analysis (City of Santa Barbara Fire Department, 2004). The WAF adjusts the 20-ft wind speed to a mid-flame wind, so a WAF of 0.6 reduces the 20-ft wind by 40 percent (Andrews, 2012). The range of slopes for each VMU was provided by the Fire Department and in

order to compare success across VMUS, the median slope from each unit was used as a comparison (Table 1). Slope assumptions were verified with on-site photos of various treatment areas. Once the model was run for each VMU under the chosen conditions, the program outputs allowed for analyses on the fire behavior of the parcels under pre-treatment conditions.

Post-Treatment Scenarios

To model fire behavior of the VMUs after the completion of vegetation removal, some assumptions were made regarding the alteration of fuel types present. Data collected by the Fire Department describing the proportion of fuel removed for each treatment helped explain how the fuel types and ratios may have affected a result. In order to adjust the software for a post-treatment scenario, either the "fuel type" input was changed or "fuel load" input was manipulated in the custom model to mimic fuel reduction. For the Alston Place VMU, the initial fuel type was TU5 "Very High Load, Dry Climate Timber-Shrub." The post-treatment condition aligned with the TU1 fuel type "Low Load, Dry Climate Timber-Grass-Shrub" because the majority of understory vegetation was removed but most large trees remained. Shrub-dominated "fuel types" are not as clearly shifted (SH7 to SH5 or SH5 to SH2) because these systems are not changing from high-density chaparral (SH7 or SH5) to coastal scrub (SH2), therefore a more complex process was necessary. For the remaining four VMUs, fuel loads within the custom model were adjusted. The fuel loads altered for the post-treatment runs included the 1-, 10-, and 100-hr fuel loads, as well as the live woody fuel load. Each one of these was reduced by the total recorded reduction by the fire department. For example, Las Canoas and St Mary's received a 2/3 fuel reduction, so each of the four variables mentioned above was individually reduced by 2/3 (Table 1). In a similar vein, Las Tunas and Hillcrest underwent a ½ fuel reduction treatment; so each of the four fuel loads was reduced by ½ (Table 1). Viewing of before-and-after photos of the VMUs helped in making the decision to manipulate only those four inputs. The photos showed that much of the removal was focused on dead-and-down vegetation, but also impacted some of the live fuels such as live shrubs and invasive species. Consultation with the Fire Department also contributed to the decisions made for the post-treatment fuel load modifications. Once the fuel load was determined for each VMU, the same steps were taken as the pre-treatment scenarios. Finally, reductions in the fire risk metrics from pre- and post-treatment were compared to measure the effectiveness of management.

Table 1. Fuel load alterations for BehavePlus pre- and post-treatment scenarios. The arrows separate the pre- (left) and post-treatment (right) values for each of the fuel loads.

Input	*Las Canoas*	*St. Mary's*	*Las Tunas*	*Hillcrest*	*Alston Place*
Size	10 acres	8 acres	13.4 acres	16 acres	11 acres
Fuel Type	SH7	SH7	SH5	SH5	TU5
Amount Removed	2/3	2/3	1/2	1/2	2/3
Median Slope (%)	50	50	50	45	40
1-hr Fuel (tons/acre)	3.50 -> 1.15	3.50 -> 1.15	3.60-> 1.80	3.60-> 1.80	TU5-> TU1
10-hr Fuel (tons/acre)	5.30 -> 1.75	5.30 -> 1.75	2.10 -> 1.05	2.10 -> 1.05	TU5 -> TU1
100-hr Fuel (tons/acre)	2.20 -> 0.73	2.20 -> 0.73	0.00 -> 0.00	0.00 -> 0.00	TU5 -> TU1
Live Woody Fuel (tons/acre)	3.40 -> 1.12	3.40 -> 1.12	2.90 -> 1.45	2.90 -> 1.45	TU5 -> TU1

Results

Standard Conditions

Percentage decreases of fire behavior metrics shed light on the level of success of the varying fuel treatments (Table 2.) Alston Place showed a substantial alteration in fire behavior across all metrics. This result is reasonable because a 2/3 removal of vegetation results in the removal of most ladder and surface fuels. A fire within this VMU will not be as intense or reach the canopy in comparison to the pre-treatment fuel load scenario. Las Canoas and St Mary's had notable reductions in heat per unit area, fireline intensity and flame length after undergoing a treatment for ⅔ removal of vegetation. These reductions however, were not as considerable as Alston Place (Table 2). Moreover, there was a minimal decrease in rate of spread. Fires spread quickly through 1-hour fuel classes, and since the ratio stayed the same between fuel classes, spread was not sizably altered. For all three VMUs that received a ⅔ fuel reduction, the variation in percentage decreases could be explained by the characteristics of initial fuel type on site (TU5 vs. SH7) or the way the post-treatment scenarios were modeled in BehavePlus (TU5 to TU1 vs direct fuel manipulation). Las Tunas and Hillcrest ranked the lowest in percentage decrease across all the metrics. That is not to say these results suggest a failure in management, but rather highlight the importance of the amount of vegetation removed during a given treatment (Figure 10). Both of these units were treated with only a ½ fuel reduction. The nuanced difference between these

units may be attributed to the slight variation of slope between the units (see Table 1). The impact of initial fuel type (SH5 vs. SH7) could also be a contributing factor in explaining the difference between Las Canoas and these two units.

Table 2. Percentage reduction of outputs for all four VMUs. See Appendix E Table 2-10 for raw outputs.

	% Reduction of Outputs			
Management Unit (Ranked Order)	*Rate of Spread*	*Heat per Unit Area*	*Fireline Intensity*	*Flame Length*
Alston Place	66.17	84.70	94.82	74.47
Las Canoas	3.73	78.19	79.02	50.86
St. Mary's	3.73	78.19	79.02	50.86
Las Tunas	2.84	62.07	63.20	36.96
Hillcrest	2.55	62.07	63.05	36.52

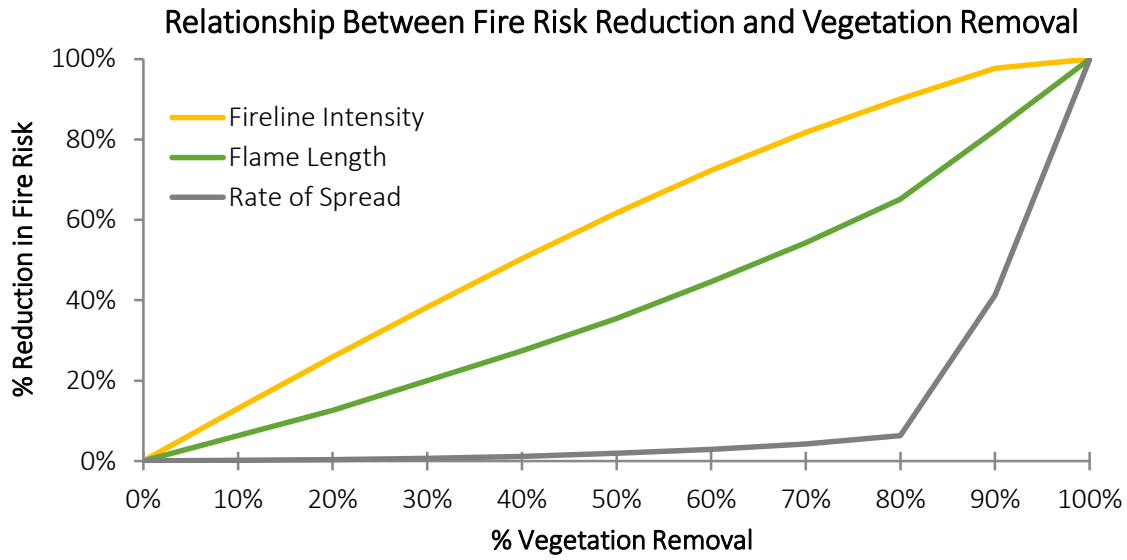

Figure 10. Relationship between fire risk and fuel removal. Various fire metrics change based off of amount of vegetation removed. These models are based off an SH7 initialized fuel model.

Sundowner Conditions

Due to high fire hazard during sundowner conditions, understanding fire dynamics under this scenario is essential for resource managers. Percentage decreases of fire risk metrics after treatments were substantial under sundowner wind conditions (Table 3). It should be noted however, that fire risk metrics for treated VMUs in sundowner scenarios were generally similar to baseline conditions (Standard, pre-treatment). The only exception was rate of spread, which showed a notable increase due to fast wind speeds (Table 4). Wind noticeably affects rate of spread, fireline intensity and flame length across all VMUs. The impact of these values and the

potential for successful management under these conditions will be explored in the findings and recommendation sections.

Table 3. Percent change from Pre- to Post-Treatment under Sundowner Conditions. Results displayed for Las Canoas. See Appendix E Tables 2-5 for full suite of VMUs.

Fuel Condition	*Rate of Spread (ch/h)*	*Fireline Intensity (Btu/ft/s)*	*Flame Length (ft)*
Change in Fire Risk	55%	90%	66%

Table 4. Percent change from Standard, Pre-Treatment, to Sundowner, Post-Treatment. Values in red represent an increase while values in black represent a decrease in fire hazard. Results displayed for Las Canoas.

Fuel Condition	*Rate of Spread (ch/h)*	*Fireline Intensity (Btu/ft/s)*	*Flame Length (ft)*
Change in Fire Risk	338%	5%	2%

Discussion

After analyzing all of the model outputs, there were three main factors that stood out as important for determining fire behavior – vegetation type, total fuel removed through management and sundowner conditions. The fuel types present within each VMU proved to have a large effect on fire behavior, even for fuel types within the same group, such as the SH5 (High Load, Dry Climate Shrub) and SH7 (Very High Load, Dry Climate Shrub). It became clear that the presence, or lack thereof, of 100-hour fuels affect all four of the outputs. For example, the presence of 100-hour fuels breaks up 1-hour fuel continuity, thus slowing fire spread. Furthermore, the dry climate timber shrub found at Alston Place, compared to the dry climate shrub found at the other four sites, showed that different compositions of a vegetated landscape can affect fire characteristics. Densely packed shrubs, as opposed to shrub understory with larger trees, can alter all four of the outputs, with the latter making fire more easily managed. Since Santa Barbara is a mixture of chaparral, oak woodland, riparian hardwoods, non-native and landscape d vegetation, management should focus on areas where the maximum amount of fire risk reduction can be obtained. Fire metrics react differently to the amount of fuel removed (Figure 10). Fireline intensity, heat per unit area and flame show gradual decreases in fire hazard as the percentage of fuel is removed. Rate of spread has a drastically different pattern where management seems to have little impact until roughly 85% of fuel is removed. Such a vast removal could be both impractical ecologically and aesthetically, unless placed in certain, strategic locations where response time is especially slow. It is clear that ⅔ fuel reduction notably reduces fire metrics when compared to ½ treatments. This is why, whenever possible,

management should attempt ⅔ fuel removal. Fireline intensity and flame length have reasonably linear relationships between percentage fuel removed and percentage reduction in fire risk (Figure 10). It is the goal of the fire department to reduce fire risk whenever possible, as the ⅔ removal is notably better than the ½ removal at reducing risk, higher fuel reductions should be aimed for. Regardless of the vegetation amount removed, there are costs associated with the biological assessment of the site, the machinery, and the manpower, so the marginal cost of going from ½ to ⅔ fuel removal is relatively small. Moreover, vegetation is not static, and the more vegetation that is removed initially, the fewer post-treatment maintenance trips are required. Management under sundowner conditions is difficult. Since most metrics are reduced to baseline conditions (Table 4), which are drastic improvements from sundowner conditions, we found that continued management is still crucial. The magnitude of untreated sundowner fire metrics, and potential catastrophic consequences of unmanaged areas, highlights the importance of reducing metrics to baseline conditions, as well as fasts response times by the fire department to curb the fast rate of spread.

In addition to focusing efforts on the sites that can receive a ⅔ fuel removal, we recommend focusing on the VMUs that exist inside of the Community Fuels Treatment Network (CFTN). The CFTN is a collaborative effort between the City of Santa Barbara, Goleta, Montecito, Carpinteria/Summerland, and the County of Santa Barbara to create a fuel break between the Los Padres National Forest and the city boundaries. By focusing efforts on these units within the CFTN, the Fire Department is not only protecting key points throughout the City, but they are also helping to protect the region as a whole.

While all sites are assessed by a biologist prior to fuel removal, we recommend long-term monitoring through a volunteer monitoring program. This program would be great for community engagement and could be staffed by volunteers from Santa Barbara City College, UCSB, or Westmont. Monitoring would consist of plant and site evaluations on a seasonal or annual basis. The main goal of the monitoring would be determine how, if at all, the site regeneration differs from the original condition after the fuel removal. This program would help to ensure that there are no long-term harmful effects of removing vegetation from the sites.

4. Program Transferability and Suitable Cities

Gathering information from the survey and fire modeling, we have determined the District is effective in reducing fire risk and has a high rate of acceptance by residents, so this project aimed to find other cities that could benefit from a similar special assessment program. The scope of this final stage focused on cities only in the state of California. Moreover, only cities that fall

within local responsibility areas were assessed to avoid complications, such as double taxation, with state responsibility areas.

Analytical Hierarchy Process

Topography, wildland-urban interface, vegetation, and fire frequency were used to measure the landscape necessity of a suppression assessment district for each city. These factors were then ranked in pairwise comparisons to assign weights to each variable with Analytical Hierarchy Process (AHP, K.Goepel, version 11.12.2012). Members of the Santa Barbara Fire Safe Council and of this Group Project provided input in determining these weights (Table 5). The weights are found using pairwise comparisons of each variable against each other.

Table 5. AHP outputs based off of pairwise comparisons [Eigenvalue (4.069) constancy ratio (2.6 %)]. According to experts, areas with wildland-urban interface are in greatest need of a district. Fire frequency and vegetation type are the next highest weights followed lastly by topography.

Factor	*Weight*
Wildland Urban Interface	35.6%
Fire Frequency	30.8%
Vegetation	24.1%
Topography	9.5%

ArcGIS Model

ArcGIS was used to model city suitability throughout California. Initially, landscape necessity was assessed for each city, and demographic factors were subsequently added to narrow down the analysis.

Wildland Urban Interface

A Wildland Urban Interface (WUI) layer was downloaded from the State of California Department of Forestry and Fire Protection (CalFire) FRAP data website. The WUI layer has numerous inputs such as development class, buffer distance, threat level, communities at risk and finally, a binary WUI field (1= WUI) (See Appendix F for full criteria explanations). The WUI layer was resampled to a 100 by 100 meter raster cell size to convert all layers to common units. A WUI value of “1” was reclassified as a “3” and a value of “0” was kept as a “0”. This was done to keep values constant across layers, as all values fell between “0” (low) and “3” (high) for all layers input to the model.

Fire Frequency

Fire frequency was acquired from the State of California and the Department of Forestry and Fire Protection FRAP data website. Fire rotation class intervals were calculated from fifty years of fire history on land areas and aggregated into four categories based on climate, vegetation, and land ownership (FRAP Metadata). The fire rotation interval for a given area is defined as the number of years it would take for past fires to accumulate enough burned area to equate to the total amount of a given area (FRAP Metadata). Fire rotation classes were kept in a 0 to 3 grouping to keep these data consistent with other layers. Raster size was resampled to 100 by 100 meter raster cell size.

Table 6. Fire Rotation Class. Fire rotation Interval classes ranked lowest to highest fire frequency.

Fire Rotation Class	*Description*	*Number of Years*
0	Undetermined	Undetermined
1	Moderate	>300 years
2	High	100-300 years
3	Very High	<100 years

Topography and vegetation

Topography and vegetation were gathered from a combined layer titled "Fuel Rank" from the State of California and the Department of Forestry and Fire Protection FRAP data website. The fuel rank layer used the Scott and Burgan Fire Behavior Fuel models for various weather conditions and at six different slopes to produce a surface rank. This surface rank was then supplemented with crown and ladder fuel data to reach a finalized fuel rank. The layer was already four levels but was reclassified to match the 0 to 3 scales and finally resampled to 100 by 100 meter raster cell size.

Table 7. Fuel Rank. Fire risk ranked by a combination of surface fuel type, slope, ladder and crown fuels.

Fuel Rank	*Description*
0	Little or No Hazard
1	Moderate
2	High
3	Very High

Weighted Sum

All three layers were combined in a weighted sum based off of AHP weights to find a suitability index for each city. The extreme foothill Zone of Santa Barbara received the highest possible suitability score (12) due to its topography, chaparral vegetation, and its designation as a wildland-urban interface area. Cities that have at least one raster cell within 25% of Santa Barbara's maximum index score were selected as cities with landscape need.

Income

Cities with higher income have a stronger chance of passing an assessment district according to John Bliss, Vice President of SCI Consulting Group. SCI specializes in helping public agencies within California with the establishment and administration of taxes, fees and special assessments. Only cities with a median family income greater than 75% of that in Santa Barbara ($77,000) were selected to be potentially feasible cities for program transferability. A new map was configured to display the narrowed down cities (Appendix F). Income by city data was gathered from the U.S. Census Bureau, American Community Survey, and the 2011 American Community Survey 5-Year Estimates.

Party Affiliation

The final demographic factor included in the analysis was political party affiliation. In the current political climate, cities with more Democrats than Republicans have a greater chance of approving a special assessment district (John Bliss, SCI Consulting Group). Cities with more registered Democrats were selected to determine optimal feasibility for a successful assessment district. Cities within the optimal feasibility map were deemed "optimal cities"

Results

The area within the District in Santa Barbara received the maximum score of 12 for the weighted sum based on landscape need for a fire mitigation special assessment district. Since this project aimed to find cities within 25% of Santa Barbara's value, the map for landscape need included cities whose maximum suitability scores ranged from of 9 to 12 (Figure 11). Upon configuring an optimal feasibility map (Figure 12), several options for sorting and filtering potential cities were explored. For each subset, the five highest-ranking cities were displayed.

Initially, optimal cities were sorted by highest mean suitability score to locate which cities have the highest landscape need out of the optimal cities (Table 8). Mean suitability scores are the average of all 100 x 100 meter cells within a given city's boundaries.

Table 8. Landscape Need**.** Cities with optimal feasibility sorted by highest mean suitability score.

City	*Mean Score (Maximum Score)*
Truckee	7.5 (10.7)
Mill Valley	6.8 (10.7)
Sonora	6.5 (10.7)
Diamond Bar	6.3 (12.0)
San Louis Obispo	6.0 (10.7)

Cities with large populations tend to have stronger support for special assessment districts, so cities were sorted by highest population size. The top 10 most populous cities were then sorted by mean suitability scores. These means may seem low, but due to their size, certain communities or zones within these cities could potentially pass an assessment district, like the foothill zones of Santa Barbara (Table 9).

Table 9. Highest Population. Top ten largest cities sorted by population and then highest mean suitability score.

City	*Mean Score (Maximum Score)*
Freemont	4.8 (10.7)
San Diego	4.7 (12.0)
Chula Vista	4.5 (12.0)
Riverside	4.2 (12.0)
Oakland	4.0 (10.7)

After discussing options with special assessment district expert John Bliss form SCI, it was concluded that cities satisfying the restrictions explained above on top of having a median household income of at least $100,000 annually. Cities with income over $100,000 were then sorted by mean suitability score (Table 10).

Table 10. Cities with the strongest potential. Cities with median family income over $100,000 sorted by mean suitability score.

City	*Mean Score (Maximum Score)*
Mill Valley	6.8 (10.7)
Diamond Bar	6.3 (12.0)
Hercules	5.9 (9.4)
Woodside	5.8 (9.4)
Los Gatos	5.7 (10.7)

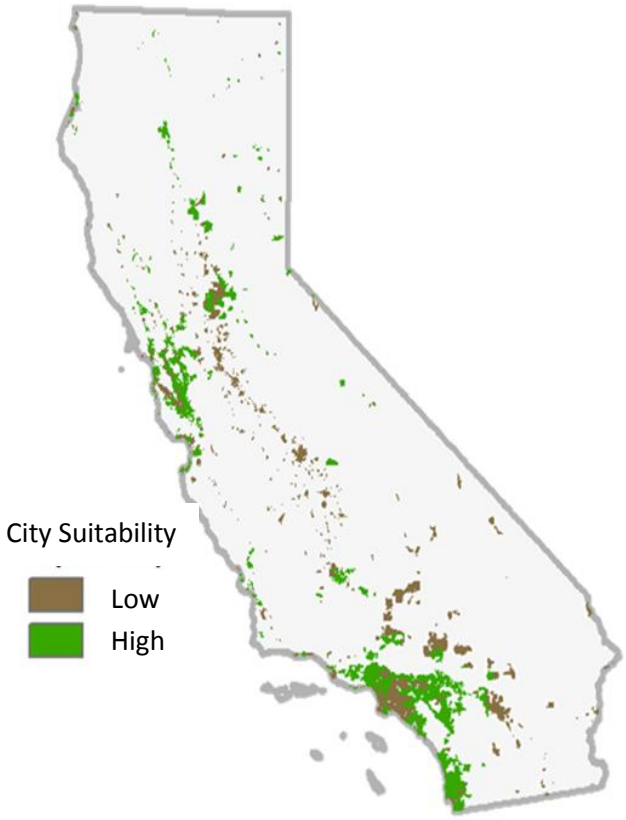

Figure 11. Cities with landscape need. Cities containing a maximum suitability score from 9 to 12 are in green while the rest are represented with brown.

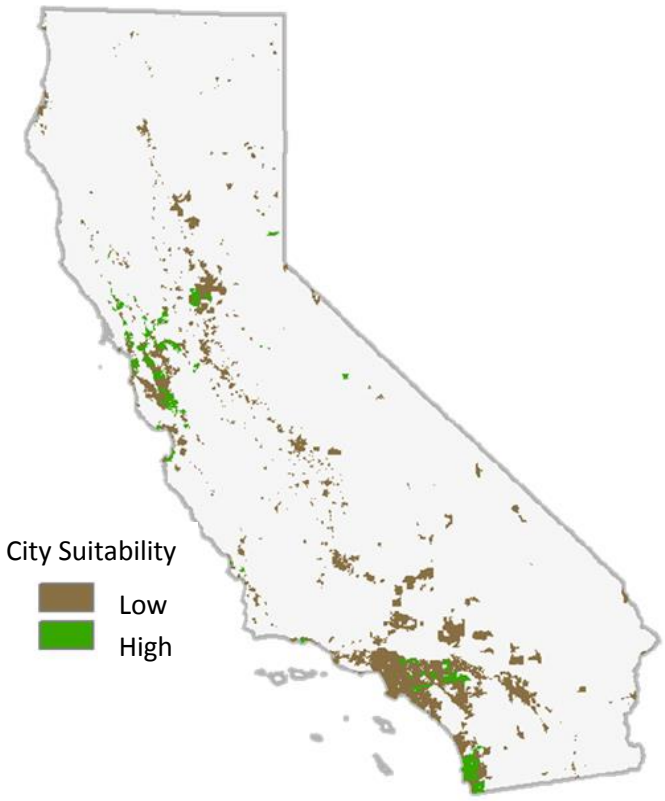

Figure 12. Cities with optimal feasibility. Cities in green represent cities that have: high landscape need more registered democrats than republicans, and at least $100,000 mean family income.

Discussion

Based off of the optimal cities alone, there are over 80 cities throughout California that could benefit from a similar special assessment district. Depending upon various demographic parameters, cities can shift ranking for optimal feasibility. The first subset of cities was sorted by mean suitability score, indicating that these cities have high fire risk across the city boundaries. Large cities often have lower means but still have areas with high fire risks. This is why the initial analysis was based off of maximum values rather than mean values. The second subset focusing on high population could be cities that have communities or neighborhoods that could utilize a special assessment district similar to the foothill zones of Santa Barbara while the rest of the city does not pay into the district. The final subset, are cities that have not only a need, but also substantial potential to approve a special assessment district. Moving forward we will work with the Santa Barbara Fire Department to create an implementation guide. We will contact the California Association of Council of Governments to help spread awareness of the potential of assessment districts. See Appendix G for letter and flyer to the California Association of Council of Governments. To conclude, the more cities that adopt strong mitigation strategies, the safer the state will be for its people and natural resources.

5. Moving Forward

Ten years after the creation of the Wildland Fire Suppression Assessment District, this study looked to determine whether or not it is approved of by residents, if it is effective in reducing fire risk, and if other cities would benefit from implementing a similar special assessment district.

The survey results indicate that the District is a resounding success in the eyes of District residents. In fact, 80% of District respondents said they believe it is beneficial and 72% said it actively creates a safer community. Although the majority of District respondents are satisfied with the program, there is an underutilization of the homeowner-scale services. Fortunately, results from this research provide several recommendations to increase use of these services. It is important to keep in mind that the recommendations provided by this research may be subject to change over time, dependent upon trends in information outlets and social media. Additionally, public opinions and perceptions may vary in the coming decade; therefore, outreach efforts should target those changing needs

The fire modeling conducted throughout this study indicates that vegetation management conducted by the Santa Barbara City Fire Department is successful at reducing fire risk. Under extreme weather conditions, such as Sundowner winds, fire management may not be as successful as it could be under normal weather conditions. It should be noted that under extreme weather patterns, fire risks are even more severe if no management action is taken. With ecological, spatial, and economic constraints in mind, vegetation management should be carried out to its furthest extent in order to reap the most benefits.

This research identified up to 80 cities that would benefit from implementing a similar fire management district. Keeping in mind that much of Santa Barbara is made up of chaparral vegetation, which has one of the most volatile fire regimes, management in other cities must be adjusted according to the local landscape. In fact, other cities may be even more successful at reducing fire risk depending on what vegetation exists within their communities. As more cities implement a similar program, California as a whole will be better equipped for fire management in the future. It is imperative that cities heed this recommendation and take advantage of the Wildfire Special Assessment District Implementation Brochure we have created (Appendix G).

Moving forward, these findings and recommendations will only help to improve the already successful Wildland Fire Suppression Assessment District. This is an exciting opportunity for other cities to follow in Santa Barbara's footsteps and develop a program of their own.

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APPENDIX A – Survey Cover Letter

Dear Resident,

The Bren School of Environmental Science & Management at UC Santa Barbara is a leading center for environmental and ecological research. For our master's research, we are collaborating with the Santa Barbara City Fire Department and the City of Santa Barbara, in conjunction with the Santa Barbara County Fire Safe Council, to assess the benefit of fire reduction programs in your neighborhood. We need your help in gathering opinions and thoughts on fire risk and prevention in your neighborhood and around your home. Please provide us with feedback by filling out and mailing the attached survey (return envelope included) by September 14, 2015.

The survey should not take more than ten minutes. For more information, please contact us at brensbfire@gmail.com.

Thank you for your participation,

Juliana Matos, Nico Alegria, and Sarah McCutcheon

Approved by the UCSB Human Subjects Committee for use thru: 6/28/2016
PURPOSE: You are being asked to participate in a research study. The purpose of the study is to assess residents' opinions and utilization of Santa Barbara City's Wildland Fire Suppression Assessment District.
PROCEDURES: If you decide to participate, you will fill this survey out to the best of your abilities and return in the envelope provided. The survey should take no more than ten minutes to complete, and we ask that you return the survey at your earliest convenience.
RISKS: There are no anticipated risks for participating in this study.
BENEFITS: There is no direct benefit to you anticipated from your participation in this study.
CONFIDENTIALITY: Other than your address being on the original envelope with the survey, your data will not be linked to your identity in any way. You do not need to include your name and address on the return envelope. **RIGHT TO REFUSE OR WITHDRAW:** You may refuse to participate and still receive any benefits you would receive if you were not in the study. You may change your mind about being in the study and quit after the study has started. You may fill out as much or as little of the survey as you wish.
QUESTIONS: If you have any questions about this research project or if you think you may have been injured as a result of your participation, please contact: Sarah McCutcheon at: brensbfire@gmail.com
If you have any questions regarding your rights and participation as a research subject, please contact the Human Subjects Committee at (805) 893-3807 or hsc@research.ucsb.edu. Or write to the University of California, Human Subjects Committee, Office of Research, Santa Barbara, CA 93106-2050

APPENDIX B.1 - Survey to District Residents

In 2006, a Wildland Fire Suppression Assessment District and an associated Fire Suppression Program was approved by voters within the City of Santa Barbara's Foothill and Extreme Foothill High Fire Hazard Zones. As you may know, this Fire Suppression District levies fees on residents in order to fund vegetation road clearance for fire response and public evacuation safety, defensible space inspections, community vegetation chipping, and fuel management projects. As a resident of the Fire Suppression District, we would like to collect information on your thoughts and opinions regarding the Wildland Fire Suppression Program.

1. How long have you lived at your current residence? ___ years ___ months
2. What do you think is the level of fire risk at your residence? Very High / High / Medium / Low / Very Low
3. Did you vote in favor of Wildland Fire Suppression Program in 2006? Yes / No / Not sure / I did not vote

For questions 4-7, please check the box that applies.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
4. The District is beneficial to residents.	☐	☐	☐	☐	☐
5. The District is successful in reducing fire risk.	☐	☐	☐	☐	☐
6. The District creates a safer community.	☐	☐	☐	☐	☐
7. The open forest lands above Santa Barbara should have more management.	☐	☐	☐	☐	☐

8. Have you ever been evacuated for a wildfire? Yes / No
9. How many times in the last 10 years have you used the free chipping services provided by the Wildland Fire Suppression Program?
   a. Once b. Two or three times c. Four or more times d. I have never used it (if not, circle best answer below)
   i. I have never heard of it ii. I do not have time iii. I do not think it would be useful
   iv. Does not pertain to my property v. other _____
10. Have you had a free defensible space inspections provided by the Wildland Fire Suppression Program?
    a. Yes b. No (if not, circle the following answer that best explains why)
    i. I have never heard of it ii. I do not have time iii. I do not think it would be useful
    iv. Does not pertain to my property v. other_____
11. How do you prepare for a wildland fire?
    a. I have an evacuation plan b. I clear vegetation surrounding my home c. My home has an agricultural buffer
    d. My home has a non-combustible roof type (including tile, asphalt, and cement shingle roofs)
    e. My home has ember-resistant vents f. My home has tempered dual-pane windows
    g. My home has other non-combustible materials h. other_____
12. Have you ever lost a home or received significant damage to a home due to a wildfire? Yes / No
    If so, what was your resulting experience with your home insurance company?_____
    _____
13. Do you rent or own your current residence? Rent / Own (Circle one)
14. Do you have any comments or suggestions regarding the Wildland Fire Suppression Program?

_____

_____

_____

15. If you would like to stay up to date on our project, please provide us with your e-mail address below.

16. If you would be willing to be contacted for a follow-up interview related to this survey, please provide your phone number below.

APPENDIX B.2 – Survey to Coastal and Coastal Interior Residents

In 2006, the Wildland Fire Suppression Assessment District was approved by voters within the High Fire Hazard Area, Foothill and Extreme Foothill Fire Zones in the City of Santa Barbara. This district levies a yearly fee on residents to fund vegetation removal, defensible space inspections, community vegetation chipping, and fuel management projects. These services are implemented to improve fire response times, evacuation routes, and overall public safety. Although you are not a resident within the Wildland Fire Suppression Assessment District, we would like to collect information on your thoughts and opinions regarding a Wildland Fire Suppression Assessment Program in your community.

1. How long have you lived at your current residence? ___ years ___ months
2. What is your perceived threat level of fire risk at your residence? Very High / High / Medium / Low / Very Low
3. Before this survey, had you heard of the Wildland Fire Suppression Assessment District that was approved by voters within the City of Santa Barbara in 2006? Yes / No

For questions 4-7, please check the box that applies.	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
4. A similar Special Benefit District would be beneficial to residents in my area.	☐	☐	☐	☐	☐
5. A similar Special Benefit District in my area would create a safer community.	☐	☐	☐	☐	☐
6. I would be willing to pay a yearly fee to receive wildfire management benefits.	☐	☐	☐	☐	☐
7. The open forest lands above Santa Barbara should have more management.	☐	☐	☐	☐	☐

8. Have you ever been evacuated for a wildfire? Yes / No
9. Have you ever lost a home or received significant damage to a home due to a wildfire? Yes / No

   If so, what was your resulting experience with your home insurance company?_____

   _____
10. Do you rent or own your current residence? Rent / Own (Circle one)
11. Do you think you could benefit from free defensible space inspections provided by SB City Fire? Yes / No
12. Do you think that your neighborhood would be safer if vegetation clearance occurred along roadways? Yes / No
13. What service(s) would make it easier for you to clear vegetation from around your house?

_____

14. How do you prepare for a wildland fire? Circle all that apply.

    a. I have an evacuation plan b. I clear vegetation surrounding my home c. My home has an agricultural buffer
    d. My home has a non-combustible roof type (including tile, asphalt, and cement shingle roofs)
    e. My home has tempered dual-pane windows f. My home has ember-resistant vents
    g. My home has other non-combustible materials h. other_____
15. What services would be most beneficial in protecting your home and/or community from a wildland fire?

_____

_____

_____

16. If you would like to stay up to date on our project, please provide us with your email below.
17. If you would be willing to be contacted for a follow-up interview related to this survey, please provide your phone number in the space below.

APPENDIX B.3 – Survey Demographic Questions to Residents

The following are *optional* demographic questions to assist us further with our analysis.

18. What is your total household income?
    a. Less than $100,000 b. $100,000 - $200,000 c. More than $200,000

19. What is your ethnicity? Circle all that apply.
    White / Hispanic or Latino / Black or African American / Native American or American Indian / Asian or Pacific Islander / Other

20. If applicable, what is your spouse's ethnicity? Circle all that apply.
    White / Hispanic or Latino / Black or African American / Native American or American Indian / Asian or Pacific Islander / Other

21. What is the highest level of education completed in your household?
    Less than High School / High School / Bachelor's Degree / Master's Degree or higher

APPENDIX C - Survey Representativeness

The special assessment district intersects four US Census Bureau tracts (Figure 1). Residents within the district often represent the higher ranges of incomes and home values for their given tract. Tracts 1.03 and 5.02 have median income values similar to the results of the survey (Table 1). Tracts 6 and 7 are slightly lower (Table 1) than the median range that we received, which was between 100,000 and 200,000 dollars. This can be attributed to the large amount of parcels that are part of these tracts, but outside the district boundary. These residents outside the district bring the median down. Chi squared tests were conducted by comparing education between district and aggregated tract data. The test was significant indicating that education levels are associated with tract and district respondents (Table 2). This difference was expected because of city and county residents outside the district are bringing values down.

Census Tracts Represented within the Special Assessment District

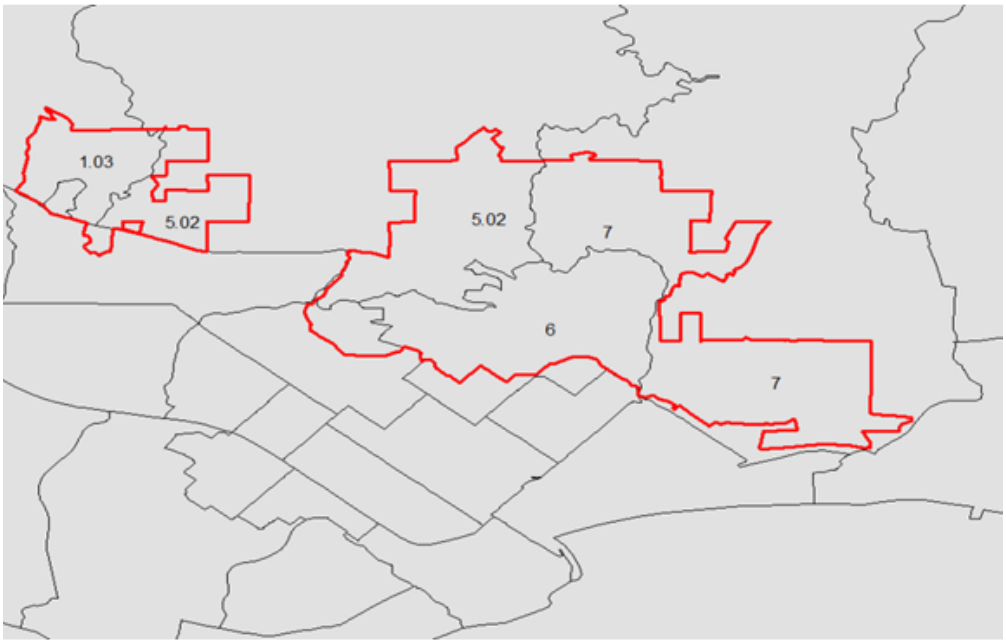


Figure 13. Census tract data. Wildland Fire Suppression Assessment District boundary in red with the four tracts that intersect the boundary.

Table 11. Median household income by tract. Source: US Census Bureau 2010

Tract	1.03	5.02	6	7
Median Household Income	$121,910.00	$111,709.00	$81,723.00	$92,109.00

Table 12. A Chi squared test was conducted comparing district responses with aggregated tract Data**.** x^2 = 202.23, df = 3, p-value < 0.001

Education level	District	Census Tract
Below High School	0%	6%
High School	8%	33%
Bachelors	32%	33%
Advanced Degree	60%	27%

APPENDIX D – Social Media Audit of the Santa Barbara City Fire Department

Overall Recommendations:

- Keep consistent formatting for terminology and logos across all social media resources.
- Reference the additional social media resources on the social media accounts, so that they are not all operating independently.
- To assess the overall reach of each social media account, I suggest using Klout.com. The site will be beneficial to see what posts are reaching what audience, and to get recommendations on how to create content that will get a larger reaction on the social media sites.
- Use LightBox Collaborative to further tailor social media messages to the events that are happening that calendar day (e.g. New Year's Eve, the Super Bowl).

Website

http://www.santabarbaraca.gov/gov/depts/fire/

The City of Santa Barbara Fire Department (the Fire Department) website is part of the City of Santa Barbara government website. Due to this, there appears to be some extraneous information and other items that make the website look a bit dated and heavy. There are also inconsistencies with the Fire Department logo (both old and new ones used) and with terminology ("defensible space inspection" vs "defensible space evaluation"). There are links on the website to the Fire Department Facebook page and the Twitter account, which is good, but throughout the website, there are not any obvious references to those other social media accounts. It would be great to let the website visitor know that they can stay up to date via other social media accounts that may be more convenient for them. The Fire Department should also work to get the Wildland Fire Suppression Assessment District events listed on the City of Santa Barbara events website calendar.

There is a specific page for the Wildland Fire Suppression Assessment District, but it is two clicks into the main website, and this may not be an obvious location for some of the website visitors. The maps used on the WFSAD page are clear and concise, but they are static maps. With the capabilities today (ESRI Online maps, R Leaflet, Google Earth, etc.) an interactive map that, at the very least, has the zoom in/out function would be a lot more user friendly and informative. I would also include a link to the fire escape garden somewhere on the webpage, maybe in the "Helpful Links" portion. In addition to that, there is also a typo on the main WFSAD webpage, so I recommend going through the website to double-check all spelling and grammar.

Wildland Fire Suppression Assessment District Blog

http://wfsad.blogspot.com/

The blog is a great additional source of information for the specific group of residents that live within the Wildland Fire Suppression Assessment District. However, it is a bit duplicative, so I recommend that the blog be used to include additional information that is not already covered on the more trafficked social media sites. Additionally, if those sites post and/or tweet about the Wildland Fire Suppression Assessment District in any way, they should include a link to the blog to increase the potential traffic to that resource. While the blog is used to target a specific group of residents that visit the Fire Department webpage, it would still be beneficial to include any time sensitive or critical information to the Wildland Fire Suppression Assessment District webpage. However, if the blog does not have a significant amount of traffic going towards it, it may be better to target the audience with this information on the Wildland Fire Suppression Assessment District webpage, or include more links to the blog on the other social media sites.

Facebook

Account: *Santa Barbara City Fire Department Information;* Likes: 3, 729; Visits: 92 *;* Rating: 4.4 of 5 stars- 21 reviews

The Fire Department does a good job of posting regularly to their Facebook account. There are a variety of topics to grab the attention of various viewers (small/large fire, alerts, fire safety information, emergency response, etc.). Most posts have associated pictures or videos that accompany the text information. There also appears to be a decent amount of foot traffic with posts receiving dozens of likes. However, I recommend that the person(s) running the Facebook page not only work on getting posts out, but also on responding to user's comments/ questions. I noticed a few comments/ questions that went unanswered, and I feel that it is important to make every user feel important and special, as well as getting valuable information to the broader audience. There were posts on the Facebook page about the Wildland Fire Suppression Assessment District, but the post only linked back to a PDF document hosted on the City of Santa Barbara Fire Department website, instead of the Wildland Fire Suppression Assessment District webpage or the blog. I would also recommend a greater effort to either integrate these sources or at least link to one another. Overall, the Facebook page looks great.

Twitter

Account: @SBCityFirePIO; Joined October 2009; Tweets: 1027; Following: 99; Followers: 698; Likes: 55

The Fire Department appears to be very active on Twitter with 1,027 tweets and 698 followers. Tweets are both informative towards emergency situations (fire, gas leak, storms, etc.) and important events (annual chipping, annual Longboard Classic, etc.). They also do a good job of using holidays and calendar events to tweet relevant information (Christmas, Super Bowl, etc.). The account has a nice mix of words, pictures, and videos in the tweets. It is also great to see the tweets that redirect to the Fire Department Facebook page. This not only increases the reach of The Fire Department, but it allows them to include descriptions longer than the 140-character restriction of their tweets. However, only 55 likes for 1,027

tweets and 698 followers seems low. This may be a sign that those 698 followers are not active Twitter users, or it could mean that they are not actively following the Fire Department posts for whatever reason.

Instagram

Username: santabarbaracityfire; Posts: 23; Followers: 277; Following: 16

There is no link to the Instagram account on the Fire Department website, nor on any other social media account. Additionally, the last post was 23 weeks ago, so this account may no longer be active. A good example account to look at is the Santa Barbara County Firefighters Instagram account. It is an active account with over 2,000 followers, and could serve as a great source of post ideas.

YouTube

With all of the videos that are posted to the SB City Fire Department Facebook page, many with original content, it seems like having a YouTube channel would be a great idea. The City Trash and Recycling-Santa Barbara and the SB Creeks Division (both with the City of Santa Barbara) are great example channels to look at and model the Fire Department YouTube channel after. The channel could include coverage of current fires, highlights of past fires, mock evacuation drills, safety and best practices for fire prevention in the household, outreach, and many other extraneous events and information. A great use of this channel, to benefit wildland fire efforts, could include defensible space walkthroughs, information on the best and worst plants to plant for fire safety, a tour of the Firescape Garden, and an interview with a wildland fire fighter (maybe highlight the best practices that they have noticed in the past that are most effective at saving a home).

APPENDIX E – BehavePlus

"Very Dry" fuel moisture levels were used for 1-hour, 10-hour and 100-hour fuels to reflect the local weather and drought conditions. Live fuel moisture data were gathered by Santa Barbara City Fire Department

Table 13. Fuel moisture scenario input for BehavePlus behavior modeling.

Fuel Type	Fuel Percentage
1-Hour	3 %
10-Hour	4%
100-Hour	5%
Live Herbaceous	30%
Live Woody	60%

Las Canoas and St. Mary's Vegetation Management Units were initially SH 7 fuel types and both received 2/3 fuel reduction treatments. The following charts are Las Canoas outputs, but St. Mary's values are the same with a slope range to 70%.

Table 14. BehavePlus output results for range of slopes in Las Canoas and St. Mary's for pre-treatment scenario with standard wind conditions.

Las Canoas Pre-Treatment Standard Winds

Slope %	ROS (max) ch/h	Heat per Unit Area Btu/ft2	Fireline Intensity Btu/ft/s	Flame Length ft
25	46.4	2545	2163	15.4
30	48.6	2545	2267	15.7
35	51.2	2545	2391	16.1
40	54.3	2545	2533	16.6
45	57.7	2545	2694	17.0
50	61.6	2545	2874	17.5
55	65.9	2545	3073	18.1
60	70.5	2545	3291	18.7
65	75.6	2545	3528	19.3
70	81.1	2545	3783	19.9
75	87.0	2545	4058	20.6
80	93.3	2545	4352	21.2

Table 15. BehavePlus output results for range of slopes in Las Canoas and St. Mary's for post-treatment scenario with standards wind conditions.

Las Canoas Post-Treatment Standard Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	45.9	552	465	7.6
30	47.9	552	485	7.7
35	50.2	552	508	7.9
40	52.8	552	534	8.1
45	55.8	552	565	8.3
50	59.1	552	599	8.5
55	62.8	552	636	8.8
60	66.9	552	677	9.0
65	71.3	552	722	9.3
70	76.0	552	770	9.6
75	81.1	552	821	9.9
80	86.6	552	877	10.2

Table 16. BehavePlus output results for range of slopes in Las Canoas and St. Mary's for pre-treatment scenario with Sundowner wind conditions.

Las Canoas Pre-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	589.1	2545	27483	49.6
30	591.3	2545	27588	49.7
35	593.9	2545	27711	49.8
40	597.0	2545	27853	49.9
45	600.4	2545	28014	50.0
50	604.3	2545	28194	50.2
55	608.6	2545	28393	50.3
60	613.2	2545	28611	50.5
65	618.3	2545	28848	50.7
70	623.8	2545	29104	50.9
75	629.7	2545	29378	51.1
80	636.0	2545	29672	51.3

Table 17. BehavePlus output results for range of slopes in Las Canoas and St. Mary's for pre-treatment scenario with Sundowner wind conditions.

Las Canoas Post-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	269.5	552	2728	17.1
30	269.5	552	2728	17.1
35	269.5	552	2728	17.1
40	269.5	552	2728	17.1
45	269.5	552	2728	17.1
50	269.5	552	2728	17.1
55	269.5	552	2728	17.1
60	269.5	552	2728	17.1
65	269.5	552	2728	17.1
70	269.5	552	2728	17.1
75	269.5	552	2728	17.1
80	269.5	552	2728	17.1

Las Tunas and Hillcrest Vegetation Management Units were both initially SH5 fuel types and received ½ fuel reduction treatments. The output charts presented are for Las Tunas but Hillcrest values will be the same with a slope range up to 60%.

Table 18. BehavePlus output results for range of slopes in Las Tunas and Hillcrest for pre-treatment scenario with standard wind conditions

Las Tunas Pre-Treatment, Standard Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	69.9	1885	2417	16.2
30	73.1	1885	2527	16.5
35	76.9	1885	2658	16.9
40	81.3	1885	2809	17.4
45	86.2	1885	2980	17.8
50	91.7	1885	3171	18.4
55	97.9	1885	3382	18.9
60	104.5	1885	3613	19.5
65	111.8	1885	3864	20.1
70	119.7	1885	4136	20.7
75	128.1	1885	4427	21.4
80	137.1	1885	4739	22.1

Table 19. BehavePlus output results for range of slopes in Las Tunas and Hillcrest for post-treatment scenario with standards wind conditions.

Las Tunas Post-Treatment, Standard Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	69.2	715	907	10.3
30	72.1	715	945	10.5
35	75.6	715	990	10.7
40	79.5	715	1042	11.0
45	84.0	715	1101	11.3
50	89.1	715	1167	11.6
55	94.6	715	1240	11.9
60	100.7	715	1320	12.3
65	107.3	715	1407	12.6
70	114.5	715	1500	13.0
75	122.2	715	1601	13.4
80	130.4	715	1708	13.8

Table 20. BehavePlus output results for range of slopes in Las Tunas and Hillcrest for pre-treatment scenario with Sundowner wind conditions.

Las Tunas Pre-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	925.1	1885	31969	53.1
30	928.3	1885	32079	53.2
35	932.1	1885	32210	53.3
40	936.5	1885	32361	53.4
45	941.4	1885	32532	53.6
50	946.9	1885	32723	53.7
55	953.0	1885	32934	53.9
60	959.7	1885	33165	54.0
65	967.0	1885	33416	54.2
70	974.9	1885	33688	54.4
75	983.3	1885	33979	54.6
80	992.3	1885	34291	54.9

Table 21. BehavePlus output results for range of slopes in Las Tunas and Hillcrest for post-treatment scenario with Sundowner wind conditions.

Las Tunas Post-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
25	570.3	715	7473	27.2
30	570.3	715	7473	27.2
35	570.3	715	7473	27.2
40	570.3	715	7473	27.2
45	570.3	715	7473	27.2
50	570.3	715	7473	27.2
55	570.3	715	7473	27.2
60	570.3	715	7473	27.2
65	570.3	715	7473	27.2
70	570.3	715	7473	27.2
75	570.3	715	7473	27.2
80	570.3	715	7473	27.2

The Alston Place Vegetation Management Unit was initially a TU5. After a 2/3 fuel reduction it became a TU1.

Table 22. BehavePlus output results for range of slopes in Alston Place for pre-treatment scenario with standard wind conditions.

Alston Place Pre-Treatment, Standard Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
20	10.6	3007	582	8.4
25	11.1	3007	610	8.6
30	11.7	3007	645	8.8
35	12.5	3007	687	9.1
40	13.3	3007	734	9.4
45	14.3	3007	788	9.7
50	15.4	3007	849	10.0
55	16.6	3007	916	10.4
60	17.9	3007	989	10.7

Table 23. BehavePlus output results for range of slopes in Alston Place for post-treatment scenario with standard wind conditions.

Alston Place Post-Treatment, Standard Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
20	3.5	460	30	2.1
25	3.7	460	31	2.2
30	3.9	460	33	2.2
35	4.2	460	35	2.3
40	4.5	460	38	2.4
45	4.8	460	40	2.5
50	5.2	460	43	2.6
55	5.6	460	47	2.6
60	6.0	460	51	2.7

Table 24. BehavePlus output results for range of slopes in Alston Place for pre-treatment scenario with Sundowner wind conditions.

Alston Place Pre-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
20	125.8	3007	6937	26.3
25	126.3	3007	6965	26.4
30	127.0	3007	7000	26.4
35	127.7	3007	7042	26.5
40	128.6	3007	7090	26.6
45	129.6	3007	7144	26.7
50	130.7	3007	7204	26.8
55	131.9	3007	7271	26.9
60	133.2	3007	7344	27.0

Table 25. BehavePlus output results for range of slopes in Alston Place for post-treatment scenario with Sundowner wind conditions.

Alston Place Post-Treatment, Sundowner Winds

Slope	ROS (max)	Heat per Unit Area	Fireline Intensity	Flame Length
%	ch/h	Btu/ft2	Btu/ft/s	ft
20	10.6	3007	582	8.4
25	11.1	3007	610	8.6
30	11.7	3007	645	8.8
35	12.5	3007	687	9.1
40	13.3	3007	734	9.4
45	14.3	3007	788	9.7
50	15.4	3007	849	10.0
55	16.6	3007	916	10.4
60	17.9	3007	989	10.7

APPENDIX F- Wildland-Urban Interface Layer Inputs

The CalFire WUI layer has numerous inputs such as development class, buffer distance, threat level, communities at risk that culminate into a binary a binary WUI field (1= WUI). In order for an area to be classified as WUI it must meet these criteria:

1. Threat to people: Within a max distance of 2400 m from high, very high and extreme threat levels.

Table 26. Fire Threat Level. Initial threat level classification from CalFire data before reclassification.

Threat level	Description
-1	Little
1	Moderate
2	High
3	Very high
4	Extreme

2. Development Buffer: it must be characterized by being a development class of 2-4 or within a buffer of 2400 m of a development class 2-4.

Table 27. Development Class. CalFire development class distribution.

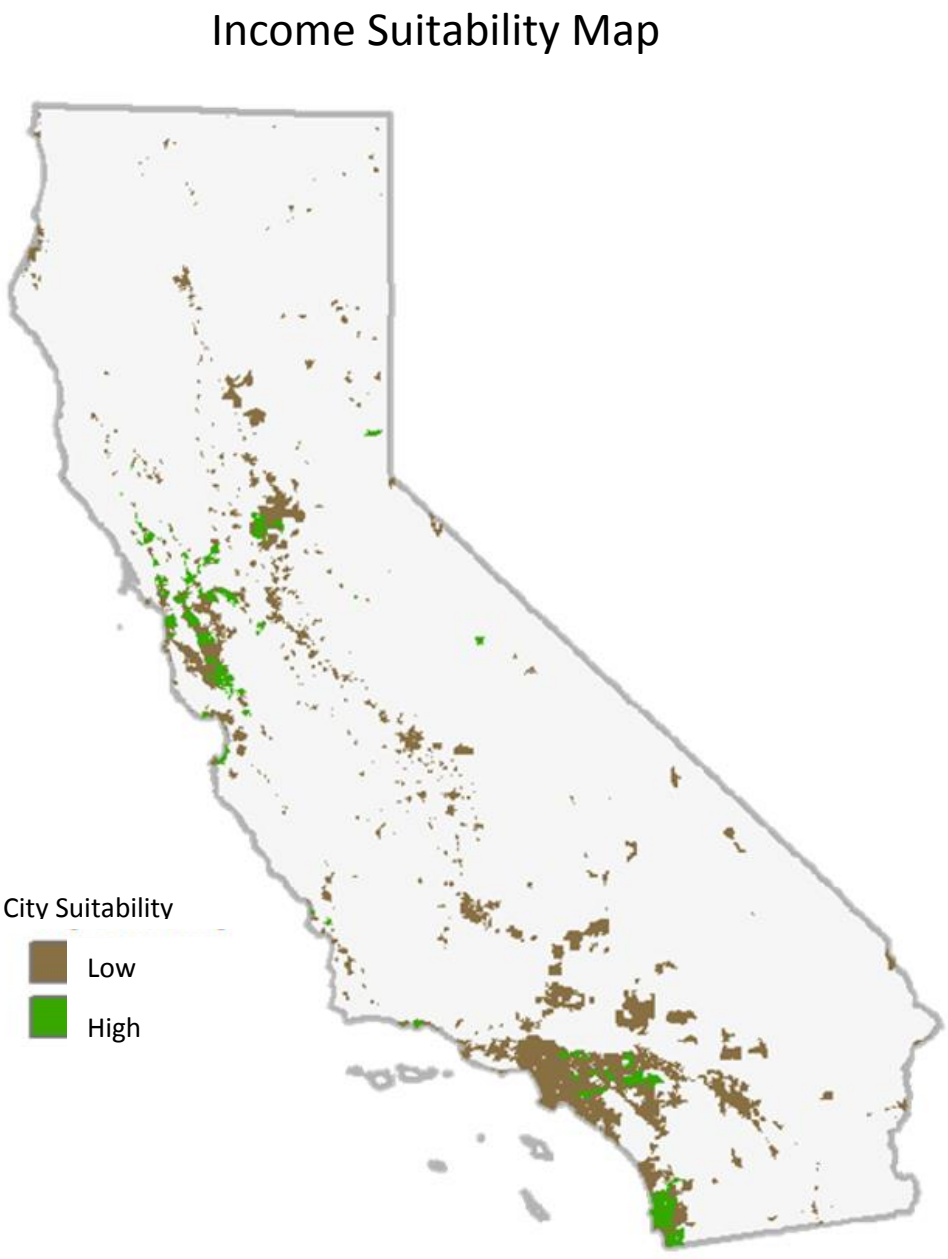
Development Class	Housing Density and Land Use
2	1 unit per 20 acres to 1 unit per 10 acres
2	1 unit per 10 acres to 1 unit per 5 acres
3	1 unit per 5 ace to 1 unit per 1 acre
4	1 unit per acre to 2 units per acre
4	2 units per I acre to 5 units per acre
4	More than 5 per acre

3. Community at risk: development class 2-4 with a threat level of “High” or greater.

Intermediate Map of Feasible Cities

The income constraint map is an intermediate step between the Landscape map and Optimal Cities map. All cites have median family income within 25% of Santa Barbara's or greater.

Figure 28. Income suitability. Green cities have both a high landscape need and meet the income constraint of 25% or greater of Santa Barbara's median family income.



APPENDIX G – Letter and Brochure to California Association of Council of Governments

Implementing a Wildland Fire Suppression Assessment District

Dear California Association of Council of Governments,

As we enter our fifth year of the historic California drought, and with the fire season quickly approaching, it is necessary to take all precautions to protect the safety and wellbeing of your constituents. In an effort to protect your citizens, it may be in your city's best interest to implement a special assessment district that levies annual fees for enhanced and increased fire protection. The City of Santa Barbara is the first city in the country to implement such a district, and for the past nine years since voter approval it has shown great success. The fire department implements the district, and the funds raised from the district augment the yearly expenses, allowing for better fire protection of homes in the wildland urban interface. A multi-criteria analysis shows that your city would also benefit from a similar district due to its weather, topography, and demographics. For more general and Santa Barbara-specific information, please review the attached fact sheet.

Sincerely,

Nico Alegria, Juliana Matos, Sarah McCutcheon
Bren School of Environmental Science & Management

Implement a Special Assessment District for Additional Wildfire Protection in Your City!

What is a wildfire special assessment district?

Fire in the wildland urban interface (WUI) is a growing problem, causing destruction of property, water supply issues, and landslides, in addition to health and safety issues for residents. However, cities have very few policy tools for managing fuels and fire in the WUI. **A special assessment district for residents in extreme high-fire zones can levy fees necessary for funding the extra fire protection that residents need.**

Santa Barbara has a unique special assessment district called the Wildland Fire Suppression Assessment District. This brochure provides lessons learned from this one-of-a-kind fire management district. The primary goal is raising funds to manage fuels and fire risk on both public and private lands in their WUI. Voters approved the district in 2006.

What are the benefits?

There are general benefits to the community through reduced fire incidence and fire intensity.

Special benefits to constituents in the District are:

- Decreased emergency response times through cleared evacuation routes
- Decreased fire intensity
- Protection of real property assets
- Enhanced utility and desirability of properties
- Protection of views, scenery, and other resource values
- Heightened fire risk awareness

The greatest benefits resulting from this program are reduced fire risk and avoided losses.

FACT:

Between 2004 and 2013, California experienced

37,432 fires

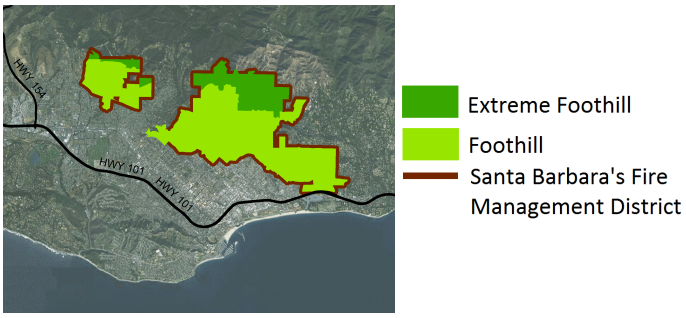
1.6 million acres burned

$4 billion lost from fires

Who may be included?

- Homes in high fire danger areas could vote for a special wildfire protection district
- High fire areas are determined by vegetation, topography, and weather
- Special attention should be paid to homes located near difficult to navigate roads, high density areas, and homes without retrofits of fire safe materials

In Santa Barbara, 3,550 homes reside within high fire risk areas in the foothills; therefore, the assessment district protects approximately 10% of the city.



How does it work?

The assessment fees fund the following:

- Implementation of vegetation management programs
- Implementation of defensible space and fire prevention inspections
- Chipping assistance program for cleared vegetation
- Expansion of the vegetation road clearance program to cover all public roads within the high fire hazard area. This reduces fuel, enhances evacuation routes, and decreases fire response times.

In Santa Barbara during the 2013-2014 fiscal year, 138 tons of vegetation was cleared from 15 miles of roads, 250 tons of vegetation was chipped, and 47 defensible space inspections occurred.

What are the costs?

- Each household within the district pays a fee that contributes to the operating costs of the district
- The costs cover materials, hourly wages for labor, and administrative support
- A majority of that cost can be recovered by the annual fee determined by the residents, and the rest of the costs are covered by a City Council contribution or the general benefits received by the city

In Santa Barbara, for the 2013-2014 fiscal year, the yearly cost was $248,907. The average fee is $75 per single family home and is increased each year by the Los Angeles Consumer Price Index (not to exceed 4% per year).

District Services

An annual fee is levied to residents in the District to fund vegetation road clearance for fire response and public evacuation safety, defensible space consultations, community vegetation chipping, and fuel management projects. Over the past eight years, fire department personnel have cleared 143 miles of roads, performed over 300 voluntary defensible space consultations, chipped over 3,200 tons of brush, and completed 126 acres of fuel management projects. All of these services would not be possible without funds raised from the District.

Vegetation Road Clearance

Defensible Space Consultation

Community Vegetation Chipping

One of the large-scale services provided by the Fire Department is vegetation management in areas with unique hazards such as heavy, flammable vegetation, lack of access due to topography and roads, and/or firefighter safety. These selected areas are known as Vegetation Management Units (VMUs). In most cases, the Fire Department removes between 1/2 and 2/3 of the vegetation found in these high fire hazard areas; the pictures below represent a VMU before and after 2/3 vegetation removal.

Before

After

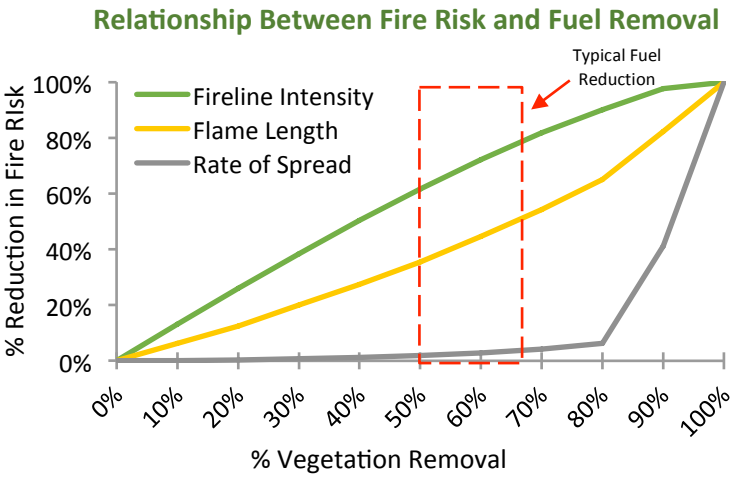
HOW TO ENSURE MAXIMUM UTILIZATION OF SERVICES IN YOUR CITY

1. **Strategic communication**
   It is important to target residents to increase fire risk awareness and encourage use of the District's services. Frequent e-mail updates and a strong social media presence will bolster residents' participation.
2. **Friendly service naming**
   Santa Barbara previously used terminology including "defensible space *inspections*", which tends to have a negative connotation. To address this, a friendlier term such as "defensible space *consultations*" is well received. Be sure to avoid terms that imply penalties!
3. **Flexible scheduling**
   To accommodate residents who are not available during the 9-5 Monday-Friday work schedule, consider adjusting the scheduling times of the services provided.

Vegetation Management is Effective

Ten years after the District's inception, the City of Santa Barbara Fire Department was interested in a comprehensive evaluation of the District and its efforts towards reducing threat from wildfire. In response, three graduate students from UC Santa Barbara's Bren School of Environmental Science & Management completed a thesis project that looked at several aspects of the District to determine its success.

To assess the effectiveness of the vegetation management program to reduce fire risk, a fire behavior modeling software called BehavePlus was used. Five representative vegetation management units were selected to model the change in fire behavior from pre- to post-treatment and under two different wind conditions. Pre-treatment modeling assessed fire behavior under no vegetation management, while post-treatment measured fire metrics based on recorded vegetation removal by the Fire Department. The first wind scenario was "standard" wind speeds of 6 mph. The second scenario was the more extreme wind conditions that can be observed during the summer months and can reach speeds up to 60 mph.

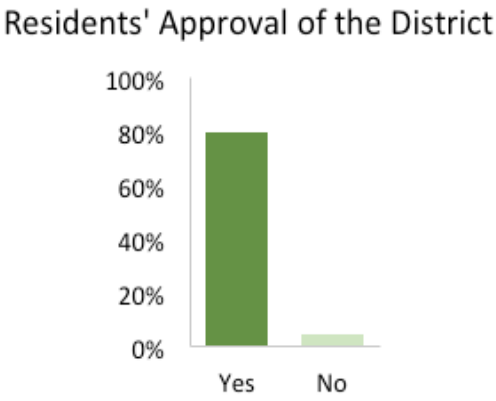


The chart on the left shows the linearity of response in fire risk reduction to vegetation removal in **chaparral ecosystems**, indicating that more removal is better. Note that the rate of spread is not affected until approximately 85% of fuel is removed. This highlights the importance of a quick response time by the fire department.

Model findings showed that management under extreme wind conditions, where flame lengths can reach up to 50 feet, is less effective than during standard winds. However, vegetation removal can reduce flame lengths down to approximately 15 feet, making the fire much more manageable.

80% of Santa Barbara Residents Approve

To determine the overall attitudes of residents towards the District and their use of its services, a survey was circulated to all 3,323 homes within the special assessment district.



50% of respondents have used the chipping services at least once.

Results from the survey showed that **80% of residents approve** of the Wildland Fire Suppression Assessment District. In fact, 72% of respondents stated that they believe the District **actively creates a safer community**.

Hear what respondents had to say:

"This program is beneficial to our property and the wildlife habitat around our home!"

"Thank you! The District makes me feel more secure!"

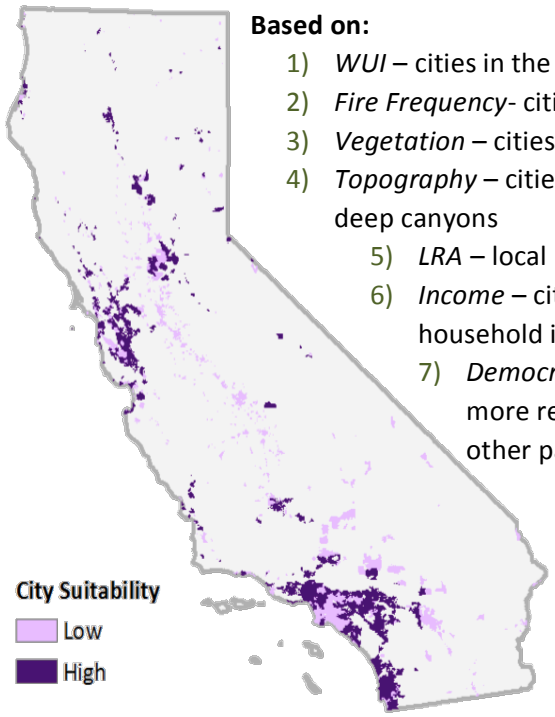
"Great value for the extra tax we pay!"

"Keep up the good work! My neighbors use the chipping service and we know that it will improve the safety in our neighborhood!"

Other Suitable Cities

American Canyon	Napa
Anaheim	Novato
Antioch	Oakland
Azusa	Pacifica
Brentwood	Palm Springs
Brisbane	Palmdale
Calistoga	Pasadena
Chico	Perris
Chino	Petaluma
Chula Vista	Pittsburg
Claremont	Pleasanton
Cloverdale	Rancho Cordova
Colton	Rialto
Concord	Richmond
Crescent City	Riverside
Cupertino	Sacramento
Diamond Bar	San Bernardino
Eastvale	San Diego
El Cerrito	San Francisco
Fairfield	San Jose
Fontana	San Luis Obispo
Fremont	San Rafael
Gilroy	Santa Barbara
Hayward	Santa Cruz
Healdsburg	Santa Rosa
Hercules	Saratoga
Jurupa Valley	Seaside
Lakeport	Sierra Madre
Lompoc	Sonora
Los Angeles	South San Francisco
Los Gatos	St. Helena
Mammoth Lakes	Tracy
Marina	Truckee
Martinez	Union City
Mill Valley	Vacaville
Milpitas	Vallejo
Monrovia	Walnut
Monterey	Walnut Creek
Moreno Valley	Whittier
Morgan Hill	Windsor
Morro Bay	Woodside

FIND YOUR CITY ON THIS LIST AND START THE JOURNEY TOWARD PROTECTING YOUR RESIDENTS FROM WILDFIRES!



Based on:

1) *WUI* – cities in the wildland urban interface
2) *Fire Frequency*- cities with high wildfire events
3) *Vegetation* – cities with flammable vegetation
4) *Topography* – cities with steep slopes and deep canyons
5) *LRA* – local responsibility areas selected
6) *Income* – cities with >$60,000 average household income
7) *Democratic leaning* – cities with more registered Democrats than other parties

IMPLEMENTING A FIRE MANAGEMENT DISTRICT

In compliance with Proposition 218, any new fee, assessment, levy, tax, etc. for a special assessment district must be approved by the constituents in the district. Unlike a tax, which requires two-thirds voter approval, only a majority vote, weighted proportionally for each property, is needed for a benefit assessment. To begin the process, a notice of the assessment is posted, and an assessment ballot is mailed to property owners within the district. There must be a 45-day return period, followed by a public hearing. If approved, the City Council takes action by a resolution to levy the assessment. After the initial vote, the City Council votes yearly for renewal. There must also be a public meeting to preliminarily approve a budget for the next year's costs and services, which are supported yearly by an engineer's report. The report must include the consumer price index adjustment, the new maximum authorized assessment rate, the yearly budget, and the amount to be charged to each parcel.

CONTACT INFORMATION

For more on the findings of this project, visit **bren.ucsb.edu/~sbfire**

For more about Santa Barbara's Wildland Fire Suppression Assessment District, contact Chris Braden, **805-564-5737**

Fore more on how to get started on implementing a special assessment district, contact John Bliss, *Vice President of SCI Consulting Group* at **707-430-4300**

CITY OF SANTA BARBARA FIRE DEPARTMENT

BRENSCHOOL UC SANTA BARBARA

SCIConsultingGroup