CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

AN EXPLORATION OF LANDSCAPE LEVEL FUEL TREATMENT STRATEGIES FOR WILDLAND FIRE MITIGATION IN THE SANTA MONICA MOUNTAINS OF SOUTHERN CALIFORNIA

A thesis submitted in partial fulfillment of the requirements
For the degree of Master of Arts in Geography,
Geographic Information Science Program

By

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May 2012

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Acknowledgments

Initially, I would like to convey my thanks to the members my thesis committee, Amalie Orme, Yifei Sun and Helen Cox, for their patience and understanding in the development of this thesis. They were not only forgiving of my false starts, change in direction and expansion of the original topic, but they provided support and encouragement at every step in the process. I would particularly like to thank my committee chair, Helen Cox, who encouraged the growth of this paper beyond the narrow technical scope of the original draft. Her persistence and support assisted in opening a new widow on my understanding of the southwestern wildfire phenomena. Without her intervention the impact of early California on wildland fire would have remained hidden.

I wish to express my gratitude to the staff and professors of the Geography Department for providing me the opportunity to expand my understanding and knowledge of this exciting field. With that said, I would like to offer special thanks to Graduate Advisor James Craine. His due diligence and willingness to intercede on my behalf allowed me to be admitted into the GIS program.

To my friends and colleagues within the fire service and the conservation community, thank you for your invaluable input and acceptance. My sincere appreciation goes to my old friend, Don Wallace, for the hours of discussion, tolerance and red wine that have led to many of the insights within this work. While I take full responsibility for the findings, he has offered an invaluable perspective into both the fire protection and the environmental side of the equation.

To my family and friends I wish to offer my apologies for the dozens of missed barbeques and family gatherings. While I cannot guarantee greater attendance in the future, the completion of this task will greatly limit my excuses. To my wife, friend, and chief publicist, Lisa, I offer only continued love, for without her editorial skills, support and encouragement this project would not have been accomplished.

For all those ships I've passed in the night, you have not been forgotten……. thank you, and may your careers be enhanced by my lack of acknowledgement.

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ABSTRACT

AN EXPLORATION OF LANDSCAPE LEVEL FUEL TREATMENT STRATEGIES FOR WILDLAND FIRE MITIGATION IN THE SANTA MONICA MOUNTAINS OF SOUTHERN CALIFORNIA

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This project explores the origins of the wildland fire threat within the urban interface of the Santa Monica Mountains and the Southern California region. It identifies the social and economic events that have transformed the region from a historically low intensity fire environment, into the current high intensity fire environment. It deviates from the conventional wisdom of what constitutes "native vegetation" and provides the reader with an alternative view that reveals new possibilities for wildland fire mitigation.

Using fire modeling, this project investigates the landscape nature of wildland fire activity within the Santa Monica Mountains and provides numerous examples of this wildfire relationship at the regional level. These new insights demonstrate the landscape nature of the fire linkage between the Santa Monica Mountains, Simi Hills and the Santa Susanna Mountains. This research demonstrates the methods and techniques necessary to identify those wildfire relationships, and provides examples of how to extinguish that relationship.

This project concludes with an evaluation of the impact of landscape level fuel treatment strategies on wildland fire risk in the urban interface of the Santa Monica Mountains. Using native vegetation and landscape level fuel management strategies, this paper demonstrates that it is possible to greatly reduce the probability of catastrophic wildland fire loss while maintaining a vibrant natural environment. Using FlamMap, a wildland fire modeling system and goal directed geovisualization; this research describes the fire behavior, prescribes a course of action, and assesses the impact of that action on residential structure loss. This research defines fuel treatment strategies that can be applied at the landscape level to contain large scale fire events, and to shield individual structures and residential communities at the parcel level. While these methods are mainly directed at fire mitigation, their application will also provide for enhanced firefighter safety and increased fire suppression opportunities.

Section 1: INTRODUCTION

For the past several decades, the southern California region and the Santa Monica Mountains in particular, have been burdened with the increasing presence of wildland fire. During this period, wildland fire has destroyed thousands of homes, taken dozens of lives and cost millions of dollars. In southern California, during a six day period in 2007 wildland fires consumed 518,021 acres, occupied more than 20,000 firefighters, destroyed 2180 homes and cost $100 million in fire suppression resources (Wildland Fire Lessons Learned Center 2007). Currently, there are two competing hypotheses for the root cause of this phenomenon (Goforth and Minnich 2007). The first, expressed by Minnich and Chou (1997) is that our current dilemma is the result of decades of fire suppression that has disrupted the natural spatial patterns of the native vegetation and has led to larger and larger chaparral fed wildfires. The second, which appears to be the prevailing view, is that large "stand replacing" wildfires are the natural order of the southern California fire regime and has existed long before organized fire suppression (Keeley et al. 1999).

The followers of the Keeley narrative imply that the extent of wildland fire risk is the direct result of recent population increases and their expansive growth into areas previously not occupied. This view sees the resident as an intruder who is damaging a fragile environment; therefore, the urban interface fire risk is the direct result of these individual choices, and the solution is mainly in the hands of the resident. Furthermore, some followers emphasize that fuel management practices directed toward landscape scale fire mitigation methods, are endangering a fragile Mediterranean environment and that these practices should be minimized (Longcore 2003).

This perspective is currently being institutionalized as the "Santa Monica Mountains Community Wildfire Protection Plan" (SMMCWPP 2010), by a multi-agency planning effort. The plan is intended to be a collaborative effort among local governments, fire protection professionals and residents, to prepare a community-wide fire protection plan. This effort, financed by national fire protection funds, is intended to identify risks, develop fire mitigation strategies, prioritize fire safety needs and generally prepare the community for wildland fire. The boundaries of the planning area are essentially from the Los Angeles City line on the east, to the Oxnard plain on the west, the 101 Freeway on the north, and the Pacific Ocean on the south (Map 1).

While the objective of this effort is laudable, its outcome is doubtful, based upon a number of questionable assumptions and misstatements. First, the plan states, "that the native shrubland is the dominant vegetation type and its conversion to grasslands make the region more prone to fire" and "more dangerous for firefighting." (SMMCWPP 2010: 3). Second, that "the natural fire regime of the Santa Monica Mountains is one of infrequent, high-intensity fires" (SMMCWPP 2010: 9). Finally, that "substantially reducing fire intensity over large portions of the landscape is not possible." (SMMCWPP 2010: 9). This perspective is emphasized in the following quote from the draft fire protection plan for the Santa Monica Mountains:

> "An important overarching point must be made about the role of vegetation in relation to fire behavior and patterns of wildfire in the vegetation types of these mountains. Given that large fires are so strongly associated with Santa Ana winds, annual patterns of wildfire are not as closely correlated with vegetation conditions here as in other parts of the western US, where factors such as fuel composition, vegetation (fuel) age, and elapsed time since the last fire (with a fuel build-up over time) play a more significant role in fire behavior. This situation and fuel-treatment rationale do not apply to the mostly shrubland vegetation types of the Santa Monica Mountains, where human activities are mainly responsible for an increase in annual area burned. Therefore fuel management in the Santa Monica Mountains area is most efficient when carefully considered and strategically placed—especially near homes—to have the greatest effect **as opposed to attempting to change landscape-level fire behavior.**" (SMMCWPP 2010:18) (Emphasis added)

This thesis will provide an alternative view to the root causes of the urban interface wildland fire threat, demonstrate new techniques for analysis of the wildland fire phenomenon, use those techniques to identify specific targets of opportunity, and offers new landscape level fuel management strategies for wildland fire mitigation in the Santa Monica Mountains. Furthermore, this thesis will show how the current wildland interface fire dilemma; at the regional level is the direct result of the transition from the land use practices of the indigenous people, to the land use demands of a pastoral-agricultural economy, and the subsequent conversion of the region into a wage-based economy. This thesis will demonstrate that the current wildland fire problem is an artifact of this economic transition and our failure to deal with it.

Section 2: HISTORICAL CONTEXT

Although the position of the SMMCWPP planning agencies represent the prevailing view and has significant support, this position ignores a number of inconvenient truths. First, the native people of southern California had long managed the local environment with fire and produced vast areas of grassland within the Santa Monica Mountains. Second, from the period of Spanish colonization through the early 20th century, the dominant vegetation type within the Santa Monica Mountains and within the region was grass. Finally, a grassland fire environment is one of the least hazardous environments from the stand- point of fire suppression forces. To ignore these issues renders any fire mitigation strategy based upon the current view, as a practice in futility and relegates the residents of the Santa Monica Mountains and the surrounding region to decades of ever larger, ever more intense wildland fires.

First Contact

The evidence indicates that at the time of first contact, the indigenous people, and particularly the Chumash, depended upon an environment that was significantly fire managed. From the first European contact with the California indigenous people, coastal explorers have remarked on the use of fire by the California Native Americans. In 1542 Juan Rodriguez Cabrillo, after having sailed along “a mountains coast, overhung with smoke,” (Ingersoll 1908:5) crossed from Catalina Island to drop anchor in San Pedro Bay which he named “Bahia de Fumos” (Bay of Smokes). Sixty years later, Sebastian Vizcaino reports a similar experience when he “found clouds of smoke hanging over the headlands and bays of the coast” (Guin 1902: 37). Throughout this period the Chumash people occupied large segments of the Santa Monica Mountains, with the Tongva people occupying the Los Angeles coastal plains (Map 8).

Other authors had remarked how the Chumash managed their environment with extensive burning to expand seed and acorn production, hunt for small game, and increase the forage for larger herd animals such as elk, deer and antelope (Timbrook et al 1982). Guin speculated that the smoke from fire was caused by the native people using small fires to capture rabbits and other small game, noting that…..

> “When the summer heat had dried the long grass of the plains and rendered it exceedingly inflammable the hunters of the Indian villages set out on hunting expeditions. Marking out a circle on the plains where the dried vegetation was the thickest they fired the grass at several points in the circle. The fire eating inward drove the rabbits and other small game back and forth across the narrowing area until, blinded with heat and scorched by the flames, they perished. When the flames had subsided the Indian secured the spoils of the chase, slaughtered and ready cooked. The

> scorched and blackened carcasses of the rabbits might not be a tempting tidbit to an epicure, but the Indian was not an epicure.” (Guin 1902:37)

First person accounts indicate that these activities produced vast expanses of grassland that were maintained by periodic burning. Juan Crespi’s journal of the first expedition into California in 1769, remarks upon entering Orange County, “the soil, all grass grown ….the bare mountain range that we are keeping upon our right to northward seems very grass-grown also like everything we have found between San Diego and here.” In a later revision he adds “very grass-grown soil almost all of which had been burnt off by the heathens” (Brown 2001:311). After camping somewhere near the present site of the Veterans’ Administration in West Los Angeles, Crespi’s party moves through the Santa Monica Mountains by way of the Sepulveda Pass and notes…”The mountains though which we were passing are quite high and steep; however, very grass-grown on all sides with very good grasses (I have seen none better anywhere),…” (Brown 2001:351).

In the early years following first contact, the evidence suggests that local people continued their practice of low intensity burning. In both 1793 and 1794 California governors issued proclamations forbidding the setting of fires by the native people, due to their effect upon local farming. In 1836 Richard Henry Dana (1899) reports a landscape along the southern California coast as treeless: “entirely bare of trees and even shrubs.” (Dana 1899). On his first visit to Santa Barbara, Dana remarks on how the hillsides were bare of large trees from a “great fire which swept them off about a dozen years ago” (Dana 1899:60). Historical authors characterize southern California as a populated coastline dominated by vast grasslands that were periodically burned off by the local inhabitants. This evidence supports, without question, that at the time of first contact, the southern California coastal landscape was dominated by grasslands, managed by fire, and with all probability had a low to moderate, fire régime.

Colonial Period

With the colonization of California by Spain in 1769, the coastal region began a slow transition from a territory dominated by the land management practices of indigenous people toward one dominated by the pastoral pursuits of the California ranchos, missions and pueblos. With this life came the introduction of European livestock: cattle, horses, sheep and European farming practices. From 1769 to 1823 the Franciscan Order of the Catholic Church established 21 California missions from San Diego in the south to Sonoma in the north. The primary function of the mission was the conversion of the native people to the Catholic religion, centered on a self-sustaining agricultural community, whose primary economic activity was the grazing of livestock. During the establishment of the missions, 7 pueblos were also established as civilian farming communities, administered by 4 military districts centered in Monterey. Beginning in 1784, grazing concessions were awarded to thirty colonists for the primary objective of developing a California cattle industry (Beebe and Senkewicz 2001). Of the thirty original ranchos, 12 of these were in southern California, mostly centered around, the pueblo of Los Angeles. (Map 2)

The locations for the missions and ranchos were selected for the same characteristics that attracted the Chumash people; vast grasslands, with available water, all to support livestock grazing. During the 70 years of Spanish and Mexican rule, the new settlers occupied the same areas of the Santa Monica Mountains as the indigenous people (Map 3). Slope analysis of the region shows that the majority of the landscape within the southern California coastal plains, and specifically the Santa Monica Mountains, offered an excellent landscape for agriculture or livestock grazing (Map 4). Within the Santa Monica Mountains over 90% of the land area is within the slope characteristics necessary for agriculture or livestock grazing. During this period, within the Santa Monica Mountains, ranchos Simi, El Conejo, Las Virgenes, and Topanga Malibu Sequit, were engaged in extensive farming and livestock operations.

Throughout the intervening period between the Spanish colonization and the secularization of the California missions in 1833, the pastoral economy grew at an alarming rate. While it is difficult to determine the growth in the independent ranchos, due to limited records for the period; the growth of the missions can be established from the audits brought on by secularization. The California State Lands Commission's records indicate that:

> "In 1834, at their zenith, the missions were a thriving concern. They claimed over four hundred thousand cattle, sixty thousand horses, over three hundred thousand sheep, goats, and swine. Wheat, maize, beans, and other staples were grown, with a combined annual product of one hundred and twenty-thousand bushels. Wine, brandy, soap, leather, hides, wool, oil, cotton, hemp, linen, tobacco, salt, and soda were also produced. The missions' annual production was estimated at two million dollars."

One of the best indicators of the extent of the ranchos livestock operations can be found in "California Pastoral" by Hubert Howe Bancroft (1888:348). Here, Bancroft notes that in the 1820s, a cautious farmer might have 20,000 sheep, 15,000 cattle and 2000 horses that he would maintain just as his seed stock that he would encroach upon only in an emergency. In these early years the economy was solely based upon the export of cattle hides and tallow, with the only medium of exchange, the hide. In "Two Years before the Mast," Dana (1899) submits that his ship, the *Pilgrim*, would transport up to 40,000 cattle hides at a time from Santa Barbara and San Pedro, to San Diego, for warehousing. After two years on the California coast the ship would return to Boston. The *Pilgrim* was only one of many ships that plied the California coastline, transporting needed manufactured goods to the Californios and returning to the eastern seaboard with tallow, cattle hides, wool and sea otter pelts. "California produced and exported more than six million hides and seven thousand tons of tallow between 1826 and 1847 (Hackel 2005:414).

Throughout the Mexican period, California's livestock-dominated economy continued to develop, driven by increased settlement and the demand generated by the California gold rush. During this period the Mexican government added 800 new ranchos; of those, 108 Grants were certified in Los Angeles, Ventura and Orange counties. The primary consideration for the location of each of these ranchos was again, based upon the lands' available grass and its suitability for grazing. By the end of the Mexican period, the lands of ranchos, ex-missions and pueblos equaled 2,960 square miles, or over 40 percent of the total land area of the future counties of Los Angeles, Ventura and Orange. West of the San Gabriel Mountains and the coastal ranges (3,254 sq miles), the Land Grants (2,736 sq miles) controlled over 80% of the prime coastal land; the vast majority of this land held for livestock grazing, a small amount for agriculture (2,648 acres) and 30 square miles for the city of Los Angeles (Map 5).

Under this economic model, virtually all of the southern California coastal landscape would have been an open rangeland of grass, with fire intensities of low to nil in most areas, and the higher fire intensities confined to steeper terrain out of the reach of grazing herds.

Statehood

At the time of statehood and up until the early 1900s, both the Santa Monica Mountains and the southern California coastal region were engaged in economic activities that further reduced wildland fire intensities. From 1850 to 1900, Los Angeles County saw a remarkable expansion of the agricultural and range based economy. During this period, in Los Angeles County, "land under cultivation" went from 5,587 acres in 1850 to 895,668 acres in 1900. Livestock numbers expanded from 125,648 in 1850 to a high of 383,307 head in 1880, and settled back to 124,431 head by 1900. Under these conditions, 895,668 acres of native grassland would have been converted from fuel model Gr1 or Gr2 into an agriculture fuel model; NB3, with zero fire intensity (see Appendix A: Vegetation Models).

Using contemporary grazing standards (Appendix A) to assess the impact of the grazing component on landscape level fire intensity, the results indicate that up to an additional one million acres, would have been transformed from a Gr2, into a Gr1 fuel model by grazing and range activities (Appendix A, Table 1). By the close of the 19th century Los Angeles County had almost 2/3 of the total land area of the county committed to agricultural uses with zero fire intensity; or grazing activities, with low to extremely low fire intensity. Within the coastal region of Los Angeles, Ventura and Orange counties, these activities would have approached 90 percent of the total land area of the three counties.

Beyond the economic activity, a number of legislative and societal changes have also played a significant role in southern California's transition from a low fire intensity environment to a high intensity fire environment. Statehood, the railroads, and the 1862 Homestead Act has each played a significant role in this conversion. Of course, statehood opened California to a vast migration of Yankee settlers and the railroads provided the means to get them here. The Southern Pacific began delivering passengers from the north in 1876 and the Santa Fe railroad opened up a more direct route to the east coast in 1887. "Thereafter, as many as three and four coach trains descended on the city (Los Angeles) each day, depositing in 1887 alone more than 120,000 tourists, health seekers, farmer, artisans and businessmen (Pitt 1966:249)." By 1900 the population of Los Angeles County had climbed from 8320 in 1850 to over 170 thousand, a twenty-fold increase. With the increase in population, the Forest Grove Association sought to convert the treeless landscape into one of "beauty and profit by planting eucalyptus trees on a large scale" (Cleland 1941:220).

However, the greatest contribution to changes in the native vegetation and the increased fire intensity was the legislation that overturned the California fence laws. At the time of statehood, California had adopted the Spanish fence law conventions, where public lands were viewed as being held in common and livestock was allowed to graze on any land available to them. Under this policy, herds would co-mingle on both private and public lands and livestock ownership would be determined annually with a rodeo where young calves were branded and individual herds counted. Under the 1785 Spanish fence proclamation, individual landowners were required to protect their farm land from trespass by livestock (Bancroft 1884:620). With these requirements, it was the farmer's responsibility to fence his land, and he could be held liable for any injury he inflicted upon the livestock in the act of protecting his crops. This policy was codified at statehood with the 1850 Trespass Act and further strengthened with the 1855 "Fence Law" (Statutes of Calif. 1855)

With the increase in American settlers and the growing demand for agricultural land, the pressure for changes in the Trespass Laws grew. During the late fifties and into the sixties this debate became a movement, and in 1863 the legislature passed the first of the California "No-Fence Laws" (Statutes of Calif. 1863). By 1872 virtually every California County had passed fence laws that protected agriculture from the trespass of grazing herds (Pulling 1947). The consequence of this legislation, over a series of years was to place the economic burden of protecting farm land from trespass by livestock on the backs of the ranchos, and reversed a 100 year old policy of open range.

Adding to the pressures on the ranchos was the Homestead Act that allowed an applicant to claim legal title of up to 160 acres of public land, providing that they improved and lived on the land for a period of 5 years (Robinson 1948:168). Simultaneously, within southern California there was pressure to break up the large ranchos into smaller tracts for agriculture (Willard 1901), and many of the large Land Grants were broken up into 40 to 200 acre farms. Within the coastal region of Los Angeles County, the Santa Monica Mountains (Map 5), held the greatest amount of public land, and by the early 1900s virtually all of it was in private hands under the 1862 Homestead Act.

The results of these events had two major impacts. First, the No-Fence movement eliminated the fire protective benefits of browsing and grazing on public lands and produced a sharp line between the low fire intensity environment of the rancho and the higher fire intensity landscape of the public lands. Second, the public land that had previously been open range were being settled, first by squatters and then by homesteaders. By the early 1900s most of the available public land within the central core of the Santa Monica Mountains had been settled. Along the borders of the ranchos, large tracts of land were being converted from public grazing land to agricultural uses or left fallow. The 1872 Plat of the Rancho Topanga Malibu Sequit, clearly details a rancho of "grassy hills" and to the north, right at what would have been the fence line, "brushy and broken hills." (Map 7)

By 1900 the agriculture and pastoral economy of southern California had reached its peak, and Los Angeles County and the Santa Monica Mountains started a slow steady land use conversion from a low fire intensity grassland agricultural environment into a high fire intensity shrubland environment. By 1930 the residential development of Rancho Topanga Malibu Sequit had begun; by 1947 only 8,515 head of cattle were range fed in all of Los Angeles County (LAC Livestock Report 1947). By 1992 agricultural acreage, in Los Angeles, Ventura and Orange Counties had fallen from 2,047,513 acres in 1900 to 511,847 acres (Appendix C, Charts 2 & 3), of that, only 137,888 is identified as "Harvested cropland" (Census of Agriculture 2002). The LandFire database currently identifies only 13,032 acres as agricultural within all of Los Angeles County and only 73,574 acres within the tri-county area, the largest fraction of it on the Ventura County coastal plain.

Fire Impact

The fire impact of these changes has been significant. With the decline of the fire protective qualities of the pastoral and agricultural economy, wildland fire began its march. In the period 1900 to 1919, wildland fire only nibbled around the edges of the agricultural landscape, with most of the fires occurring outside the coastal ranchos. (Appendix D, Historical Map Series). From the 1900 to the present, as the beneficial effects of large scale grazing and agricultural production began to recede, the increase in the fire intensity of the landscape began to develop.

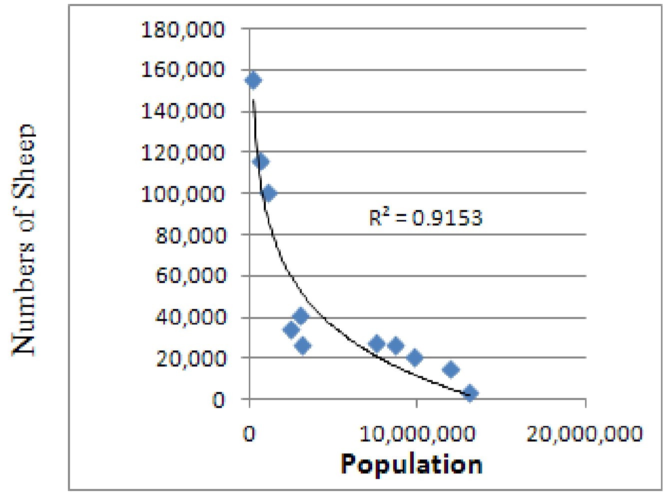


Chart 1

Using the historical numbers of sheep within the region as a surrogate for the impact of grazing livestock upon the fire environment, the following exhibits illustrate this relationship. First, Keeley (2002) and others are correct in that fire frequency has increased with the increase in population throughout the region. However, they failed to recognize that during the same period, the numbers of grazing livestock had significantly decreased and that the two are closely related (Chart 1). Furthermore, the significances of a correlation of grazing livestock to regional "acres burned" (Chart 2) is a clear indication of a significant relationship between the current wildland fire regime and the decline of agriculture and livestock grazing

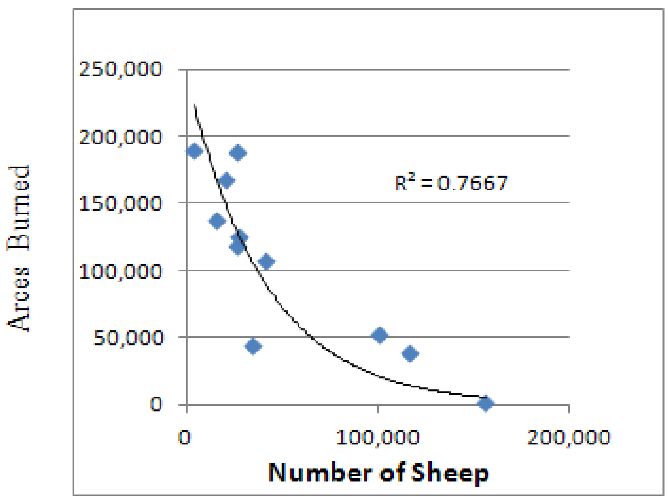


Chart 2

With the fire protective qualities of grazing livestock and the vast size of herds during the late 19th and early 20th century, it should be easy to understand why the region had sustained little fire impact during the period. In addition, throughout this period any periodic drought would only have enhanced the fire protective qualities provided by the grazing of livestock.

Grassland Wildfire Risk

The relative risk of a grassland fire environment vis-à-vis the relative risk of a shrubland or chaparral fire environment is easy to demonstrate. The most objective method of evaluating the relative fire risk of the individual fuel categories is by using the fire behavior modeling software BehavePlus (Burgan and Rothermel, 1984, Anderson 1986). Using the BehavePlus software, I have modeled the major vegetation fuel types, for the Santa Monica Mountains, as defined by the National LandFire database. The LandFire database identifies the primary vegetation fuel models within the Santa Monica Mountains as 5% grass, 46% grass/shrubs, and 21% shrubs (Appendix C, Map 1). Within the Community Wildfire Protection Plan (CWPP) grass represents approximately 5%, grass/shrub 52 %, and shrubs 29% of the vegetation fuel load. Within the public lands parcels of the Los Angeles County section of the CWPP the proportions are less than 3% grass, 50% grass/shrub and approximately 37% shrub models, SH2 and SH7 (Appendix C, Table 2). Each fuel category was modeled using 4% dead fuel moisture, 60% live fuel moisture and a 20 mi/h wind speed. The fire behavior of each of these fuel models are defined in Scott and Burgan's "Standard fire behavior fuel models: a comprehensive set of fuel models for use with Rothermel's surface fire spread model" (Appendix B).

The result of the modeling indicates that for Heat per Unit Area (Appendix C), every fuel category is greater than grass and that the shrub categories are significantly greater. If we look at the total heat load per acre for each category this relationship is even more dramatic. The highest grass model GR2 has half the heat load of GS2 and only one sixth the heat load of SH7. Relative to firefighter safety, every fuel category requires a larger safety zones than the grass models, with the exception of fuel model GS1 which is somewhat of a transitional fuel model and represents less than 1% of the total fuel load. In flame length, the two grass models are well below the critical 8 foot mark. (Appendix C, Table 1). After modeling each vegetation category, the results indicate that there would be little hazard in subjecting the landscape to a grassland environment. In fact the results indicate there could be a considerable reduction in hazard if a major proportion of the landscape was returned to a more historically correct grassland or agricultural landscape. To claim that a grassland fire environment is more hazardous to firefighters is simply false.

To recap, it is the position of this thesis, and supporting evidence indicates that the current wildland urban interface fire risk is the direct result of long term policy and social changes that have suppressed wildland fire and withheld the grazing of domestic livestock from the region, and specifically, the Santa Monica Mountains. Furthermore, the evidence supports that the dominant historic vegetation is grassland, produced by the management practices of the indigenous people, and reinforced by the pastoral agricultural pursuits of later generations.

The following sections of this thesis will demonstrate that landscape level fuel modification strategies are not only possible, but can have significant benefits. The techniques offered by this research will define a fuel treatment strategy that can be applied at the landscape level to limit large scale fire events, and to shield individual structures and residential communities at the parcel level. While these methods are mainly directed at fire mitigation, their application will also provide for enhanced firefighter safety and increased fire suppression opportunities.

Section 3: LITERATURE REVIEW

The intention of this review is to provide the reader with a sense of the primary building blocks of fire behavior modeling and to identify the modeling environment necessary to evaluate a fuel treatment strategy. In that regard, if one were attempting to identify a starting point for the beginning of scientific inquiry into the world of wildland fire behavior, the establishment of the Forest Service's Intermountain Research Station in 1961 would be a logical starting point. That first decade of recruits provided the individuals and the energy to propel fire behavior from the observations of firefighters and smoke jumpers into a true science with a fifty year body of work.

Attempting to define the primary document in the field of Fire Behavior Modeling, most would agree that Rothermel's (1972) work, "A Mathematical Model for Predicting Fire Spread in Wildland Fuels" is that document. With the stated goal of applying system analysis techniques to the fire behavior aspects of forest land management, Rothermel provides the analytical structure that will define wildland fire scientific efforts up to the present. Building on the work of others (Fons 1946), Rothermel lays out the conceptual requirements for a quantitative fire spread model to assist the Forest Service in the growing wildland fire problem. Within this work he identifies the primary variables of fuel moisture, fuel loading, wind velocity, relative humidity, slope and solar aspect; defines the fundamental relationships between the variables, and assembles a series of mathematical equations to describe those relationships. Following identification of his primary variables, he develops the empirical methods necessary to quantify their functional relationships.

With the ground work laid down for the fire spread calculations, Rothermel turns his attention to the fuel side of the equation. Conceptually he defines the requirements for the development of a national set of vegetation fuel models that would support wildland fire spread modeling. Within this context he identifies the concepts of fuel particle heat content, and particle size; the fuel arrangement condition by class size, and whether the fuel is alive or dead; surface to volume ratios and the mean depth of the fuel; plus the environmental values of the wind speed, angle of slope and the vegetation fuel moisture content. Arguing for a national fuel model that can be refined to provide predictive qualities, Rothermel graphically describes the relationship between his variables, the current national fuel models and their impact on fire spread and intensity.

Based upon the concepts developed by Rothermel, Albini (1976) develops a series of graphics (Nomographs) that describe the fire behavior characteristic of each of the fuel models for the purpose of providing foresters and firefighters with a method of estimating fire spread and intensity under various fire conditions. Albini (1979) continues his contribution with the development of a predictive model for the maximum spot fire distance to be expected when burning brands are cast downwind from a wildland fire. His model is based upon the assumption that burning brands are cast ahead of the fire front when a single or groups of trees burn-out. In 1983 Albini expands his model to include the strength of an uplifting thermal air current, brand particle size, and wind speed.

In the following decades advancement in quantifying fire behavior moves forward on a number of fronts. In 1977 C.E. Van Wagner (1977) identifies the characteristic necessary for the prediction of crown fire in pine forests. He defines the 3 stages of a crown fire as passive, active, independent, and describes the conditions that lead to each. He develops the criteria for categorizing the crown of a tree as its height from the ground, its foliar bulk density and its moisture content. In 1982 H. E. Anderson provides a photographic guide to assist fuel management specialists in the selection of a fuel model. Within this field guide, vegetation is categorized into four groups: Grass, Shrub, Timber and logging Slash and 13 individual fuel models (Anderson 1982). Each model is based upon the fuel characteristics as described by Rothermel (1972).

With the development of methods to determine the size and shape of wildland fires (Anderson 1983) fire behavior science moves from the laboratory into the classroom (Rothermel 1983). In the early 1980s the Forest Service initiates a series of fire behavior instructional courses and equips TI-59 (Burgan 1979) calculators with microchips that automate the process of predicting wildland fire behavior for field personnel. With these innovations the Forest Service was now capable of providing a method to evaluate the input variables describing the fuels, the fuel moistures, windspeed, and slope. Subsequently, they had obtained the tools capable of calculating the fire behavior characteristics of the rate of surface fire spread and fire line intensity. Lastly, they had developed the methods necessary to determine burn area, spread distance, flame length, and to identify the conditions that led to spotting and crowning. In 1986, the Forest Service presented an interactive computerized version of the fire behavior prediction (Andrews 1986) and fuel modeling system (Burgan and Rothermel 1984), called BEHAVE. With BEHAVE, fire and fuel modelers had the capabilities of testing alternative fire scenarios to evaluate possible outcomes and to determine the impact of changes in fuel profiles. The primary objective of the BEHAVE system was to provide tools for fire officers to develop fire growth predictions during initial fire attack, and to evaluate alternatives for prescribed fire planning.

In 1987 Burgan provides an expanded version of the fuel modeling concepts first presented in the BEHAVE fire modeling application. In this report he provides the mathematical foundations for the fire behavior input variables and their relationship to the criteria of the advanced fuel models. Within this work he graphically illustrates and provides extensive examples of the impact of variations in environmental conditions on fire spread rates and fire intensity. While BEHAVE was a major step forward that provided fire managers with quantifiable results for fire spread and intensity, it did not provide any true spatial information beyond the gross area burned or the values of the output variables.

In 1993 Mark A. Finney announced the development of FARSITE (Fire Area Simulator), a fire growth model (Finney 1993). Intended to be used by wildland fire and forest managers, it was a true simulation. Within a GUI, it implemented the most up to date fire behavior research and provided a platform for the testing of additional variables as they became available. In a series of dropdowns and functions, FARSITE assists in the entry of the necessary input variables, allows for the application of fire suppression activities, and provides for a spatial and temporally correct display of fire behavior.

Over the following ten years, Joe Scott and Robert Burgan (2005) develop and present a series of advanced fuel models that are specifically designed to implement Rothermel's (1972) surface fire spread criteria. Within this research, they present a series of 40 different fuel models, define their fire behavior characteristics, relate them to Anderson's original thirteen fuel models, and provide a photographic selection guide to assist in identifying each fuel model in the field. By 2002 the Forest Service fully documents the "Fuel Characteristic Classification System" (Ottmar, et. al. 2002)

Over the course of the same period Finney (1998) expands the features of FARSITE. Using the capabilities of more advanced computing power he works toward an optimization algorithm that is capable of identifying the landscape characteristic most likely to produce the fastest fire pathways and develops methods to optimize the location of fuel treatments (Finney 2002, 2004). The concepts of minimum travel time fire paths and fire influence nodes are developed and introduced as advanced features of the FlamMap fire behavior modeling system. These more advance features are specifically designed to test the impact of fuel treatment, at the landscape level.

With the establishment of these innovations and their introduction into the FlamMap (Finney 2006) modeling environment, the methods are now available to test the benefits of alternative fuel treatment strategies. By 2006, Forest Service projects in Flagstaff, Arizona and the Sierra Nevada Mountains were using FlamMap for the basic fire behavior characteristics in support of prescription burning and long range planning. In 2008, the Forest Service introduced FlamMap into their advanced fire behavior analysis curriculum (S-495), to provide an understanding of its tools to a wider audience.

Up to this point, the most definitive research in comparative fuel modeling involves a simulated fuel treatment in the Mt. Emily area of the Wallowa-Whitman Nation Forest (Ager, et.al. 2010). This project investigates the tradeoffs between the placement of fuel treatments near residential structures, or nearer to forest environmental resources. From the perspective of this research, the most valuable outcome of the Mt. Emily project is that it is the subject matter of an Arcfuels Tutorial (Ager 2009) that provided the framework for this project. In the area of comparative fuel treatment modeling, most of the research is directed toward current practices within the National Forest, and virtually no work is directed toward new treatment methods or the Southern California chaparral community.

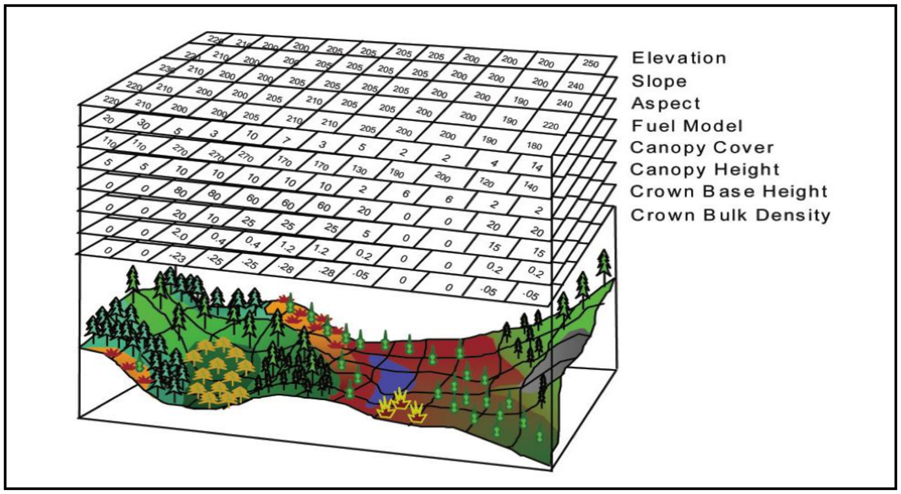
Section 4: MODELING ENVIRONMENT

To evaluate the comparative advantages of one fuel treatment method over another, a series of GIS tools and fire behavior software were assembled. The primary platform for this evaluation was the ArcGIS 9.3.1 software, distributed by ESRI of Redlands, California. The ArcGIS operating environment provides the necessary GIS tools and functions for the assembly of the required variable layers, and the comparison of the results of the individual treatment scenarios.

Supplementing the ArcGIS software was ArcFuels (http://www.fs.fed.us-/wwetac/arcfuels/), LandFire (http://www.landfire.gov/), and the fire behavior modeling software, FlamMap (http://www.firemodels.org/index.php/national-systems/flammap). ArcFuels is a series of ArcGIS macros and extensions developed to provide a streamlined method of fire behavior modeling and spatial analysis for use in forest fuel treatment planning. Intended for use by U. S. Forest Service fire behavior analysts and for long range forest management purposes, it provides a useful interface and organizational framework for wildland fire modeling. Within the Arcfuels operating environment, the user has access to a host of fire behavior modeling and simulation programs, toolsets for forest stand analysis, and project management capabilities that are useful in the organization of a fire modeling project.

After the installation of the LANDFIRE Data Access tool within the Arcfuels environment, a direct internet linkage is provided to the LANDFIRE national database. LANDFIRE is a national effort by the U. S. Department of Agriculture Forest Service and the U. S. Department of the Interior to provide the landscape level spatial data necessary for forest fuel management, conservation planning and wildfire modeling. The primary objective of the LANDFIRE dataset is to support the National Fire Plan and to provide the data necessary to correctly identify vegetation fuel buildups in the nation’s forests. For the purposes of wildland fire modeling, LANDFIRE provides the raster layers that describe the landscape topography, vegetation fuel type, and the characteristics of the canopy cover. Each of these raster layers are served in an ArcGIS raster grid format with a 30 meter resolution, and in a NAD 1983 Albers projection.

Once the LANDFIRE grid layers have been assembled into the ESRI operating environment, and the appropriate vector layers, such as streets and political boundaries have been obtained, the dataset is composed into the fire modeling Landscape File. The Landscape File is a spatially referenced dataset consisting of five mandatory layers and three optional layers. The dataset contains three topographic layers: elevation, slope and aspect; a vegetation fuel model, and a layer identifying the existence of a canopy and three optional layers: canopy height, crown base height, crown bulk density. Within the Arcfuels environment, these eight raster layer are composed into the fire modeling "Landscape File" (Graphic 1.).



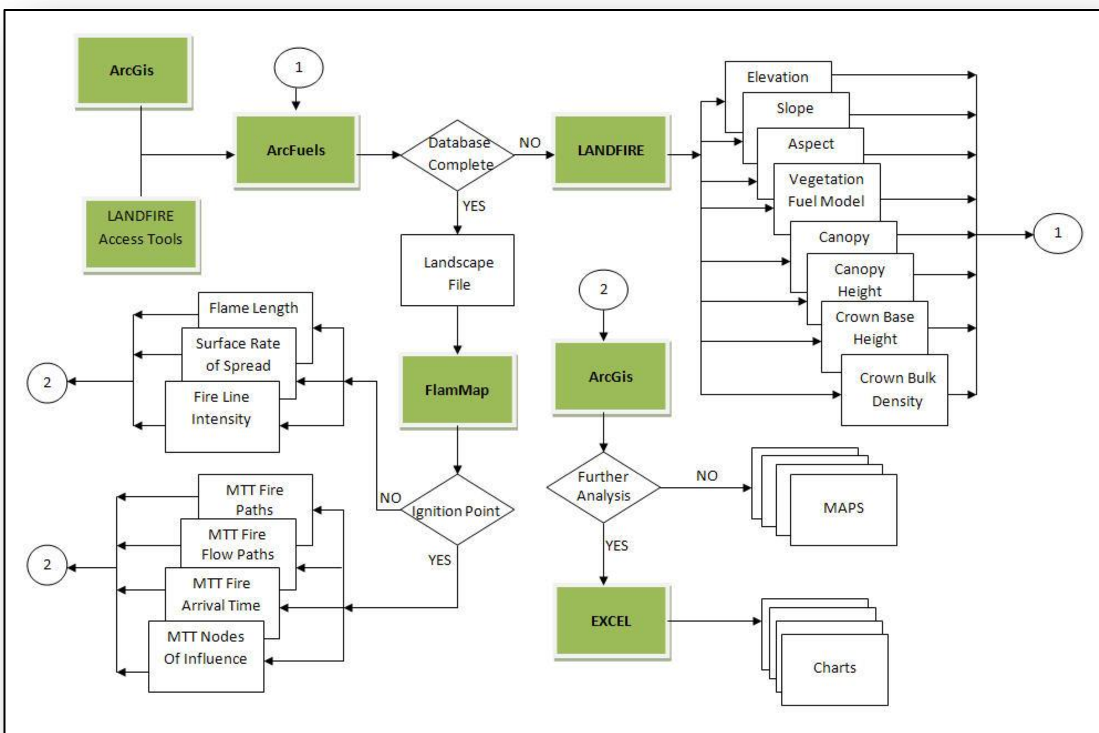
Graphic 1: FlamMap Landscape File Layers (USFS Research Lab)

Within the ArcFuels environment, the primary fire modeling programs are FARSITE and FlamMap. FARSITE is a true simulation, in that it simulates a wildland fire burning from cell to cell in the same temporal and spatial sequence as an actual wildland fire. Within FARSITE, weather and environmental conditions can vary over time and space and the impact of fire suppression activities can be modeled. FARSITE's primary function is to provide real time support for fire suppression forces in combating wildland fire.

FlamMap is more of a modeling system than a simulation, and uses the same environmental conditions over the course of a fire run. Within this format, the fuel moisture and weather variables can be held constant and only the vegetation layers are varied to suit the treatment assumptions. The consequence of this difference is that while the burn patterns of each modeled fire are similar, FlamMap runs faster and provides a greater array of output variables for comparative analysis. In this evaluation of the fire behavior characteristics of the Oak Woodland Treatment Method and the Limited Grazing alternative, the FlamMap fire modeling system is used.

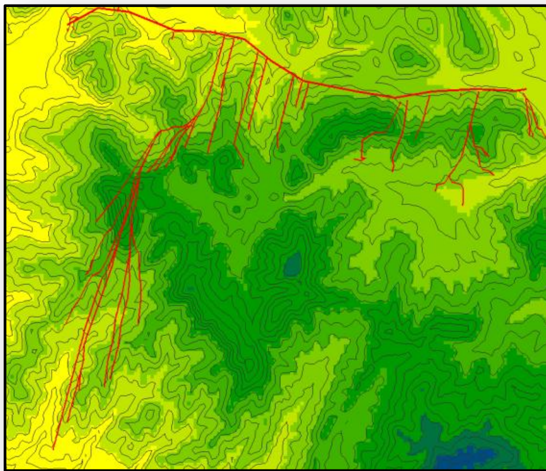
The FlamMap operating environment provides a GUI graphic display of each of the individual map layers, pixel by pixel identification, and generates a standard set of legend properties. Performing a FlamMap modeling run provides the user with a set of basic fire behavior output raster grids that describe the Fireline Intensity, Rate of Fire Spread, Flame Length, Heat per Unit Area and Crown Fire Activity of the study area. In the development of the fire behavior output data, FlamMap implements the Rothermel (1972) surface fire spread model, Van Wagner's (1977) crown fire initiation model, Rothermel's (1991) crown fire spread model, and Nelson's (2000) dead fuel moisture model. In defining the vegetation fire characteristics, FlamMap can use the Basic 13 Anderson (1982) vegetation fuel models, the more advanced 40 Scott/Burgan (2005) fuel models, or custom fuel models developed by the user or others.

Within the context of comparative fire behavior modeling, FlamMap's more advanced feature of Minimum Travel Time (MTT) provides the greatest utility. The MTT functions calculate a set of fire spread pathways that minimizes the time for fire growth from a particular point, moving across the landscape, for a specific period of time. The MTT functions allow for the modeling of a wildland fire based upon an ignition at a specific point, with specific weather conditions for a specific time period. Within the MTT

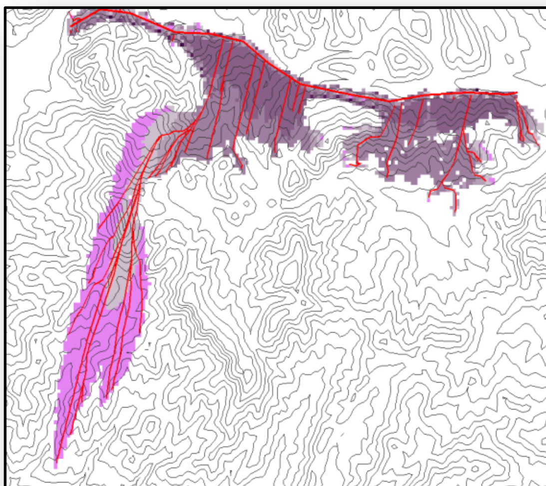


Graphic 2: FlamMap Modeling Environment

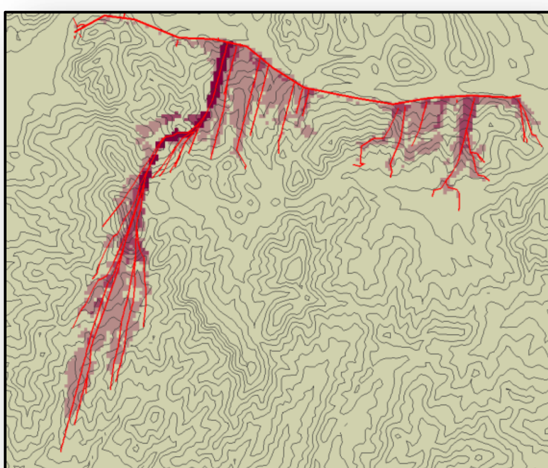
functions, only the cells that would be consumed within the burn period are documented. Within this modeling environment it is possible to vary the underlying vegetation fuel models that conform to a particular treatment method, while holding the fuel moisture and weather variables constant. Using these methods it is possible to quantify the impact of any specific treatment method.



Graphic 3: Fire Paths



Graphic 4: Fire Arrival Time



Graphic 5: Nodes of Influence

The MTT features of the greatest utility to the comparative modeler are the vector layers, MTT Major Fire Paths (Graphic 3), MTT Fire Flow Paths and the raster grids, Nodes of Influence (Graphic 5), and Arrival Time (Graphic 4). The MTT Fire Flow paths are a vector display that describes the minimum travel time pathways between all nodes within the burn area, The MTT Major Fire Paths are a subset of the MTT Flow Paths that show only the most significant of the fire spread pathways. The Arrival Time raster grid represents the arrival time, in minutes, of the modeled fire to reach each node in the display. The Nodes of Influence provides a graphic display of the logarithmic number of downwind cells that are affected by fire in a particular cell.

This progression of the fire spread provides a simulated fire shape that is based upon the vegetation attributes and topographical features, under a well defined set of environmental conditions. Using the MTT functions, FlamMap provides a series of fire behavior outputs that describe specific fire paths, estimate their arrival times across a landscape and determine the cells of the greatest relative influence on future fire behavior. Using these more advanced MTT fire attributes, it is possible to identify areas of the greatest influence of future fire growth, apply a recommended fuel treatment, and test their fire mitigation outcome.

Section 5: LANDSCAPE LEVEL FUEL MITIGATION

Within the Santa Monica Mountains wildland fire mitigation is generally preformed at the individual parcel level. The vegetation of each parcel is evaluated by fire authorities, relative to its potential fire impact on any nearby structures. If the vegetation is deemed a hazard to nearby structures, the property owner will be required to perform vegetation treatment in accordance with the mandates of the local agency.

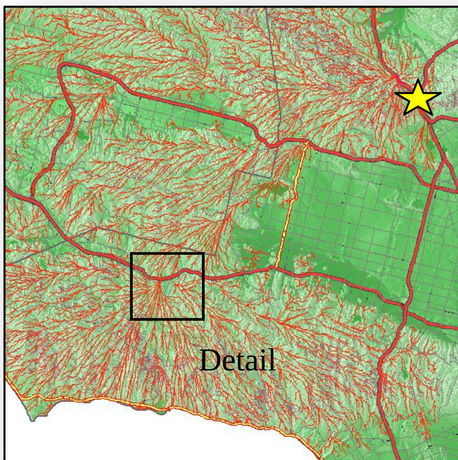
For the private property owner, wildland fuel treatment takes the form of one of three methods. The first method is mechanical brush removal, either by using heavy equipment to crush or remove vegetation, or by using hand clearing; this is the customary method used within the area. The second method is chemical treatment, which is usually in the form of growth inhibitors or defoliants. The final technique is biological treatment, which customarily uses grazing or browsing animals, such as goats, to reduce fuel loads (Los Angeles County Fire 2010). A fourth method is prescribed burning, which is used only by fire authorities, but is difficult to execute within the Santa Monica Mountains due to the risk involved.

Each of these methods has its own advocates and benefits. While each of these methods is different, the result is generally the same: vegetation is removed and the land is left bare until the vegetation returns within its normal growing cycle. In the best case scenario, plants within the chaparral fuel community can be thinned and limbed up and the treatment will last three or four years. In the worst case scenario, the area is cleared, and then covered by invasive grasses or fast burning shrubs that must be cleared on an annual basis. The result is a temporary change in fire behavior (Finney 2004) and individuals or agencies are thrust into a treatment cycle that must be maintained annually if low levels of fire risk are to be maintained.

In this process little attempt is made to evaluate the strategic value of the individual fuel treatment effort within an overall fire mitigation strategy. The SMMCWPP is an attempt to provide a wildland fire mitigation strategy based upon the individual parcel. The majority of these parcels are privately owned, single family homes. Within this strategy, groups of homeowners would be encouraged to provide for their own fire defense by coordinating their individual mitigation efforts. This effort would be directed toward those parcels nearest residential structures and would be the sole responsibility of the individual homeowner. The position of the planning authorities is that high intensity wildland fires are the natural fire regime of the Santa Monica Mountains and that a landscape level fire mitigation strategy is not warranted or not possible.

This thesis, using fire behavior modeling techniques, will demonstrate that landscape level fuel modification is not only possible but would have significant benefits. Within this section I will examine three major components of a landscape level wildland fire strategy. The first illustrates that the wildland fire regime within the Santa Monica Mountains is undeniably a landscape level problem. The second identifies a number of specific landscape level targets that would offer immediate beneficial fire mitigation results. The last demonstrates the potential benefits of a landscape level fuel modification strategy on the wildland fire risk within the Santa Monica Mountains.

To demonstrate the landscape level scale of the wildland fire situation within the Santa Monica Mountains, three separate study areas will be developed, each supported by a fire behavior model. The first is a regional model that defines the fire linkages between the Santa Susanna Mountains, Simi Hills, and the Santa Monica Mountains. The second is a model that demonstrates the impact of mitigation strategies applied at the landscape level to the fire linkages between the Santa Monica Mountains and the Simi Hills. The third model will define the major fire corridors within the Santa Monica Mountains. A subset of this last model will be used to evaluate the proposed fuel treatment methods. This subset will concentrate on the Malibu Canyon major fire path of the Santa Monica Mountains, bounded on the north by the 101 Freeway, easterly from Las Virgenes Road (Malibu Canyon) to Old Topanga Canyon Road, and southerly to the Pacific Coast Highway



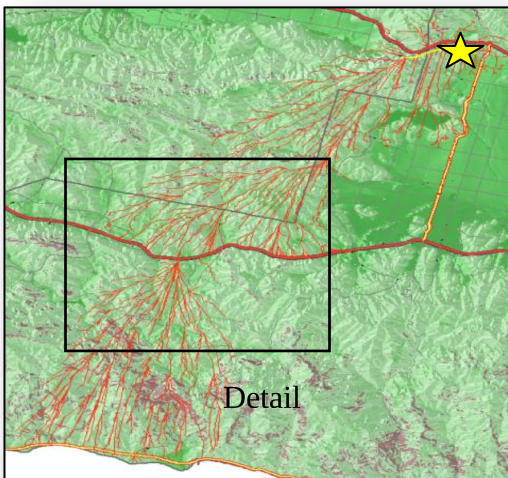
Graphic 6: Fire Scenario One

Detail Graphic 6:

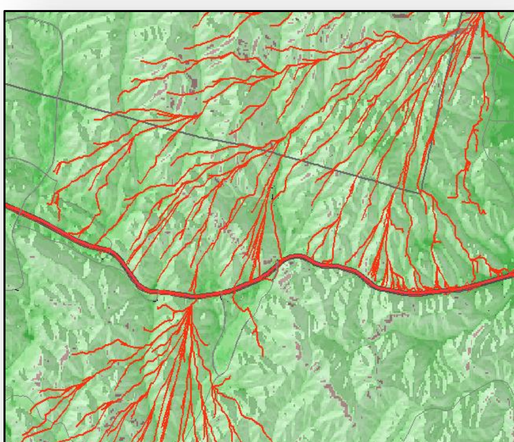
Landscape Level Wildland Fire Linkages

To illustrate the landscape nature of the Santa Monica Mountains fire problem, I have modeled two separate fire scenarios. The first fire scenario duplicates the 1970 Clampitt/Wright Fire (Graphic 6) with an ignition point near the junction of the 5 and 14 Freeways. The fire pathways are modeled in red, with the yellow star as the ignition point. The second, an arbitrary ignition along Santa Susanna Pass near the junction of Topanga Canyon Blvd. and the 118 Freeway. Each fire scenario is modeled under extreme fuel conditions, with the wind speeds at 30 MPH and a wind azimuth of 15 degrees.

The first fire scenario (Graphic 6) clearly shows that the Santa Monica Mountains and the Santa Susanna Mountains are linked through the Simi Hills. The connection is exposed at the Santa Susanna Pass, with a lateral linkage approximately 2½ to 3 miles long. After traversing the Simi Hills, the fire develops 2 point connections between the Simi Hills and the Santa Monica Mountains, within the Malibu Canyon fire corridor. From these 2 linkages any fire could potentially burn in either the east or the west direction, depending upon the wind shift. The results indicate that a fire burning along the southern flanks of the Santa Susanna Mountains, under extreme conditions will make this 20 mile run into the Santa Monica Mountains in less than a day, if not contained. In 1970 the Clampitt/Wright Fire burned to the coast in approximately the same amount of time.

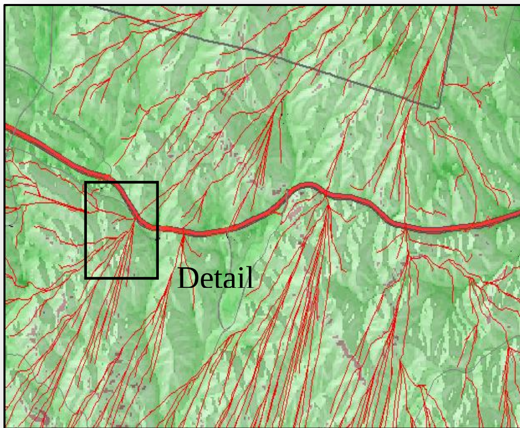


Graphic 7: Fire Scenario Two



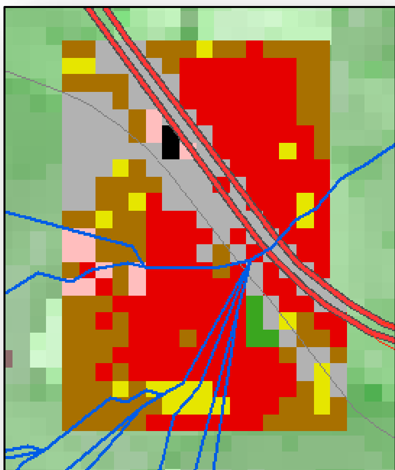
Detail Graphic 7:

The second scenario, an ignition in Santa Susanna Pass (Graphic 7) is the more likely event. Fires have burned from this location a number of times; the 23 thousand acre Topanga Fire in 2005, the most recent. Every fire that starts from this location has the potential of burning into the Santa Monica Mountains and would, if not for luck and outstanding fire suppression efforts. This Santa Susanna fire path will cross into the Santa Monica Mountains in one of 2 locations. The location with the greatest potential will cross the 101 Freeway between Lost Hills Road and Liberty Canyon (Detail). This fire path has the potential of burning to the Pacific Ocean in a matter of hours under the right conditions. The second path, crossing near Las Virgenes Road would have very little potential; it is slow moving and would be easily contained by fire suppression forces.



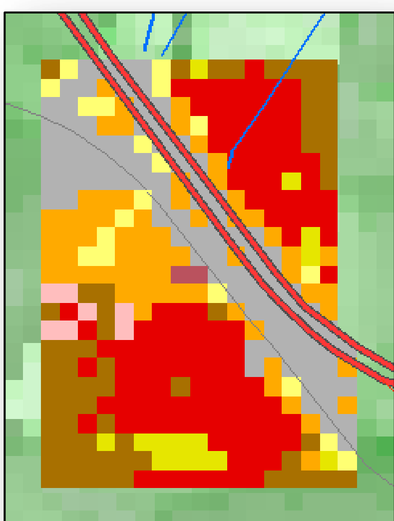
Graphic 8: 2007 Fuel Model

In a previous version of this scenario, developed from a fuel model layer acquired in 2007 (Graphic 8), the fire paths cross into the Santa Monica Mountains in four locations, instead of the two locations in the current version. This occurrence provides an opportunity to investigate the minor changes that can have significant landscape level benefits. In the earlier case (Detail A), one of the fire paths crosses the 101 Freeway approximately ½ mile west of Liberty Canyon, moves up the canyon and reaches the coast on a several mile front. In the current version (Detail B), constructed with a more recent fuel model, the fire path approaches the north side of highway but does not have the fire intensity to cross.



Graphic 8: Detail A

The assumption is that some alterations must have occurred to the landscape between the development of the first fuel model (2007) and the second (2011). To evaluate this assumption, an 84 acre clip was assembled to sample the two fuel model layers, exported from ArcMap as database files and transferred into Excel for analysis. Once transferred into Excel each fuel model was standardized using the theoretical heat content of each fuel class. The results indicate that the overall heat load of the site was reduced by approximate 26%, with most of that reduction coming from changes in the acreage of fuel model SH7 (Very High Load Shrubs), colored red. Urban cover, colored gray increased by less than 2%. The vegetation amounts remains above 75% of the parcel, with most of the changes coming from an alteration in the proportions allotted to each fuel class.



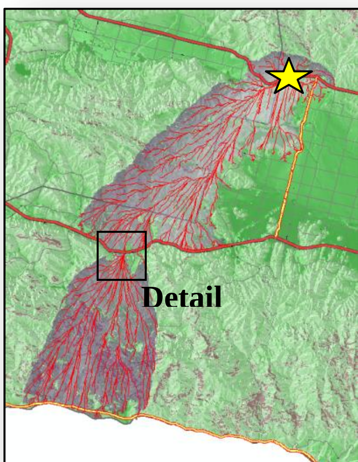
Graphic 8: Detail B

The fuel category changes at this site occurred as part of some random process, without any effort to influence the fire behavior at this location; Caltrans reduced the fuel load along the freeway, a builder planted dozens of oak trees as part of development migration project just west of the location, and the Mountain Conservatory had an oak tree planting project on their property. Each of these events serendipitously occurred, without any preplanned coordination; however, they had significant fire mitigation impact at the landscape level. These results indicate that a few subtle vegetation changes, in the correct location, can have major beneficial fire protection results.

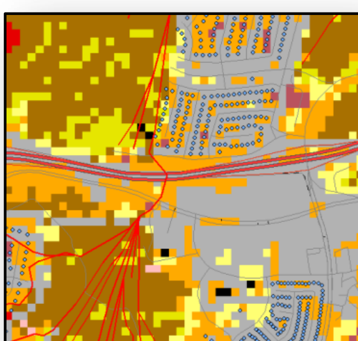
These two scenarios graphically illustrate the fire mitigation potential of landscape level strategies. Each of these scenarios demonstrates that a little preplanning can significantly alter the long term wildland fire risk in the Santa Monica Mountains.

Impact of Landscape Level Mitigation

The primary objective of any landscape level strategy should be to implement mitigation projects that slowly over time, not only reduce the fire loss, but also reduce the scale of each event. The primary method would be one that slows the fire's advance while at the same time breaks the firescape into smaller and smaller, more manageable segments.



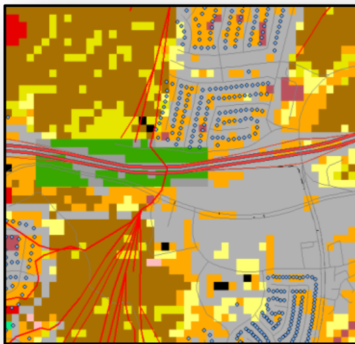
Graphic 9: Pre-Treatment



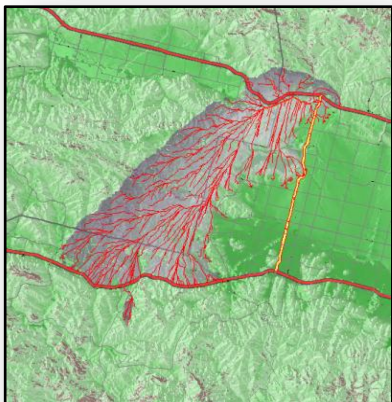
Graphic 9: Detail A

By reducing the scale of the event, a number of issues are resolved. First, is the ability to concentrate fire protection resources. Second, is a reduced potential for the fire to become plume-dominated, which greatly increases its intensity and reduces the probability of control. Third, the smaller the amount of vegetation damaged at one time, should assist in its recovery. Finally, with a smaller event, there is significantly reduced downstream impact after the fire.

To illustrate the implementation of a landscape level fire mitigation strategy, a fire scenario will be used that simulates a fire ignition at the 118 Freeway. This scenario (Graphic 9) would replicate a fire beginning at the fire linkage between the Santa Susanna Mountains and the Simi Hills. Such a fire would cross the 101 Freeway at two points; a primary location at Lost Hills Road (Detail A), and a minor linkage at Las Virgenes Canyon. Within this mitigation exercise, the fire will only be obstructed at Lost Hills Road, the primary fire linkage.



Detail B Graphic 9



Graphic 10: Post-Treatment

The first step is to develop a FlamMap fire behavior model of the pre-treatment scenario. Then a vegetation model is developed that simulates the fuel modification strategy. In this case it is a ½ mile greenbelt (NB3, agricultural), approximately 18 acres along the 101 Freeway corridor (Detail B, green). This vegetation model is then merged with the original fuel model layer, the landscape file recomposed, then transferred into FlamMap to assume the role as the post-treatment fire scenario.

The results (Graphic 10) demonstrate that with a relatively minor effort, a well conceived landscape level mitigation strategy can have significant results. The pre-treatment fire was approximately 43,468 acres, with the post-treatment fire approximately 25,692 acres. With an investment of 18 acres of fuel treatment, along a freeway, the fire was confined to the Simi Hills, which reduced the size of the simulated fire by over 40%.

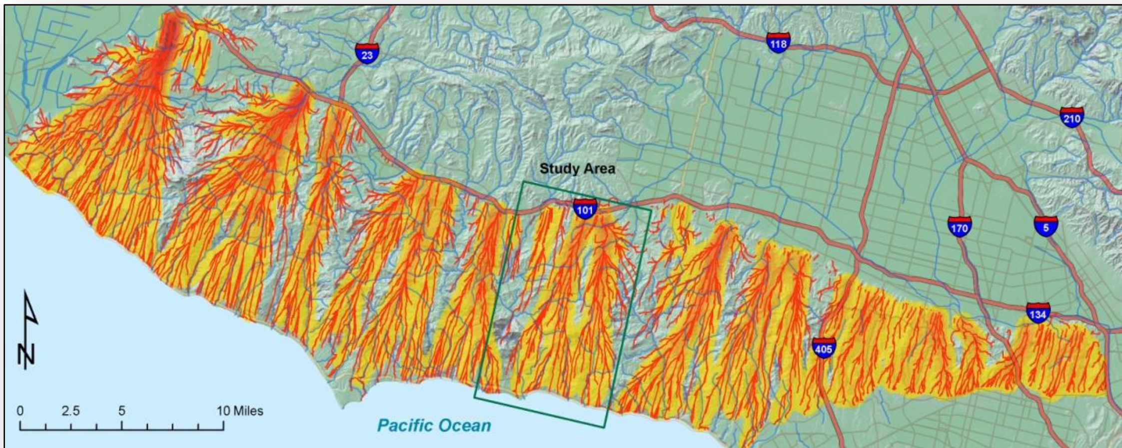
Santa Monica Mountains Fire Corridors

The current strategies for wildfire mitigation in the Santa Monica Mountains are primarily defensive strategies, where fuel treatment is applied nearest to the structures that need to be defended. Underlying this strategy is the assumption that these major fire events are inevitable and there is little that can be done to mitigate them at the landscape level.

In a landscape level fuel management strategy, the assumption is made that there are natural pathways that wildfire uses to transverse the mountainside. In this strategy, fire pathways are defined, and mitigation efforts are applied to these fire pathways, based upon the anticipated results. To identify the major fire corridors within the Santa Monica Mountains, the following assumptions were made: first, major fire events in the Santa Monica Mountains will have a north/south direction; second, ignition sources will be located near transportation routes. In this work the analysis is directed toward defining those fire pathways that begin along the northern boundary of the Santa Monica Mountains that would be driven by Santa Ana winds.

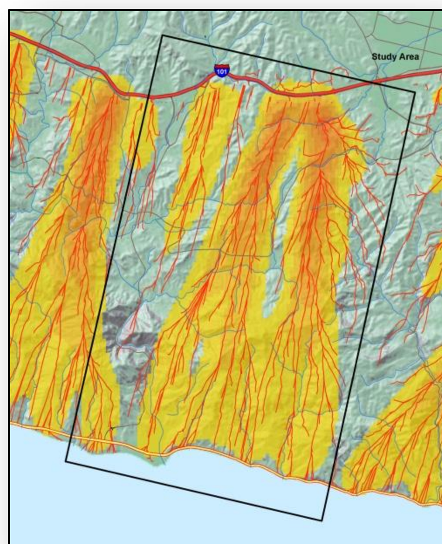
Using ArcGis, a polyline shape file was developed that would simulate a 45 mile long fireline, that approximated the closest east/west running transportation route. With this fireline and the Santa Monica Mountains landscape file, a minimum travel time model was developed that provided the MTT major path results. These results were then transferred back into ArcMap, enhanced and displayed as Graphic 11.

The results indicate that within the Santa Monica Mountains there are 10 or 12 major fire pathways between the Oxnard Plain on the west and the 405 Freeway on the east. Each of these pathways or corridors are likely targets of a landscape level fire mitigation strategy.



Graphic 11: Santa Monica Mountains Fire Corridors

To demonstrate the impact of a more aggressive fire mitigation strategy, the Malibu Canyon fire corridor has been selected (Graphic 12). Within this fire corridor a series of FlamMap fire behavior models will be developed that further demonstrates the impact of landscape level fire mitigation alternatives. The first alternative will be the Oak Woodland Fuel Treatment Method, then the Limited Grazing Alternative and finally, an alternative that combines the two methods.



Graphic 12: Malibu Canyon Fire Corridor

Section 6: LANDSCAPE LEVEL MITIGATION METHODS

Oak Woodland Fuel Treatment Method

During previous research and investigation of the Corral Canyon fire of 2007 (CA-LAC-258483 2007), it became evident that the Oak trees within the Malibu Bowl section of the fire area had sustained very little fire damage, even though the area had lost 23 of 107 homes. A Baer report survey (FEMA-1731-DR. 2007) of the area revealed that "a high percentage of Coastal Sage Scrub habitat burned at high severity" and that the eastern portion of the Chaparral habitat also received significant fire impact.

Personal observations of the fire scene indicated that the Oak trees in the area had added little to the fire intensity, and in some cases, had acted as shields or buffers to the residential structures. On parcels that were heavily Oak canopied and had an Oak litter understory, the Oak trees showed some heat stress, little fire damage, and no crown fire activity. From these observations, it seemed possible that a fuel treatment strategy based upon the fire resistive characteristics of the California Oak Woodland (Horney et.al. 2002, McCreary 2004) might provide a useful alternative to the existing methods of fuel treatment.

In the treatment method being proposed, the Oak Woodland Treatment Method, strategically selected parcels of grass or shrub would be converted to an Oak Woodland vegetation type, with a hardwood litter understory, and a 50% to 60% Oak canopy cover. In parcels with established Oak Woodlands, the surface fuels would be hand treated to convert the current surface vegetation into a hardwood litter fuel model. The converted parcels would then be linked with established parcels of Oak Woodlands to form a continuous band of Oak canopy, with a hardwood litter surface understory. These treatment parcels would be placed in such a manner as to block the natural fire paths. As the Oak Woodland Treatment Method plots matured, the risk levels would decline, fire protection would be enhanced and maintenance costs could be reduced. After a few years of treatment, the converted parcels would never again return to their baseline risk level, even if the level of commitment or funding falters.

Limited Grazing Fuel Treatment Alternative

The Limited Grazing Fuel Treatment Alternative is based upon the historical evidence that the native vegetation of the Santa Monica Mountains had been heavily influenced by the occupation of native people and the ranching activities of later landholders. Furthermore, slope analysis of the Santa Monica Mountains (Map 4) reveals that approximately 90 percent of the land area within the Santa Monica Mountains would have been accessible to some combination of agricultural use and livestock grazing. Analysis indicates that approximately 5 to 6% of the land was within the slope characteristics of prime to good agricultural land, roughly 55% was realistic for cattle grazing and about 85% of the land was accessible for sheep grazing.

Considering that the Malibu Canyon fire corridor was the location of Chumash population centers and was surrounded by a number of major ranching and grazing operations; it seems reasonable that a Limited Grazing Alternative would be a historically correct vegetation management method.

Based upon the above realizations, a 3,036 acre parcel was selected for the application of the Limited Grazing Fuel Treatment Alternative. The site chosen is within the Malibu Canyon fire corridor, near the junction of the 101 Freeway and Las Virgenes Road. (Graphic 21) This location was also the site of one of the last sheep grazing operations in the Santa Monica Mountains.

Combined Fuel Treatment Alternative

The combined fuel treatment alternative is the implementation of the Oak Woodland strategy in conjunction with the Limited Grazing strategy. The location of the combined fuel treatment would be intended to support the placement of the Oak Woodland Treatment. The combined fuel treatment alternative is the attempt to determine if there could be some additional benefit in combining an Oak Woodland Fuel Treatment with the Limited Grazing Alternative.

Section 7: FIRE CORRIDOR STUDY AREA

Graphic 13: Grass-GR2

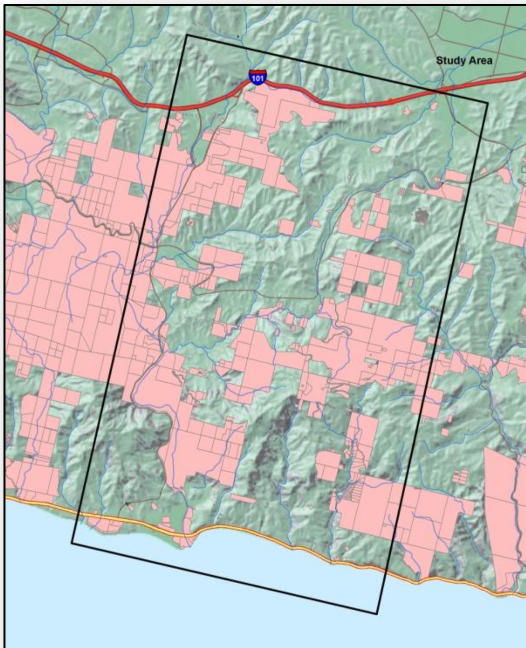
Graphic 14: Grass/Shrub-GS2

Graphic 15: Shrubs-SH7

The Santa Monica Mountains are a transverse mountain range running east to west from the coastal agricultural plains of Ventura County to the Los Angeles River, encompassing approximately 246,600 acres. The mountains are characterized by sheer east and west facing slopes, with steep drainages running down to coastal plains or into the Pacific Ocean. The Santa Monica Mountains are roughly defined by the 101 Freeway on the north, the Pacific Ocean on the south, the Los Angeles River on the east and the coastal plains of Ventura on the west (Map 1).

The study area is a subset of the Santa Monica Mountains encompassing a 28,000 acre fire corridor that is approximately bounded on the north by the 101 Freeway, the Pacific Ocean on the south, Las Virgenes Road on the west and Topanga Canyon on the east (Graphic 17)

Within the study area the vegetation communities range from lightly covered lower southern slopes of grasses and Coastal Sage Scrub to the higher northern slopes heavily forested with stands of Oaks and old growth Chaparral. Riparian woodlands line the canyon and valley bottoms fortunate enough to have perennial or intermittent streams; while Valley Oak Savannas spread out over the broad grasslands of the interior valleys (Map 1: Appendix C)



Graphic 16: Public Lands (pink)

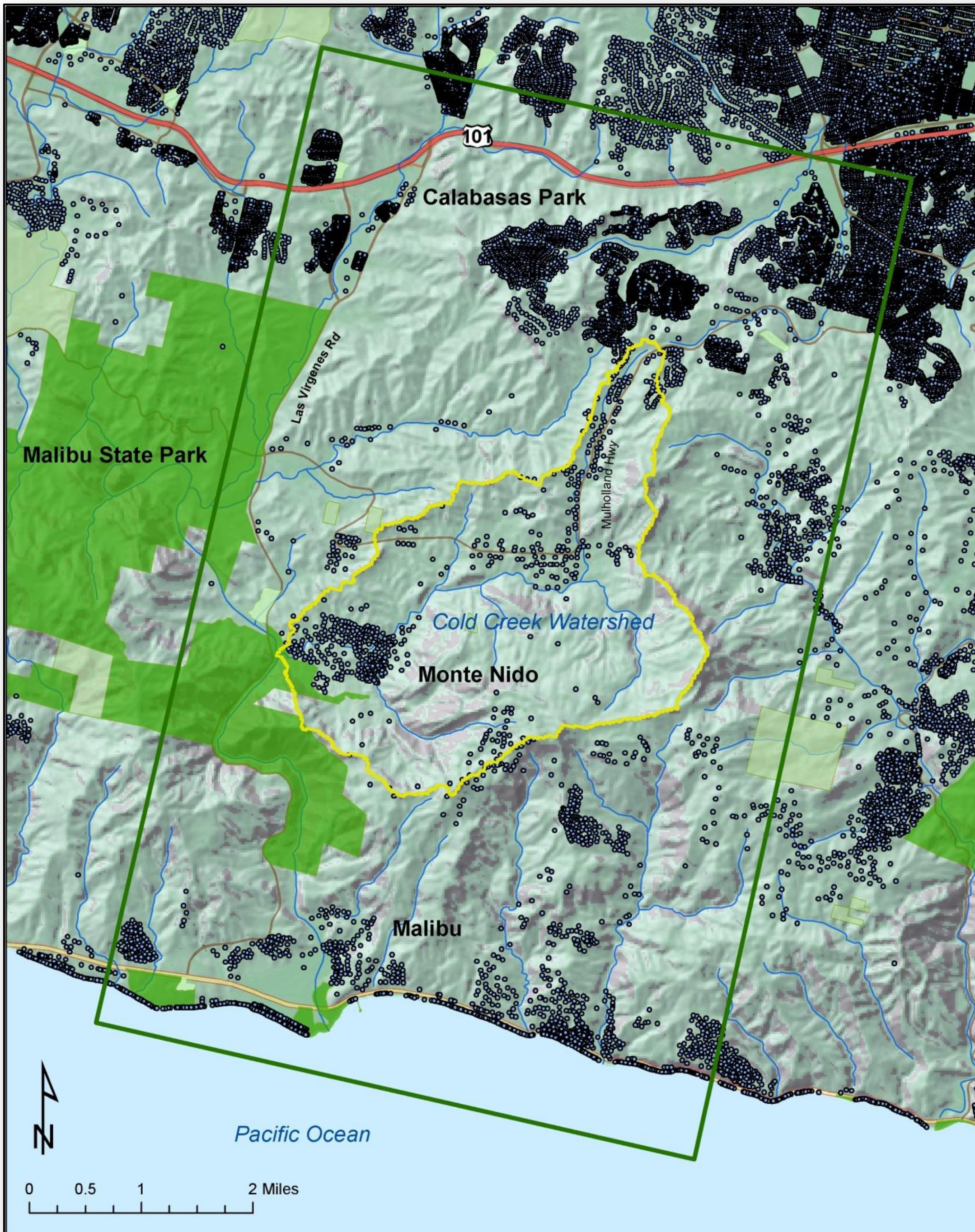
Within the boundaries of the study area grass (fuel models GR1 & GR2) represents approximately 6% of the landscape, with grass and shrub (FM GS2) 40%, and shrubs (FM SH7) 28% of the vegetation fuel load. Public Lands occupy approximately 36% of the total area within the study area (Graphic 16). The LandFire database classifies the vegetation within the public lands parcels as less than 6% grass, over 51% grass/shrub, and approximately 32% as fuel model SH7.

Communities at Risk

Individual properties at risk within the Malibu Canyon fire corridor study area are as varied as the landscape. The area contains approximately 7,760 residential structures with the median parcel size of .31 of an acre. Within the interior of the Malibu Canyon fire corridor, structures are generally within small lot subdivisions of ½ acre or less, rural in character, and with few amenities. Throughout this area one will find legacy owners of 5, 10 or 20 acres; only two parcels are larger than 100 acres. Strung out around the Mulholland Highway and the upper Cold Creek watershed, there are 150 to 200 homes. In the community of Monte Nido, 275 homes lie along the floor of the canyon as Cold Creek meanders south to join Malibu Creek and then runs to the Pacific Ocean. Monte Nido is one of the older communities in the Santa Monica Mountains and its heart is often passed over by the fires that sweep the canyon walls. Along the 101 Freeway, the area is populated by more conventional tracts and subdivisions constructed with curbs and sidewalks and the normal amenities of suburban living. Calabasas Park, at the northern edge of the study area, includes a full range of parks, schools, and commercial activities, with many developments offering gated entry. Calabasas Park and the surrounding area houses over 2,000 homes that are directly in the path of the Malibu Canyon fire corridor.

As a Malibu Canyon fire corridor event boils out onto the coast, another 1,500 to 2,000 homes are at risk. In the 1993 Old Topanga Fire, 268 homes were lost within the City of Malibu, most with views of the Pacific Ocean. State of California officials estimated the total loss, public and private, at half a billion dollars. Along the length of the coast, parcels are generally smaller and homes are more densely clustered. Oceanfront structures are generally on 30 to 60 foot wide parcels. On the mountain side of Pacific Coast Highway the parcels can range from ¼ acre to 1, 2 or 3 acres. Assessed values for individual structures can range from $10,000 for a semirural homestead to several million for a beachside cottage. Parcel sizes within the Santa Monica Mountains can range from small lot subdivisions of ¼ acre or smaller, to estates of 5 to 10 acres, and up to hundreds of acres owned by public agencies (Graphic 17).

Graphic 17: Malibu Canyon Fire Corridor Study Area



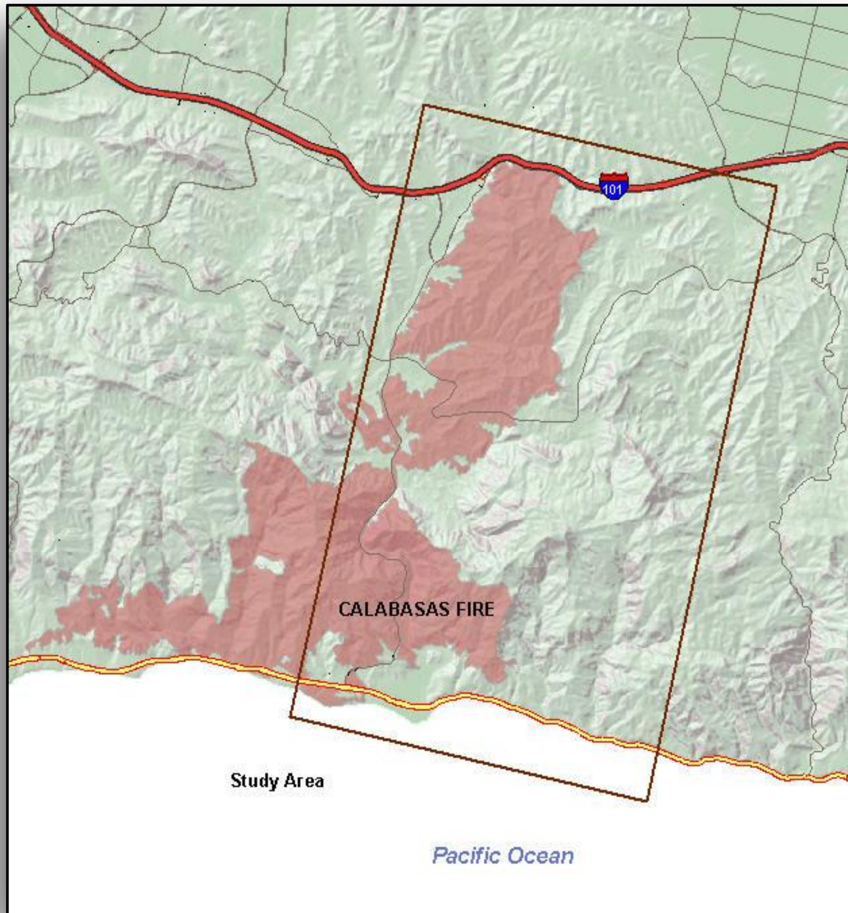
Fire Activity

Starting in the mid 1920s, fire incidences within the Santa Monica Mountains have occurred at an increasingly steady tempo; several years of moderately sized events of 1000 to 2000 acres, punctuated by extreme events of 10,000 to 15,000 acres, to mega-events of over 100,000 acres. Within the past 85 years, California state fire records indicate that 332 wildland fires have occurred within the Santa Monica Mountains, and 86 within the Malibu Canyon fire corridor. The most recent is the Calabasas Fire of 1996, which burned 1250 acres and destroyed a number of homes as it raced to the Pacific in less than a day (Graphic 18). Within the specific parcels selected for the modeling of the fire ignition line, 10 major fire events have occurred since 1938.

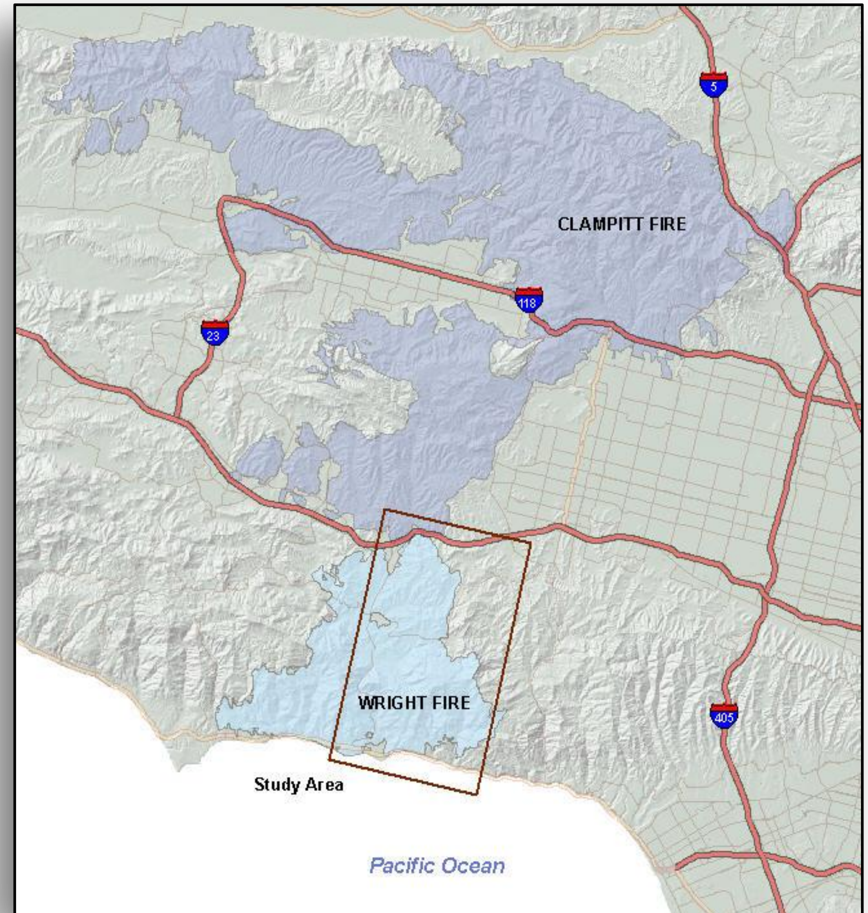
Within this coastal range, lightning-caused fire is virtually unknown and fire ignitions in the Santa Monica Mountains are generally anthropomorphic in origin. The greatest number of ignitions are arson or suspicious in origin, and are clustered along transportation and travel routes. Next, are mechanical means related to the use of some tool or devise, typically close to locations of human activity. Finally, are electrical power lines which are generally blown down by Santa Ana winds that reach sustained speeds of 30 to 50 miles per hour, with gusts up to 100 at the ridgelines.

October is the primary month of extreme fire events, driven by northeasterly Santa Ana winds that drive up temperatures, and drive down both humidity and live vegetation fuel moisture. During these events, air humidity will drop into the single digits, with live fuel moisture in the range of 60% or less. While October is the primary fire month, the "fire season" can stretch into December and January, depending upon the timing of the first major rainfall. The chaparral fuel community is generally considered to have fire return characteristics of between 30 to 50 years; however, within the Malibu Canyon corridor the pace has quickened, with some areas experiencing fire returns of 5 to 6 years.

While the Santa Monica Mountains appear isolated on the map, from a firescape perspective, they are connected on the north by the Simi Hills and the Santa Susanna Mountains even further to the north. Each of these mountainous areas has played a significant role in the fire history of the Santa Monica Mountains. The 1982 Dayton Canyon Fire crossed the 101 Freeway in a number of locations; burned 43,097 acres and 97 homes as it raced to the Pacific Ocean. The most spectacular, a 143,000 acre giant that began in the mid morning of September 29, 1970, at the junction of the 5 Freeway and Highway 14, burned as the Clampitt Fire across Porter Ranch, into the Simi Hills at Chatsworth, south to the 101 Freeway, then crossed the Highway at Malibu Canyon and advanced to the coast as the Wright Fire (Graphic 19).



Graphic 18: Calabasas Fire, October 21, 1996



Graphic 19: Clampitt/Wright Fire, September 25, 1970

Section 8: FUEL TREATMENT STRATEGIES

Oak Woodland Fuel Treatment

The methods employed to determine the benefits of the proposed Oak Woodland Fuel Treatment consist of five steps. First, is the development of the FlamMap Landscape file. Second, the development of a pre-treatment fire scenario that provides the baseline for the major fire characteristics within the study area. Third, is the establishment and creation of the necessary changes to the surface fuel and canopy attribute layers that will simulate the proposed Oak Woodland Treatment Method. Fourth, the running of the treatment fire scenario using the adjusted surface fuel model that will describe a post-treatment fire outcome. Finally, is the comparison of the pre-treatment fire characteristic with the post-treatment fire behavior outcomes.

Within each of the fire scenarios, two separate fuel moisture files were used. The first moisture file simulated vegetation fuel moistures under moderate weather conditions, late June to early July. The second represents fuel moistures under more extreme weather conditions. Each fuel moisture file provides FlamMap with the major classes of fuel moisture across the vegetation fuel model classes (Table 3).

Landscape File

Using the LandFire national seamless server website, the eight landscape raster layers were downloaded into an ArcMap document equipped with the ArcFuels toolset. After assembly the fuel model layer was modified, to adjust the model for major changes that had occurred since the assembly of the national dataset. Field inspection had determined that, the area of the Calabasas golf course was changed from fuel model 147 (very heavy shrub) to fuel model 93 (agriculture). Additionally, a new section of housing on the west end of Calabasas Park was changed from fuel model 122 (moderately coarse grass) to fuel model 91 (urban). Using the ArcFuels toolset, the eight raster layers were arranged into the pre-treatment Landscape File and uploaded into FlamMap for processing.

Pre-Treatment Scenario

After the pre-treatment Landscape File was loaded into FlamMap, a fire ignition line shape file was developed that would provide the location of the ignitions for each of the fire scenarios. The fire ignition line runs from Las Virgenes Road on the west to Calabasas Parkway on the east, and travels approximately parallel to the 101 Freeway (Graphic 20). This location was chosen since it intersects with two of the four major fire paths that cross the 101 Freeway from the Simi Hills to the north and it duplicates the location of two recent extreme fire events. Using the Minimum Travel Time (MTT) functions, four pre-treatment fire scenarios were modeled. Two scenarios were modeled under moderate Santa Ana weather, and two under extreme Santa Ana conditions. Under moderate weather conditions, burn period one, at 960 minutes, and burn period two, at

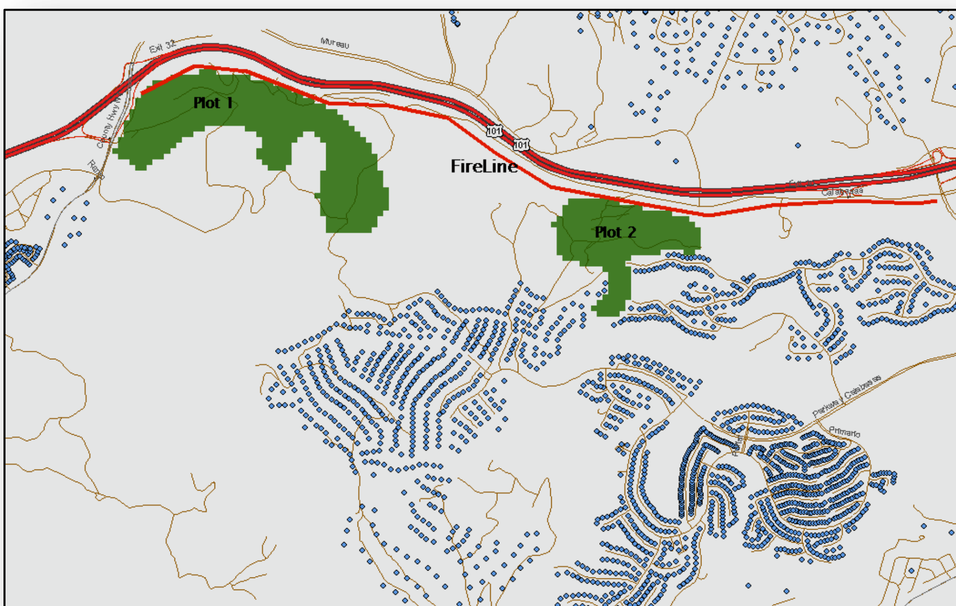
1220 minutes, were modeled. Under extreme weather conditions, burn period one, at 120 minutes, and burn period two, at 240 minutes, were modeled. Each fire scenario was modeled without fire suppression activities. The Arrival Time grids, Major Fire Paths, Flow Paths and the Influence Nodes grid layers for each fire scenario were transferred back to ArcMap for processing.

Treatment Layers

To define the attributes of the Oak Woodland Treatment prescription, a sample site within the Santa Monica Mountains was selected that contained a significant number of cells identified by the Scott/Burgan fuel model as Hardwood Litter surface fuel (182, TL2). Using the sample site, zonal statistics were developed for each of the canopy attributes (Table 43). These canopy characteristics were then used as the attributes for the simulated post fuel treatment fire modeling within the FlamMap software.

Based upon the above analysis, the treatment attributes are as follows:

- Fuel Model 182 (Hardwood Litter)
- Canopy Cover 65% (current test uses 55%)
- Canopy Height 17.5 meters
- Canopy Bulk Height 10.0 meters
- Canopy Bulk Density 1 kg/m^3



Graphic 20: Oak Woodland Treatment Plots with Ignition Fireline and Structure Locations

Following the development of the fuel and canopy criteria, one 120 acre (plot 1) and one 60 acre (plot 2) test plots were selected for application of the proposed treatment method (Graphic 20).

The location criterion was based upon the assumption that the fuel treatment would be most effective if it disrupted the natural major fire paths, as defined by FlamMap. Secondly, the treatment would accentuate the protection offered by infrastructure and provide an anchor point to other fire resistive landforms. The placement of the treatment sites was also aided by the MTT output, Nodes of Influence. The Node of Influence is a FlamMap grid layer that represents those cells that have the greatest influence on the fire path. After the treatment sites were selected, turned into polygon shape files, provided with the treatment fuel and canopy attributes; they were converted into raster layers and merged with the pre-treatment landscape fuel and canopy raster layers. These merged fuel and canopy layers were then converted to the treatment scenario's Landscape File.

Treatment Scenario

The post-treatment fire scenario is run in the same manner as the pre-treatment scenario, with the exception that the fuel model and canopy layers have been altered to reflect the Oak Woodland Treatment Method. After the MTT fire behavior layers have been developed, they are transferred back into ArcMap for further processing.

Treatment Comparison

The means of comparison consisted of three methods. First, the Pre-Treatment and the Post-Treatment fire scenario fire behavior characteristics of Flame Length, Fire Line Intensity, and Surface Fire Rate of Spread were compared for the first burn period. The fire behavior characteristics of Surface Fire Rate of Spread and Flame Length were compared for both the overall fire area and for their values within the treatment plots. Second, the geographic areas consumed by the simulated fire, were compared for the Post-Treatment and Pre-Treatment fire scenarios. This comparison was completed for the first burn period and the overall fire. Finally, to complete the impact analysis, comparisons were developed to evaluate the number of structures exposed to fire conditions within the two treatment scenarios.

Limited Grazing Fuel Treatment Alternative

The methodology for the modeling of the Limited Grazing Alternative will follow the same basic sequence as the previous fuel treatment, with a few minor adjustments. The same landscape file, pre-treatment and post-treatment scenarios are modeled. The major difference is in the development of the Limited Grazing Alternative treatment layers.

Landscape File

Refer to Oak Woodland Fuel Treatment Method.

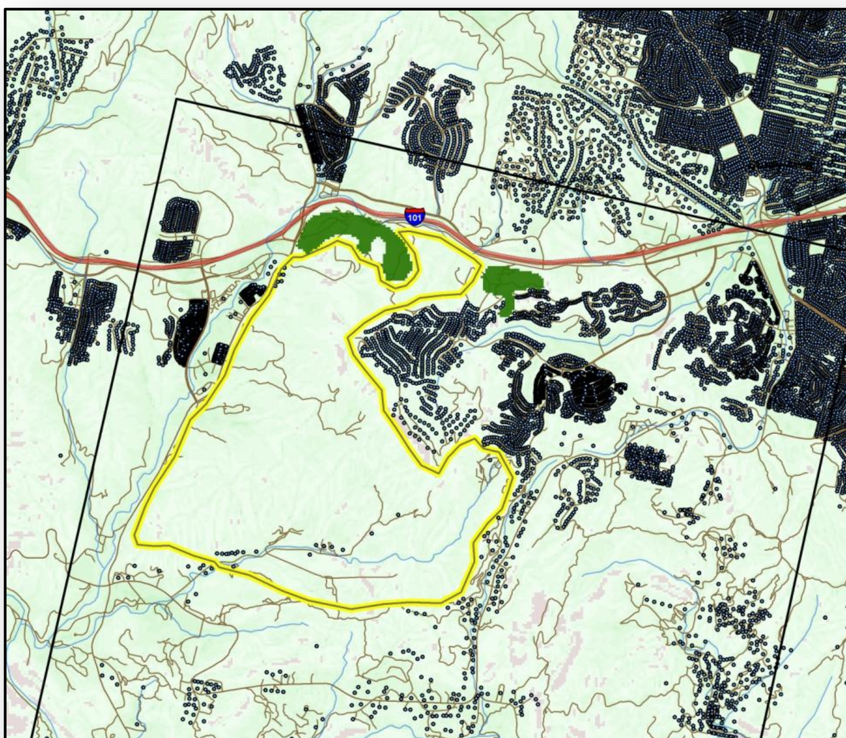
Pre-Treatment Scenario

Refer to Oak Woodland Fuel Treatment Method.

Treatment Layers

To define the attributes of the Limited Grazing Fuel Treatment Alternative a sample site was selected in the southeast quadrant of the intersection of the 101 Freeway and Las Virgenes Road (Graphic 21). In this simulation it is assumed that limited grazing would transform approximately 50 percent of the site into Scott/Burgan's grass model 1 (GR1). The site selection seems historically reasonable due to the fact that it is adjacent to a heavily traveled north-south herding route and near several large ranchos.

Using the current site vegetation proportions and locations, the grass fuel model locations were buffered until they reached approximately 50 percent of the site and then all of the selected class was transformed into grass fuel model GR1. This procedure gives 1,424 acres of simulated grazed grass landscape within the 3,036 acre site. It is assumed that limited grazing would transform grass fuel model GR2 and grass/shrub fuel model GS2 into grass fuel model GR1. The grazing assumptions would allow for something in the order of 850 lbs of forage per acre. Using current grazing standards (appendix A) of 30 lbs. of feed per grazing unit, this acreage would provide approximately 90 grazing days for approximately 450 head of cattle or 2,240 sheep.



Graphic 21: Limited Grazing Plot (yellow)

Treatment Scenario

The treatment fire scenario is run in the same manner as the pre-treatment scenario, with the exception that the fuel model layer has been altered to reflect the Limited Grazing Fuel Treatment Alternative. After the MTT fire behavior layers have been developed, they are transferred back into ArcMap for further processing.

Treatment Comparison

Refer to Oak Woodland Fuel Treatment Method.

Combined Fuel Treatment Alternative

The methodology for the modeling of the combined fuel treatment alternative will follow the same basic sequence as the previous fuel treatments, with a few minor adjustments. The same landscape file, pre-treatment and post-treatment scenarios are modeled. The major different is in the development of the combined treatment layers.

Landscape File

Refer to Oak Woodland Fuel Treatment Method.

Pre-Treatment Scenario

Refer to Oak Woodland Fuel Treatment Method.

Treatment Layers

To define the attributes of the Combined Fuel Treatment Alternative, the sample sites of the Oak Woodland Treatment Method was combined with the Limited Grazing Alternative sites (Graphic 21)

Treatment Scenario

The treatment fire scenario is run in the same manner as the pre-treatment scenario, with the exception that the fuel model layer has been altered to reflect both the Oak Woodland Treatment Method and Limited Grazing Fuel Treatment Alternative. After the MTT fire behavior layers have been developed they are transferred back into ArcMap for further processing.

Treatment Comparison

Refer to Oak Woodland Fuel Treatment Method

Section 9: MODELING RESULTS

Fire Behavior Characteristics

The fire behavior characteristics were compared for differences within the fire boundaries of the first burn period for each of the fuel treatment methods and fire weather scenarios. The Limited Grazing Alternative provided a 53.1% reduction in flame length when compared to the No Treatment alternative during the moderate weather scenario, and a 41.6% reduction under extreme weather conditions. The Oak Woodland Treatment alternative resulted in a 65.1% overall reduction in flame length for the moderate weather scenario. During the extreme weather scenario the Oak Treatment Method was less impressive with only a 16.9% reduction in flame length over the No Treatment alternative (Tables 5 and 6).

When just the treatment plot areas were considered, there was a reduction of 63.9 % for the Oak Treatment Method under the moderate weather scenario and a 97.5% reduction during extreme weather conditions. With the Limited Grazing Method, there was a 35% reduction during the moderate weather and 79.9% reduction during extreme weather. Under the extreme weather scenario, within the Oak Woodland Treatment plots, mean flame lengths were reduced from 11.35 meters to less than one meter (Tables 7 and 8).

The Fire Line Intensity, within the moderate weather scenario, was reduced by 77.8% for the Limited Grazing Method, 76.62% for the Oak Treatment and 82.5% for the Combined Treatment. Under the extreme weather scenario, the Grazing Method reduced the Fire Line Intensity by 31.8%, Oak Treatment by 35.7% and the Combined Treatment by 69.1% (Table 9 and 10).

Evaluating the Surface Rate of Spread, the reductions were equally as dramatic. Under the moderate fire scenario, the Oak Woodland Treatment reduced the Rate of Spread by 57.9%, and under extreme conditions it was reduced by 22.0%, during the first burn period (Tables 11 and 12). With the combined treatments of Limited Grazing and the Oak Woodland Treatment, the reduction was 66.6% under a moderate weather scenario, and a 46.9% reduction with an extreme weather scenario. Comparing just the area of the Oak Woodland Treatment plots, this allowed for a fire spread rate reduction from 34.6 to 5.3 meters per minute (Table 14).

Area Consumed

The areas consumed by the simulated fires were significantly reduced by all of the treatment methods, under both the moderate and the extreme weather scenarios, ranging from a low of 42.9% to a high of 87.7% (Table 17). In the first burn period, under moderate conditions, there was a 42.9% reduction in the area consumed with the Limited Grazing Alternative, from 1054 hectares (2,603 acres) to 602 hectares (1,487 acres).

Under extreme weather, the reduction was from 1,784 hectares (4,410 acres) to 829 hectares (2,048 acres), for a decrease of 53.6%. In the first burn period of the extreme weather scenarios the Combined Treatment Method had a reduction of 87.2%, with the Oak Treatment Method having a 80% reduction and Limited Grazing a 62% reduction During the second burn period, under the moderate weather scenario, the Combined Treatment had a reduction of 78.7%, from 1,784 hectares (4,410 acres) to 381 hectares (1,016 acres). Under the extreme weather alternative, the reduction was 87.7%, 4,407 hectares to 1,997 hectares (Graphics 22 and 23).

Structures Exposed

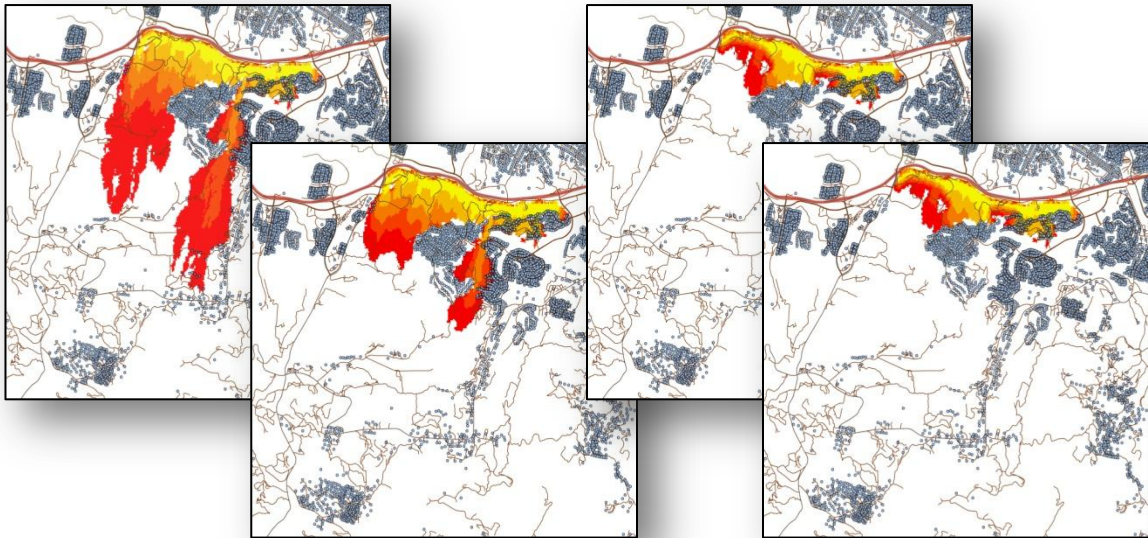
In the total area burned (1784 hectares) under the moderate weather scenario, using the No-treatment alternative, the simulated fire exposed a total of 428 structures with an assessed value of improvements of $233 million. Using a Limited Grazing scenario there were 829 hectares (2048 acres) burned, with 352 structures exposed, with an accessed evaluation of $135 million. Within the total fire area of the Oak Woodland Treatment alternative (411 hectares) there were 185 structures exposed with an assessed value of improvements of $99 million. Under moderate weather conditions, the reduction of value exposed, by the Oak Woodland Treatment alternative was $135 million, for a 58% reduction. The Combined Treatment Alternative provided similar result to the Oak Treatment Method (Tables15 and 16).

Under extreme weather conditions, the total area consumed was 4407 hectares, without fuel treatment, exposing 850 structures with an assessed valuation of $420 million. Simulating the Oak Woodland Treatment Method, under the same extreme conditions, the number of structures exposed was reduced to 447, with an assessed value of $248 million, for a reduction of $171 million or 41%. The Combined Treatment alternative provided a further significant reduction, with 321 structures exposed, and an assessed value of $181 million.

Graphic 22: Moderate Weather Burn Period Results

Moderate Weather Burn Period One (960 minutes)

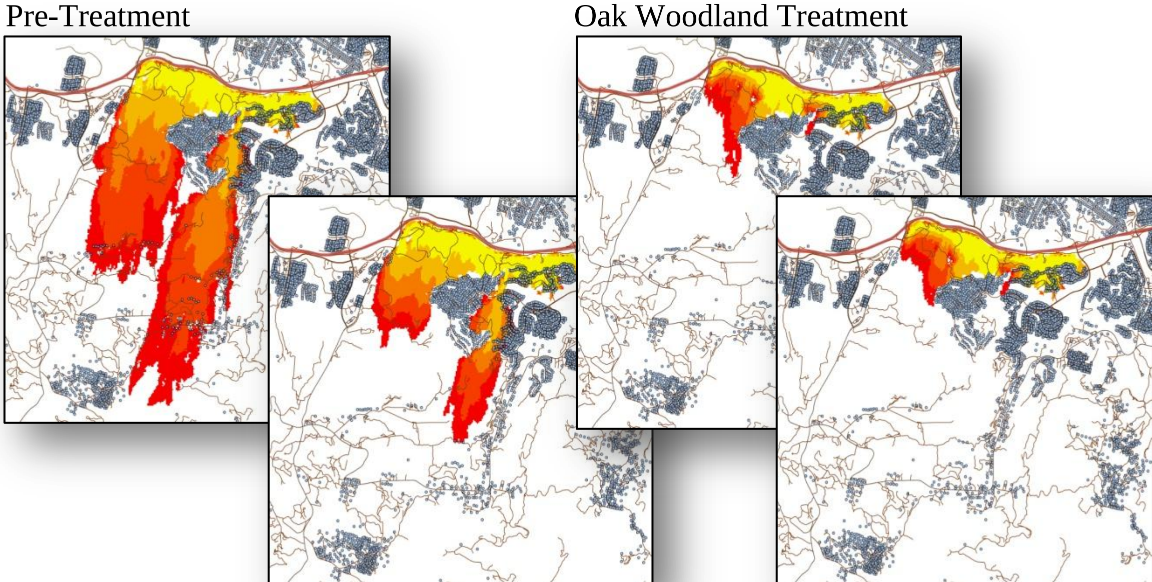
Pre-Treatment Oak Woodland Treatment



Limited Grazing Treatment Combined Treatment

Moderate Weather Burn Period Two (1220 minutes)

Pre-Treatment Oak Woodland Treatment

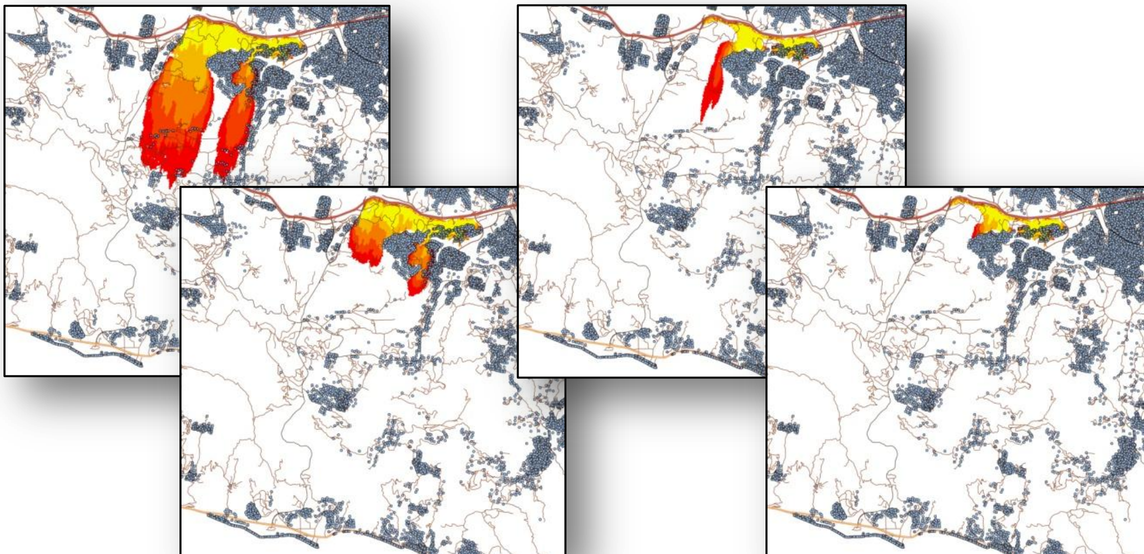


Limited Grazing Treatment Combined Treatment

Graphic 23: Extreme Weather Burn Period Results

Extreme Weather Burn Period One (120 minutes)

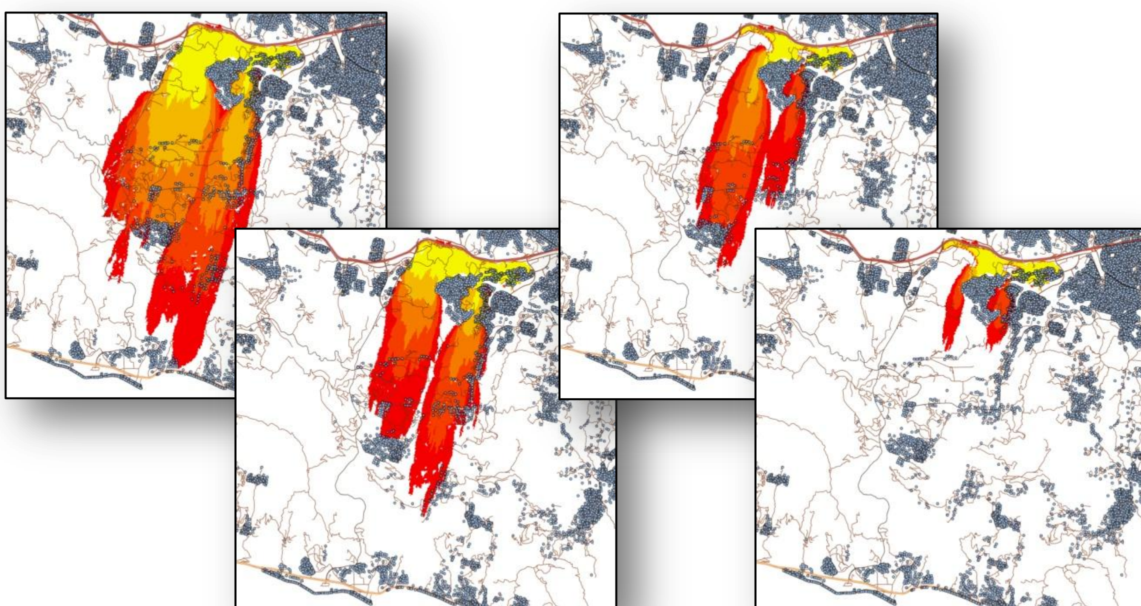
Pre- Treatment Oak Woodland Treatment



Limited Grazing Treatment Combined Treatment

Extreme Weather Burn Period Two (240 minutes)

Pre-Treatment Oak Woodland Treatment



Limited Grazing Treatment Combined Treatment

Section 10: DISCUSSION

This paper presents a landscape level fuel treatment strategy that utilizes the natural fire resistive characteristics of the California Oak Woodland and a historically appropriate Limited Grazing Alternative. Using the FlamMap fire modeling software, this research has developed a series of fire scenarios that simulate the impact of those strategies on wildland fire behavior under a variety of fire weather conditions. In comparing the pre-treatment to post-treatment fire behavior, this research has established that both strategies can significantly reduce environmental and structure loss from wildland fire in the urban interface of the Santa Monica Mountains. In this assessment it has been determined that the Oak Woodland Treatment Method and the Limited Grazing strategy would have a significant impact under both moderate and extreme fire conditions.

At the landscape level, FlamMap modeling indicates that the strategic placement of Oak Woodland Treatment plots can effectively block or obstruct the major fire paths and spread patterns of wildland fire within the Santa Monica Mountains. Furthermore, modeling indicates that the Limited Grazing Alternative in conjunction with Oak Treatment or as stand-alone method would have significant impact at the landscape level. These findings indicate that anchoring treatment plots against urban infrastructure and blocking fire path chokepoints would have a considerable impact on the total acreage consumed by wildland fire. Within the study area, FlamMap has identified a number of locations where the implementation of a long term, landscape based fuel treatment strategy would greatly reduce the probability of extreme fire events. Fire modeling indicates that it would be quite possible to limit the extension of wildland fire from the Simi Hills to the Santa Monica Mountains during extreme Santa Ana fire events. Considering these findings, it appears likely that over a period of time, applying the Oak Woodland Treatment strategy, in conjunction with the Limited Grazing Method, major fire corridors could be reduced into a series of smaller and smaller fire mitigation zones, which could effectively isolate one area from another.

When both the Oak Woodland Treatment Method and the Limited Grazing strategy were evaluated relative to their potential for limiting structure loss, the results were very encouraging. In each of the fire scenarios, the methods significantly reduced the amount of land consumed by wildland fire and greatly reduced the number of structures exposed to wildland fire risk. Modeling indicates that with just minor adjustments to the treatment plots, one could virtually eliminate a major fire event originating from the test locations. As an indirect protection, the methods offer the potential to slow and or turn the wildland fire as it approaches a residential community. For the direct protection of structures and residential communities, the Oak Woodland Treatment Method and the Limited Grazing strategy both appear to have great possibilities as a method for reducing wildland fire loss. FlamMap fire modeling indicates that both treatment methods would have significant potential for reducing fire intensity near structures, if they were positioned as a buffer or shield surrounding WUI communities.

In evaluating the strategies relative to their potential for assisting in fire suppression activities, the outcomes are extremely encouraging. In wildland fire suppression activities, flame lengths less than 4 feet are generally considered safe for direct attack by firefighters using hand tools or small hand lines. In the Oak Treatment plots, flame lengths, even under extreme conditions, were just over one foot at their maximum, well within a safe operating environment. Within the two treatment plots spread rates were significantly reduced, greatly enhancing firefighter safety. In reviewing the fire rate of spread, in conjunction with the flame length values, it is evident that an aggressive, safe fire attack is possible within the boundaries of the Oak Woodland Treatment plots. Under the majority of extreme wildland fire situations, direct fire attack activities are considered too hazardous or ineffective. Under extreme conditions within an Oak Woodland Treatment plot, direct fire attack could be both safe and effective. Within the Oak Woodland Treatment sectors, wind speeds would be low and the tree canopies would protect firefighters from the most hazardous conditions. Using the concepts involved within these strategies, treatment plots could be specifically placed to aid in fire suppression activities and pre-planned for use in both direct and indirect fire attack.

Section 11: CONCLUSION

This project has explored the origins, nature and mitigation of the wildland fire threat within the urban interface of the Santa Monica Mountains. Using firsthand accounts and historical records, it has investigated the social and economic events that transformed the region from a low intensity fire environment, into the current, high intensity fire environment. The findings indicate that at the time of first contact, the southern California coastal region was a landscape dominated by grassland vegetation types, maintained by periodic burning carried out by the indigenous people. Evidence indicates that this low intensity fire environment prevailed throughout the Spanish and Mexican periods primarily through the extensive cattle operations of the California Ranchos. With California statehood, this low intensity environment was sustained, reinforced by the growth of agribusiness, subsistence farming and continued grazing. This low fire intensity environment began to collapse in the early twentieth century, as the region transitioned from a pastoral agricultural economy into more of a wage-based industrial economy. The evidence indicates that the current high intensity fire environment within the Santa Monica Mountains is an artifact of this transition.

This research has questioned the policy proclamation that landscape level fire mitigation is “not possible” or warranted within the Santa Monica Mountains. Using FlamMap fire modeling, this study has investigated the landscape nature of the wildland fire activity. Using these modeling techniques it has identified landscape level fire path linkages between the Santa Monica Mountains, Simi Hills and the Santa Susanna Mountains. Demonstrating the more advanced features of FlamMap, it has identified numerous targets of opportunity for landscape level fuel mitigation within the Santa Monica Mountains.

Based upon the findings of this research, it appears that a landscape level fuel treatment strategy is a realistic alternative to the current individual parcel directed methods of wildland fuel treatment. These findings also demonstrate that the implementation of a fuel treatment strategy directed toward the interruption of major fire paths would have a significant impact on wildland fire spread. Additionally, this evidence points out that strategically placed fuel treatments can block or turn the advancement of wildland fire on residential communities. Furthermore, these finding clearly indicate that a landscape level fuel treatment strategy, directed toward the interruption of major fire paths, would significantly reduce the potential for large scale residential structure loss within the Santa Monica Mountains.

While this research was chiefly directed toward testing the application of landscape level fuel treatment strategies, it has made a number of other significant findings. First, it has demonstrated that the FlamMap modeling environment is an effective method of evaluating the impact of alternative fuel treatment prescriptions. Secondly, using the advanced MTT functions, this research has identified previously unknown fire path linkages between the Simi Hills and the Santa Monica Mountains. Furthermore, the findings indicate that landscape level fuel treatment at these locations would significantly reduce the risk of a major wildland fire extending from the Simi Hills into the Santa Monica Mountains. Thirdly, the application of the FlamMap MTT major fire path function to the entire Santa Monica Mountains has identified hundreds, if not thousands, of potential sites where the application of the landscape level fuel treatment would have a significant impact on wildland fire loss. Finally, this research indicates that both direct and indirect fire suppression strategies can be developed using the impact of both the Oak Woodland Fuel Treatment Method and the Limited Grazing Alternative on flame lengths and fire spread rates. Clearly, the findings of this research offer a number of opportunities for wildland fire mitigation in the urban interface of the Santa Monica Mountains.

However, if these opportunities are to be realized, a consensus needs to be reached on a number of issues. The first issue is the question of what constitutes a native grassland environment. Some have argued that the contemporary grasses are introduced species and should not be considered native. The position of this research is that these grasses are just part of the natural evolutionary process that has occurred since the Spanish occupied the southwest in the early 1600s. Southern California is a virtual sea of introduced species and it would seem counterproductive to argue over what is native or not native, particularly for grass species that have been here for hundreds of years. It would seem reasonable to attempt to reestablish native grasses, particularly on public parklands. The most important criteria, aside from non-invasiveness, should be whether or not the species promotes wildland fire safety or not.

The next issue would be the question of what would constitute the proper proportions of grass to coastal sage, to chaparral. During the period of Spanish and early American settlement most of the region was committed to either agriculture or grazing. Under these conditions the majority of the landscape would have been agriculture (NB3) or grassland fuel types GR1 or GR2. Slope analysis of the Santa Monica Mountains indicates less than 10% of the topography would have been out of reach of the grazing herds. This situation would dictate approximately 10% chaparral, coastal sage along the margins, and the dominant vegetation type grass, somewhere around 80%. These figures seem to be supported by Dana’s observations in the 1830s that the coastline from Santa Barbara to San Diego was treeless and barren.

The question of the correct vegetation proportions, during the period prior to colonization, is somewhat more problematic. The evidence clearly indicates that the region was grassland, maintained by periodic burning; however, there is little indication of what the proportions might have been. The location of missions, pueblos and ranchos give us a clue, but no definitive answers. The most likely solution would be a model that estimated the size of wildlife herds and acreage allotted to seed and acorn production, based upon the caloric needs of the indigenous people.

The one remaining issue of concern is the negative impact of wildland fuel mitigation on native vegetation. Longcore has argued that the implementation of a 200 foot fuel management buffer would require up to 3 acres of habitat destruction for an average sized residential structure (Longcore 2003). Using Longcore's values, the CWPP area of 128,180 acres, and 16,543 existing structures, would require 49,500 acres of vegetation clearance for fuel management purposes. Using the same method for the study area, this would require over 23,000 acres of vegetation clearance. Obviously, a fire mitigation procedure that requires a 38% reduction in native vegetation would have significant negative environmental impacts. However, if one evaluates the current placement of structures within the Santa Monica Mountains, using more rigorous methods, the results are much less threatening.

Applying the buffering toolset and assuming an average structure size of approximately 2800 square feet, existing structures within the CWPP would require a total of 15,584 acres (Table 18) for a 200 foot fuel management zone; of that, 11,379 acres are vegetation, or less than seven tenths of an acre per structure. Within the Malibu Canyon fire corridor study area with 27,712 acres and 7,760 structures, the 200 foot clearance guidelines require a little over one half acre per structure. This analysis indicates that the impact of fuel management, for the purposes of fire mitigation is something in the order of 4 or 5 times less than previously analysis would indicate. Clearly the negative impact of fuel management guidelines on native vegetation is less onerous than some would have us believe; particularly considering that compliance for fuel management purposes is never 100%.

In Los Angeles County, the transition from a low fire intensity environment of the pastoral economy to the high fire intensity of the post-industrial economy required something in the order of 75 to 100 years. On the central coast of California this transition is occurring before our eyes. In vast tracts of northern Santa Barbara County and southern San Luis Obispo County, prime agricultural land is being converted to housing and commercial uses. Along the margins of these new commercial centers, large tracts of former grazing lands are being converted to vineyards and other agricultural uses. The very process that turned southern California from a low intensity fire environment into a high intensity fire environment is occurring on the central coast now.

Over the past decades the wildland fire risk has grown to threaten every rural community within California. In the future this risk will potentially grow to threaten our urban cores and commercial centers. With climate change and limited resources for fire suppression, California cannot afford to stand by without applying every opportunity to decrease the wildland fire risk. Fire modeling, landscape level fuel mitigation and fuel management strategies that provide for long term benefits are just such an opportunity.

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Appendix A: Livestock Grazing Capacity

This appendix describes the grazing model used in this thesis to determine the vegetation impact of livestock grazing during the late 19^{th} and early 20^{th} century, in southern California. It is not intended to be a definitive analysis of the grazing capacity of the Santa Monica Mountains, only a tool to aid in evaluating the impact of the historical numbers of livestock.

The model uses contemporary stocking rates as described by professional cattle management associations and livestock bulletins supplied by academic institutions. These methods generally illustrate a rule of thumb that would have the stockman "graze half, leave half." This process is intended to graze only half of the available forage, leaving the remainder for the following year. It is doubtful that early stockman would have been so restrained; however, this seems to be a reasonable assumption, in the absence of firsthand accounts.

Stocking Assumptions:

- One animal unit (Table 1) will consume approximately 30 pounds of dry-weight forage per day.
- This amount will be approximately 3 percent of the animal's body weight.
- 25% of the available forage will be destroyed by trampling, defecation and the bedding needs of the livestock.

In order to estimate the dry-weight forage amounts necessary for the above assumptions, this grazing model uses the fine fuel load calculations as described by Scott and Burgan in "Standard Fire Behavior Fuel Models: A Comprehensive set for use with Rothermel's Surface Fire Spread Model." Within this work, the authors provide, along with the fire characteristics of the fuel class, the fuelbed depth and the tons per acre for each vegetation category. The LandFire database identifies two range land grass fuel models for the southern California region: Grass models GR1 and GR2. Grass model 2 is assumed to be the initial forage condition before grazing and grass model 1, the condition after grazing. Grass model 2 is a continuous dry-climate grass with approximately 1 foot of fuel depth.

To provide a greater range of possible forage conditions, grass model GR4 has been included in the analysis to supply a grass condition that would be more representative of a very heavy rainfall year. Grass model 4 would be representative of range conditions with approximately 2 feet of grass. Currently, there are no parcels within southern California that are identified as having a GR4 vegetation cover.

Vegetation Models

Grass Model 1 (GR1) Drought Conditions or, After Grazing

Description: The grass in GR1 is generally short, either naturally or from grazing, and may be sparse or discontinuous. The grass model used for drought conditions or after grazing – Fine Fuel Load (t/ac) 0.40

Grass Model 2 (GR2) Normal Weather Conditions

Description: The grass in GR2 is short, fuelbed depth of approximately 1 foot. Load is greater than GR1, may be more continuous. Grass model used for normal rainfall amounts – Fine Fuel Load (t/ac) 1.10

Grass Model 4 (GR4) After Heavy Rainfall

Description: The grass in GR4 has a fuelbed of approximately 2 feet. The grass model used to represent heavy rainfall conditions – Fine Fuel Load (t/ac) 2.15

Animal Unit Equivalents

Kind of Animal	**Class of Animal**	**Number of Animal Unit Equivalents**
Cow & Calf	1000 lb & < 4 mos.	1.00
Long Yearling Cattle	12 -17 mos.	0.80
Short Yearling Cattle	7 – 12 mos.	0.60
Mature Bulls	———————	1.35
Mature Horses	———————	1.25
Adult Female Goats with Kids	———————	0.17
Weaned Kids to Yearlings	———————	0.10
Mature Bucks	———————	0.22
Mature Ewes with Lambs	———————	0.20
Weaned Lambs to Yearlings	———————	0.12
Mature Rams	———————	0.25

How to Determine Livestock Grazing Capacity (http://www.cattlemanagement.com/determine-livestock-grazing-capacity)
By Robert Fears - viewed May 19, 2011

Based upon the above assumption on range conditions and stocking rates, the following calculations can be made: under normal rainfall amounts southern California rangeland will provide 1.10 tons per acre of forage. If 25% of the available forage would be destroyed due to trampling, defecation and bedding needs, that would leave 1650 pounds of forage for grazing. Using the rule of thumb to “graze half, leave half,” one acre of southern California rangeland would supply approximately 825 pounds of forage to a prudent stockman.

Appling the grazing assumption that a 1000 lb. cow will eat 3% of its body weight per day, that animal would require 30 pounds of forage per day or 10,950 pounds per year. Converting those conditions to acreage, this one Grazing Unit would require approximately 13.25 acres of open rangeland for a year’s worth of forage.

Los Angeles County Estimated Grazing Acreage

	Improved		Grazing		Grazing		Grazing		Grazing	Total	
	Farm		Horse	Dairy	Cow	Beef	Cattle		Sheep	Grazing	Combined
Period	Acres	Horses	Acres	Cows	Acres	Cattle	Acres	Sheep	Acres	Acres	Acreage
1850	5,587	12,173	201,961	48,424	642,719	65,051	863,404	6,541	17,363	1,725,447	1,731,034
1860	20,600	14,035	232,853	3,397	45,087	71,078	943,399	94,630	251,200	1,472,539	1,493,139
1870	234,883	9,652	160,135	2,468	32,757	19,178	254,544	247,603	657,273	1,104,710	1,339,593
1880	303,386	10,233	169,775	4,965	65,899	7,061	93,719	360,488	956,932	1,286,324	1,589,710
1890	759,933	17,288	286,824	10,418	138,275	10,511	139,510	87,632	232,623	797,232	1,557,165
1900	895,668	21,222	352,092	24,646	327,120	12,701	168,577	65,862	174,834	1,022,622	1,918,290
1910	757,985	22,424	372,035	20,524	272,409	22,571	299,579	72,725	193,052	1,137,075	1,895,060
1920	882,333	18,420	305,605	24,211	321,346	7,752	102,890	50,234	133,348	863,189	1,745,522

Table 1: Estimated Grazing Acreage

Source: United States Census, 1850 – 1920
United States Statistics of Agriculture 1850 – 1920
Los Angeles County Crop and Livestock Reports

Tri-County Historical Agricultural Time Series
Los Angeles, Orange, and Ventura Counties

Period	Population	FarmAcres	Horses	Cows	Cattle	Sheep
1850	8320	5,587	12,173	48,424	65,051	6,541
1860	11333	20,600	14,035	3,397	71,078	94,630
1870	15309	234,883	9,652	2,468	19,178	247,603
1880	38454	389,419	13,117	5,991	9,551	458,047
1890	125114	1,349,702	31,651	14,878	30,175	253,426
1900	204361	2,047,513	39,227	44,129	26,890	158,624
1910	556914	1,679,876	44,469	29,374	60,970	148,174
1920	1026554	1,652,172	34,132	30,445	13,116	44,540
1930	2382142	1,199,956	16,768	54,701	60,998	52,646
1940	2986088	1,289,735	13,158	88,736	138,154	27,494
1950	3116514	1,745,915	11,775	118,982	182,834	28,936
1960	7570920	1,288,363	7,682	131,148	139,446	49,375
1969	8690012	1,174,311	6,882	57,229	100,310	35,892
1982	9819490	783,606	14,173	13,749	51,578	36,451
1992	11942736	564,906	11,683	4,883	27,734	15,412
2002	13118824	511,847	10,138	894	13,880	3,631
2007	13677780	454,953	17,658	4,579	11,782	3,900

Table 2: Historical Agricultural Time Series

Source: United States Census, 1850 – 2010
United States Statistics of Agriculture 1850 – 2007
Los Angeles County Crop and Livestock Reports

Appendix B: Scott/Burgan Fuel Models

Grass fuel model - GR1 (101)

Description: The primary carrier of fire in GR1 is sparse grass, though small amounts of fine dead fuel may be present. The grass in GR1 is generally short, either naturally or by grazing, and may be sparse or discontinuous. The moisture of extinction of GR1 is indicative of a dry climate fuelbed, but GR1 may also be applied in high-extinction moisture fuelbeds because in both cases predicted spread rate and flame length are low compared to other GR models. (This model is representative of grass conditions under grazing or during more drought-like conditions)

Fine fuel load (t/ac) 0.40
Characteristic SAV (ft-1) 2054
Packing ratio (dimensionless) 0.00143
Extinction moisture content (percent) 15

Grass fuel model - GR2 (102)

Description: The primary carrier of fire in GR2 is grass, though small amounts of fine dead fuel may be present. Load is greater than GR1, and fuelbed may be more continuous. Shrubs, if present, do not affect fire behavior.

Fine fuel load (t/ac) 1.10
Characteristic SAV (ft-1) 1820
Packing ratio (dimensionless) 0.00158
Extinction moisture content (percent) 15

Grass-Shrub Fuel Model - GS1 (121)

Description: The primary carrier of fire in GS1 is grass and shrubs combined. Shrubs are about 1 foot high, grass load is low. Spread rate is moderate; flame length low. Moisture of extinction is low.

Fine fuel load (t/ac) 1.35
Characteristic SAV (ft-1) 1832
Packing ratio (dimensionless) 0.00215
Extinction moisture content (percent) 15

Grass-Shrub Fuel Model – GS2 (122)

Description: The primary carrier of fire in GS2 is grass and shrubs combined. Shrubs are 1 to 3 feet high, grass load is moderate. Spread rate is high; flame length moderate. Moisture of extinction is low.

Fine fuel load (t/ac) 2.1
Characteristic SAV (ft-1) 1827
Packing ratio (dimensionless) 0.00249
Extinction moisture content (percent) 15

Shrub Fuel Model –SH2 (142)

Description: The primary carrier of fire in SH2 is woody shrubs and shrub litter. Moderate fuel load (higher than SH1), depth about 1 foot, no grass fuel present. Spread rate is low; flame length low.

Fine fuel load (t/ac) 5.2
Characteristic SAV (ft-1) 1672
Packing ratio (dimensionless) 0.01198
Extinction moisture content (percent) 15

Shrub Fuel Model - SH5 (145)

Description: The primary carrier of fire in SH5 is woody shrubs and shrub litter. Heavy shrub load, depth 4-6 feet. Spread rate very high; flame length very high. Moisture of extinction is high.

Fine fuel load (t/ac) 6.5
Characteristic SAV (ft-1) 1252
Packing ratio (dimensionless) 0.00206
Extinction moisture content (percent) 15

Shrub Fuel Model –SH7 (147)

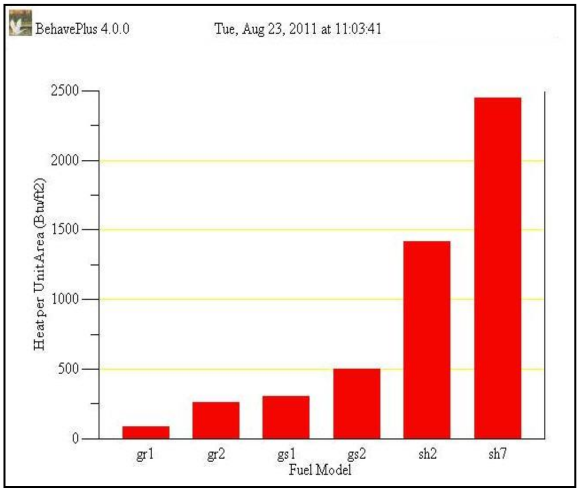
Description: The primary carrier of fire in SH7 is woody shrubs and shrub litter. Very heavy shrub load, depth 4 to 6 feet. Spread rate lower than SH5, but flame length similar. Spread rate is high; flame length very high.

Fine fuel load (t/ac) 6.9
Characteristic SAV (ft-1) 1233
Packing ratio (dimensionless) 0.00344
Extinction moisture content (percent) 15

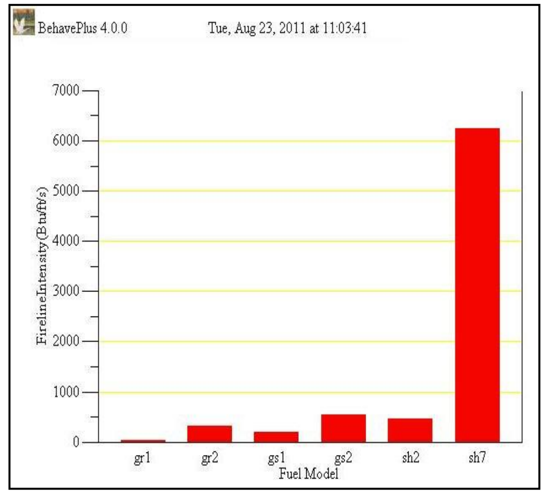
Scott, Joe H.; Burgan, Robert E. 2005. **Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model**.
Gen. Tech. Rep. RMRS-GTR-153.
Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Appendix C: BehavePlus4 Result

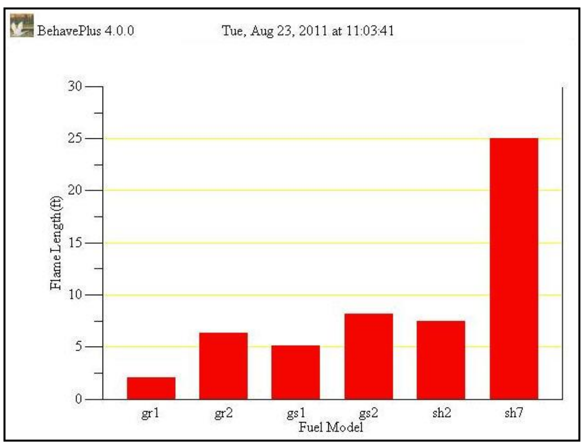
Santa Monica Mountains' Fuel Models



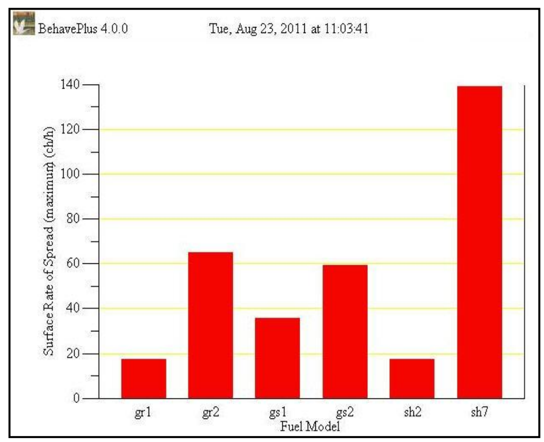
Heat per Unit Area



Fireline Intensity



Flame Length



Spread Rate

BehavePlus Results

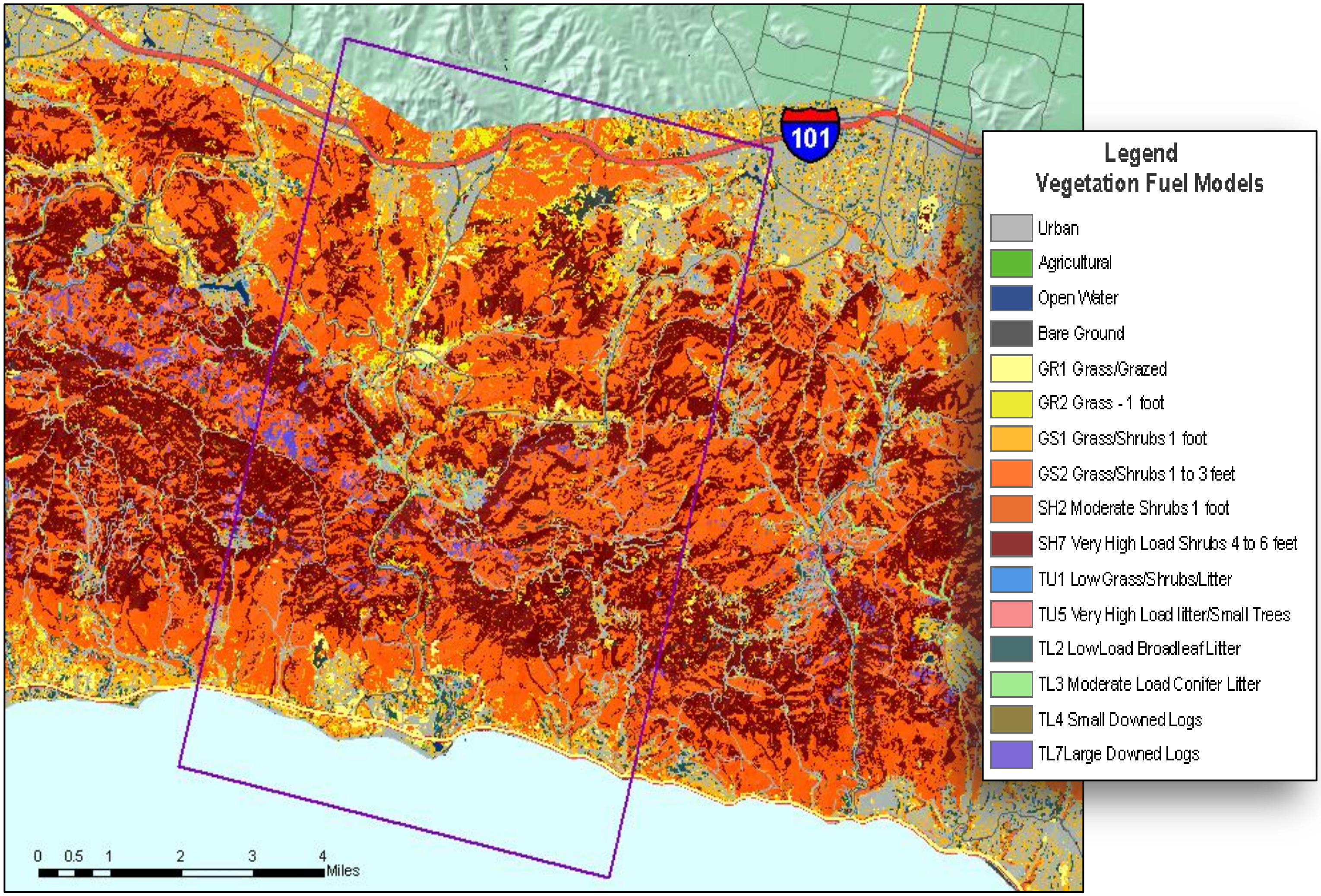
BehavePlus 4.0.0 Wed, Oct 12, 2011 at 16:37:27

Fuel Model	ROS (max) ch/h	Heat per Unit Area Btu/ft2	Fireline Intensity Btu/ft/s	Flame Length ft	Separation Distance ft	Zone Size ac	Zone Radius ft
gr1	17.4	88	28	2.1	8	0.02	16
gr2	65.1	261	311	6.3	25	0.08	33
gs1	35.7	301	197	5.1	20	0.06	28
gs2	59.5	502	548	8.2	33	0.12	41
sh2	17.5	1419	454	7.5	30	0.10	38
sh7	139.1	2446	6239	25.1	100	0.84	108

Table 1. Fire Behavior Characteristics

Fuel Model Discriptions

Fuel Model	
gr1	Short, sparse, dry climate grass (D) (101)
gr2	Low load, dry climate grass (D) (102)
gs1	Low load, dry climate grass-shrub (D) (121)
gs2	Moderate load, dry climate grass-shrub (D) (122)
sh2	Moderate load, dry climate shrub (S) (142)
sh7	Very high load, dry climate shrub (S) (147)

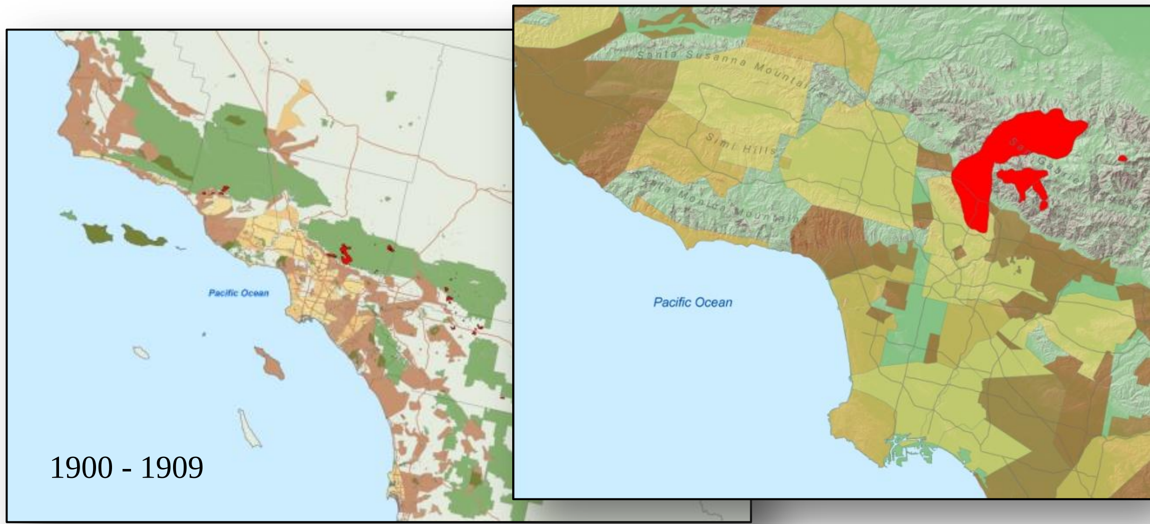


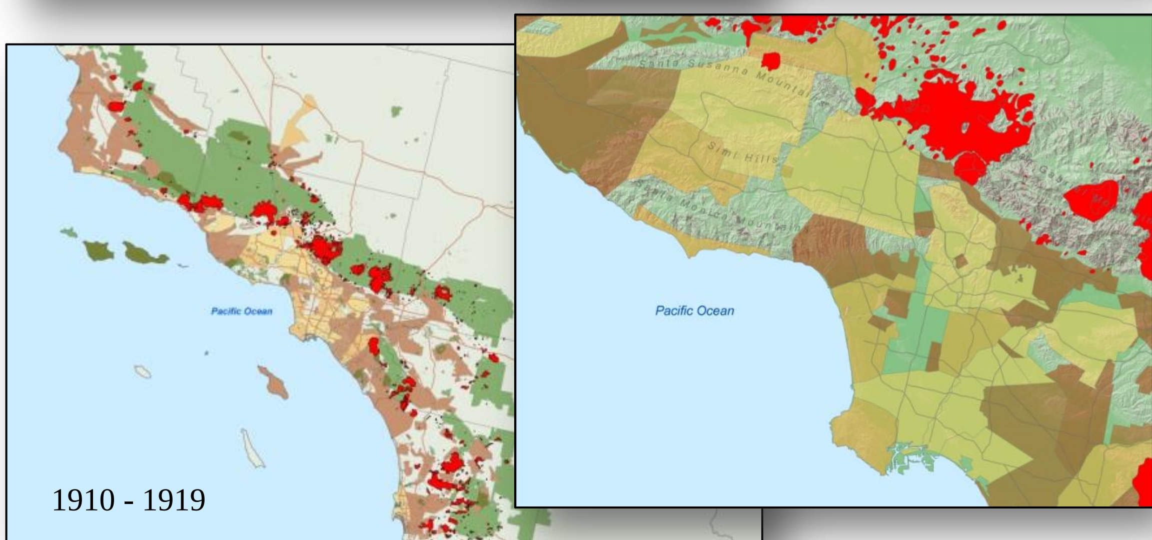
Map 1. Vegetation Fuel Types

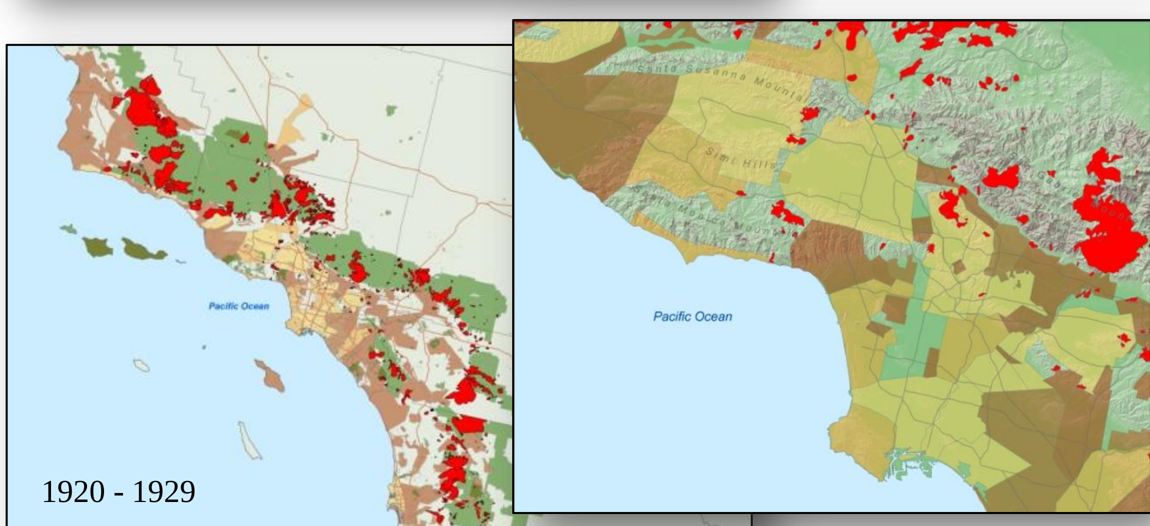
	Santa Monica Mts.		CWPP		CWPP Public Lands	
Vegetation Fuel Type	Acres	Percent	Acres	Percent	Acres	Percent
Urban	46,883	19.01%	11,839	9.24%	1,966	5.35%
Agricultural	6,243	2.53%	10	0.01%	1	0.00%
Open Water	839	0.34%	380	0.30%	12	0.03%
Bare Ground	1,547	0.63%	1,150	0.90%	248	0.68%
GR1 grass/grazed	8,719	3.54%	3,668	2.86%	279	0.76%
GR2 grass 1 foot	4,137	1.68%	2,953	2.30%	675	1.84%
GS1 grass/shrubs 1 foot	26,639	10.80%	7,695	6.00%	1,014	2.76%
GS2 grass/shrubs 1 to 3 feet	87,010	35.28%	58,606	45.72%	17,237	46.94%
SH2 Moderate Shrubs 1 foot	1,084	0.44%	492	0.38%	155	0.42%
SH7 Very High Load Shrubs 4-6	50,822	20.61%	36,293	28.31%	13,383	36.45%
TU1 Low grass/shrubs/litter	2,220	0.90%	394	0.31%	73	0.20%
TU5 Very High Load litter/small trees/shrubs	441	0.18%	369	0.29%	222	0.61%
TL2 Low Load Broadleaf Litter	6,652	2.70%	1,641	1.28%	269	0.73%
TL3 Moderate Load Conifer Litter	1,116	0.45%	759	0.59%	280	0.76%
TL4 Small downed logs	397	0.16%	386	0.30%	145	0.40%
TL7 Large Downed Logs	1,869	0.76%	1,548	1.21%	760	2.07%
Total Acres	246,618		128,180		36,719	

Table 2. Vegetation Fuel Types

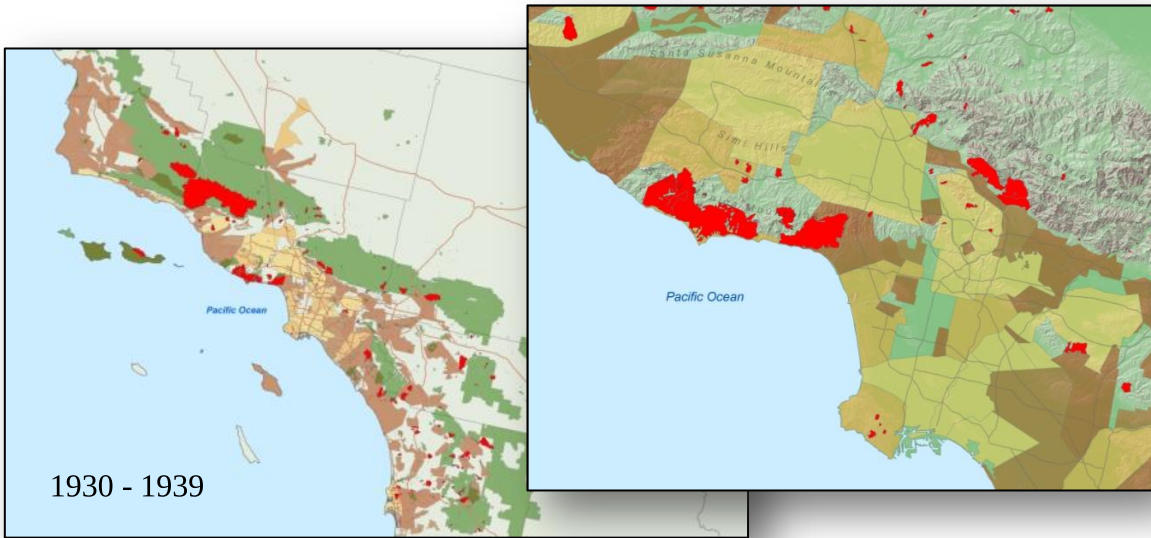
Appendix D: Fire History Map Series

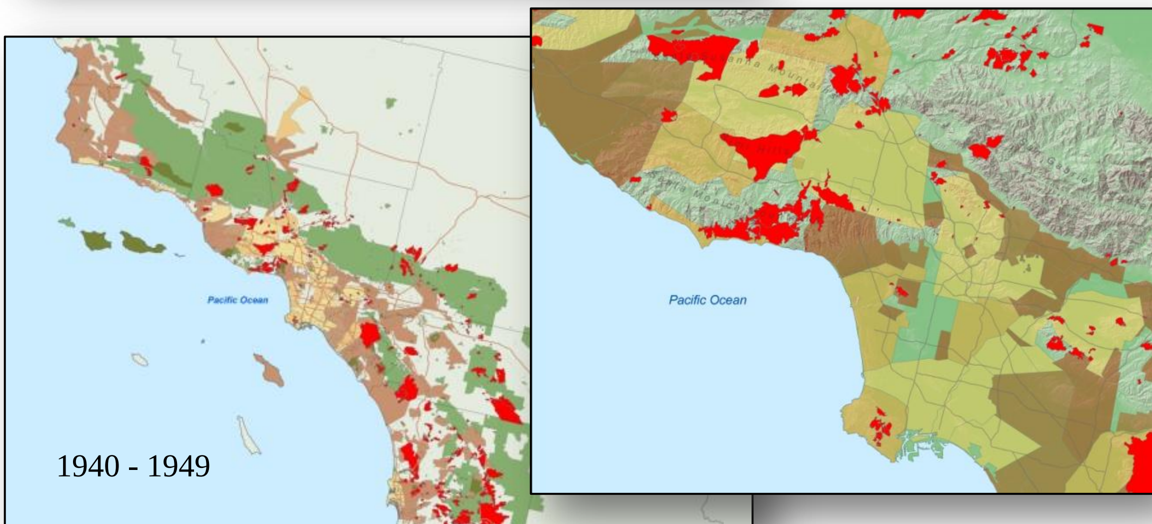


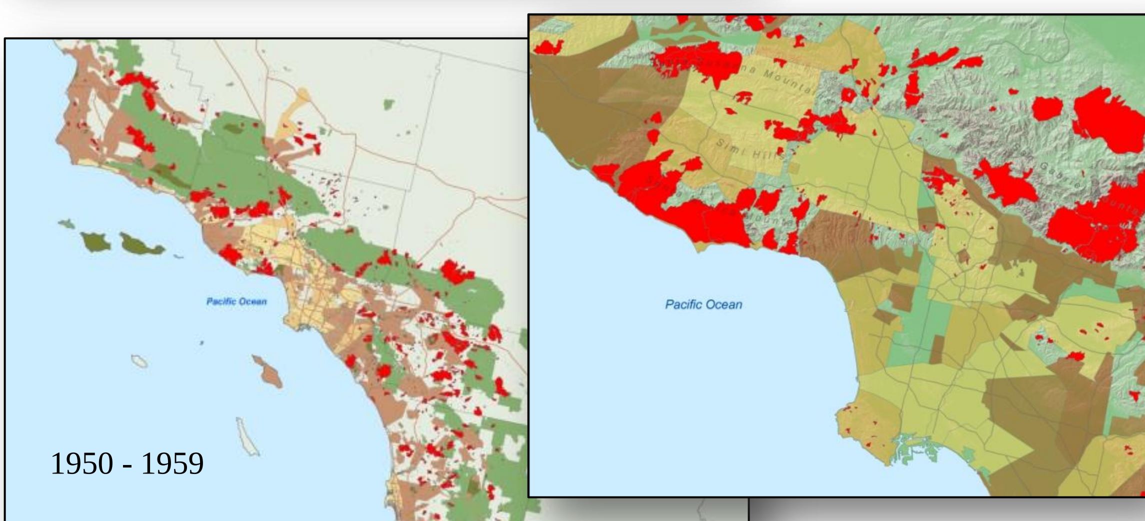




Fire History Map Series







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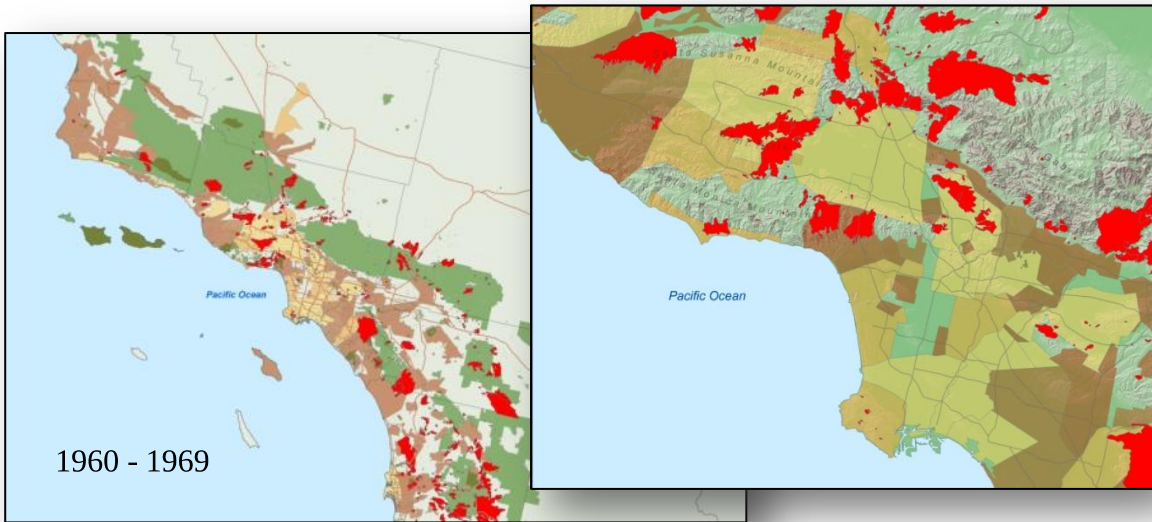
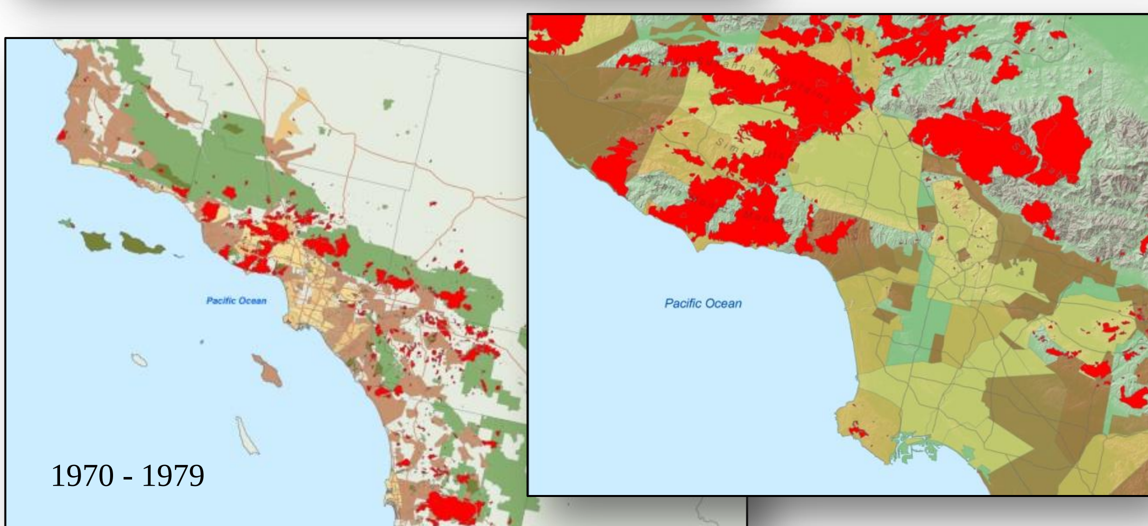
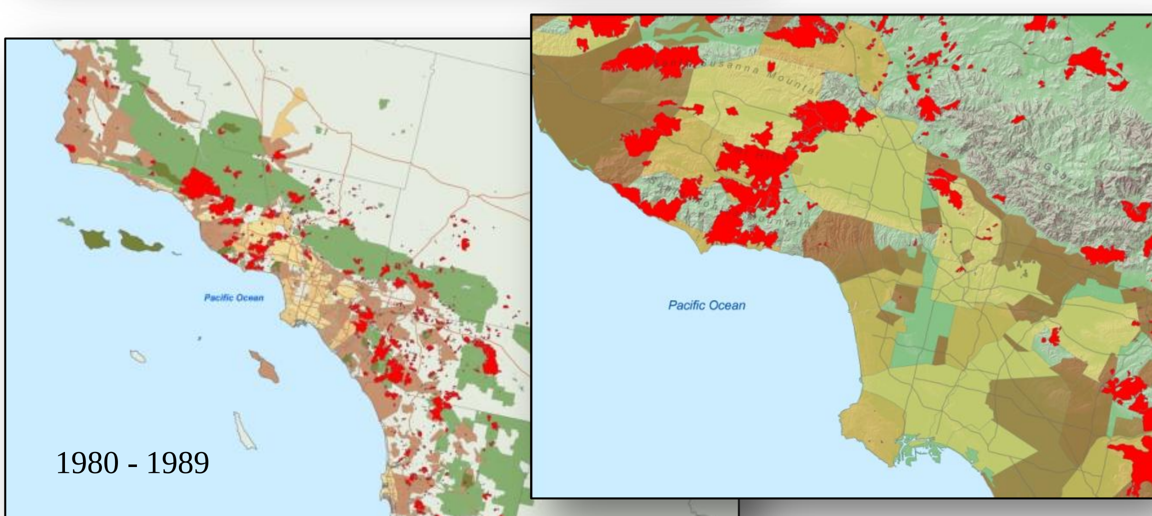
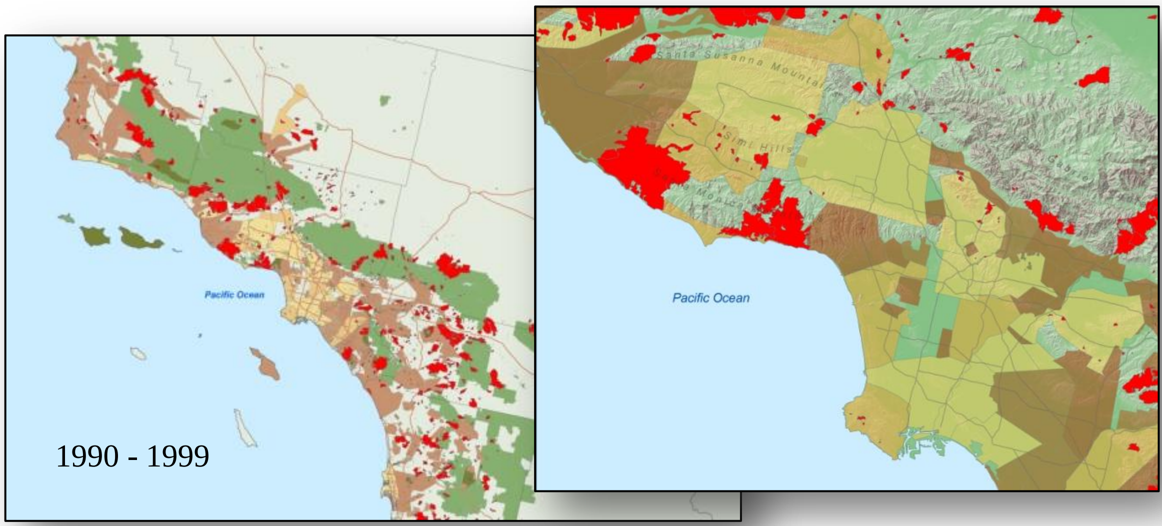
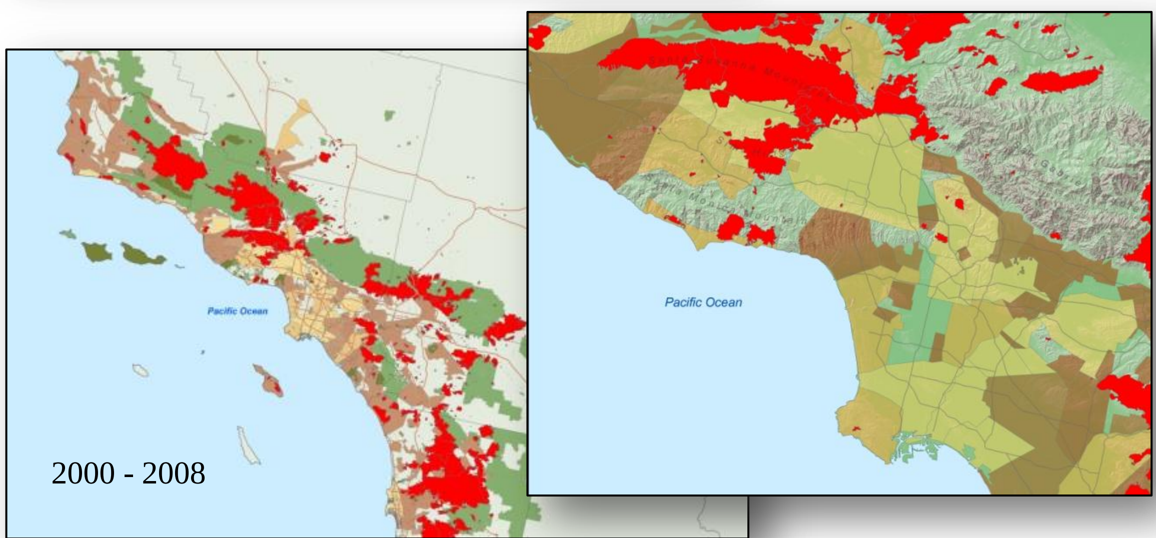






Fire History Map Series





Tables and Charts

Table 3: FlamMap Fire Behavior Weather and Fuel Moisture Inputs

FlamMap Variable	Moderate Weather Conditions	Extreme Weather Conditions
1 hour fuel moisture	5%	2%
10 hour fuel moisture	8%	3%
100 hour fuel moisture	12%	7%
Live herbaceous moisture	100%	30%
Live woody moisture	100%	60%
20-ft. wind speed	30 MPH	30 MPH
Wind direction	15 degrees Azimuth	15 degrees Azimuth

Table 4: Oak Woodland Canopy Attributes

Canopy Attribute	Count	Min	Max	Majority	Minority	Median
Canopy Cover	243	35 %	75%	65%	35%	65%
Canopy Height	243	18 m	18 m	18 m	18 m	18 m
Canopy Base Height	243	10 m	10 m	10 m	10 m	10 m
Canopy Bulk Density	243	1 kg/m^3	1 kg/m^3	1 kg/m^3	1 kg/m^3	1 kg/m^3

Table 5: Zonal Statistics Flame Length-Moderate Weather

Burn Period One (960 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2600	1052	49.78 m	2.89 m	2.15 m		
Limited Grazing	1492	604	7.32 m	1.88 m	1.01 m	1.14 m	53.09%
Oak Treatment	767	310	7.15 m	1.43 m	0.75 m	1.4 m	65.07%
Combined	758	307	7.15 m	1.33 m	0.66 m	1.49 m	69.10%

Table 6: Zonal Statistics Flame Length-Extreme Weather

Burn Period One (120 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	4406	1783	114.52 m	3.54 m	5.14 m		
Limited Grazing	1670	676	14.91 m	2.62 m	3.00 m	2.14 m	41.58%
Oak Treatment	875	354	24.27 m	2.75 m	4.27 m	0.87 m	16.87%
Combined	563	228	113.89 m	3.54 m	3.04 m	2.10 m	40.91%

Table 7: Zonal Statistics Flame Length-Moderate Weather
Burn Period One (960 minutes) Treatment Plots Only

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2925	1184	7.23 m	3.01 m	2.46 m		
Limited Grazing	2925	1184	8.88 m	2.51 m	1.60 m	0.86 m	35.06%
No Treatment	188	76	7.14 m	0.86 m	0.60 m		
Oak Treatment	188	76	0.25 m	0.01 m	0.22 m	0.39 m	63.90%

Table 8: Zonal Statistics Flame Length-Extreme Weather
Burn Period One (120 minutes) Treatment Plots Only

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2925	1184	73.22 m	10.66 m	18.36 m		
Limited Grazing	2925	1184	24.51 m	3.55 m	3.69 m	14.7 m	79.89%
No Treatment	188	76	34.51 m	4.57 m	11.35 m		
Oak Treatment	188	76	0.33 m	0.01 m	0.28 m	11.1 m	97.50%

Table 9: Zonal Statistics Fire Line Intensity-Moderate Weather
Burn Period One (960 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2550	1032	55744 KW/m	3777 KW/m	1535 KW/m		
Limited Grazing	1445	585	18848 KW/m	1624 KW/m	340 KW/m	1194 KW/m	77.82%
Oak Treatment	734	297	18646 KW/m	1934 KW/m	359 KW/m	1176 KW/m	76.62%
Combined	725	293	18646 KW/m	1650 KW/m	268 KW/m	1266 KW/m	82.51%

Table 10: Zonal Statistics Fire Line Intensity-Extreme Weather
Burn Period One (120 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	4,316	1747	370143 KW/m	11408 KW/m	8307 KW/m		
Limited Grazing	1,670	676	46933 KW/m	11121 KW/m	5715 KW/m	2592 KW/m	31.20%
Oak Treatment	844	341	82272 KW/m	8619 KW/m	5339 KW/m	2967 KW/m	35.72%
Combined	533	216	43256 KW/m	5408 KW/m	2569 KW/m	5737 KW/m	69.07%

Table 11: Zonal Statistics Rate of Spread-Moderate Weather
Burn Period One (960 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2600	1052	46.25 m/min	10.51 m/min	7.09 m/min		
Limited Grazing	1492	604	48.66 m/min	12.22 m/min	5.82 m/min	1.26 m/min	17.82%
Oak Treatment	767	310	46.14 m/min	6.53 m/min	2.99 m/min	4.10 m/min	57.86%
Combined	757	307	46.14 m/min	5.59 m/min	2.37 m/min	4.72 m/min	66.56%

Table 12: Zonal Statistics Rate of Spread-Extreme Weather
Burn Period One (120 minutes) Total Acreage

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	4406	1783	84.82 m/min	23.15 m/min	35.49 m/min		
Limited Grazing	1670	676	91.55 m/min	24.90 m/min	32.54 m/min	2.95 m/min	8.31%
Oak Treatment	875	354	84.37 m/min	23.22 m/min	27.69 m/min	7.80 m/min	21.98%
Combined	563	228	84.37 m/min	19.01 m/min	18.85 m/min	16.64 m/min	46.88%

Table 13: Zonal Statistics Rate of Spread-Moderate Weather
Burn Period One (960 minutes) Treatment Plots Only

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2590	1048	84.82 m/min	23.07 m/min	35.94 m/min		
Limited Grazing	694	281	44.61 m/min	2.74 m/min	1.8 m/min	34.14 m/min	94.99%
No Treatment	187	76	45.59 m/min	3.66 m/min	2.51 m/min		
Oak Treatment	170	69	3.59 m/min	0.40 m/min	0.39 m/min	2.12 m/min	84.46%

Table 14: Zonal Statistics Rate of Spread-Extreme Weather
Burn Period One (120 minutes) Treatment Plots Only

Method	Acres	Hectares	Max	STD	Mean	Diff	Reduction
No Treatment	2590	1048	84.82 m/min	23.07 m/min	35.94 m/min		
Limited Grazing	829	336	83.52 m/min	10.91 m/min	14.77 m/min	21.17 m/min	58.90%
No Treatment	187	76	83.66 m/min	21.30 m/min	34.64 m/min		
Oak Treatment	55	22	76.22 m/min	11.50 m/min	5.33 m/min	29.31 m/min	84.61%

Table 15: Total Structures Exposed

Method	Weather/Period	Structures Exposed	Exposure Reduction
No Treatment	Moderate/1	318	
Limited Grazing	Moderate/1	307	3.46%
Oak Treatment	Moderate/1	169	46.86%
Combined	Moderate/1	169	46.86%
No Treatment	Moderate/2	428	
Limited Grazing	Moderate/2	352	17.76%
Oak Treatment	Moderate/2	185	56.78%
Combined	Moderate/2	185	56.78%
No Treatment	Extreme/1	416	
Limited Grazing	Extreme/1	360	13.46%
Oak Treatment	Extreme/1	192	53.85%
Combined	Extreme/1	192	53.85%
No Treatment	Extreme/2	850	
Limited Grazing	Extreme/2	627	26.24%
Oak Treatment	Extreme/2	447	47.41%
Combined	Extreme/2	321	62.24%

Table 16: Residential Assessed Values at Risk

Method	Weather/Period	Improvement Value	Percentage Reduction	Amount Reduction
No Treatment	Moderate/1	$172,961,168		
Limited Grazing	Moderate/1	$160,077,718	7.45%	$12,883,450
Oak Treatment	Moderate/1	$88,735,065	48.70%	$84,226,103
Combined	Moderate/1	$88,735,065	48.70%	$84,226,103
No Treatment	Moderate/2	$233,480,214		
Limited Grazing	Moderate/2	$185,683,830	20.47%	$47,796,384
Oak Treatment	Moderate/2	$98,816,190	57.68%	$134,664,024
Combined	Moderate/2	$98,816,190	57.68%	$134,664,024
No Treatment	Extreme/1	$234,125,433		
Limited Grazing	Extreme/1	$194,856,387	16.77%	$39,269,046
Oak Treatment	Extreme/1	$103,940,951	55.60%	$130,184,482
Combined	Extreme/1	$103,940,951	55.60%	$130,184,482
No Treatment	Extreme/2	$420,137,152		
Limited Grazing	Extreme/2	$333,831,263	20.54%	$86,305,889
Oak Treatment	Extreme/2	$248,448,583	40.86%	$171,688,569
Combined	Extreme/2	$181,221,727	56.87%	$238,915,425

Table 17: Acreage Burned

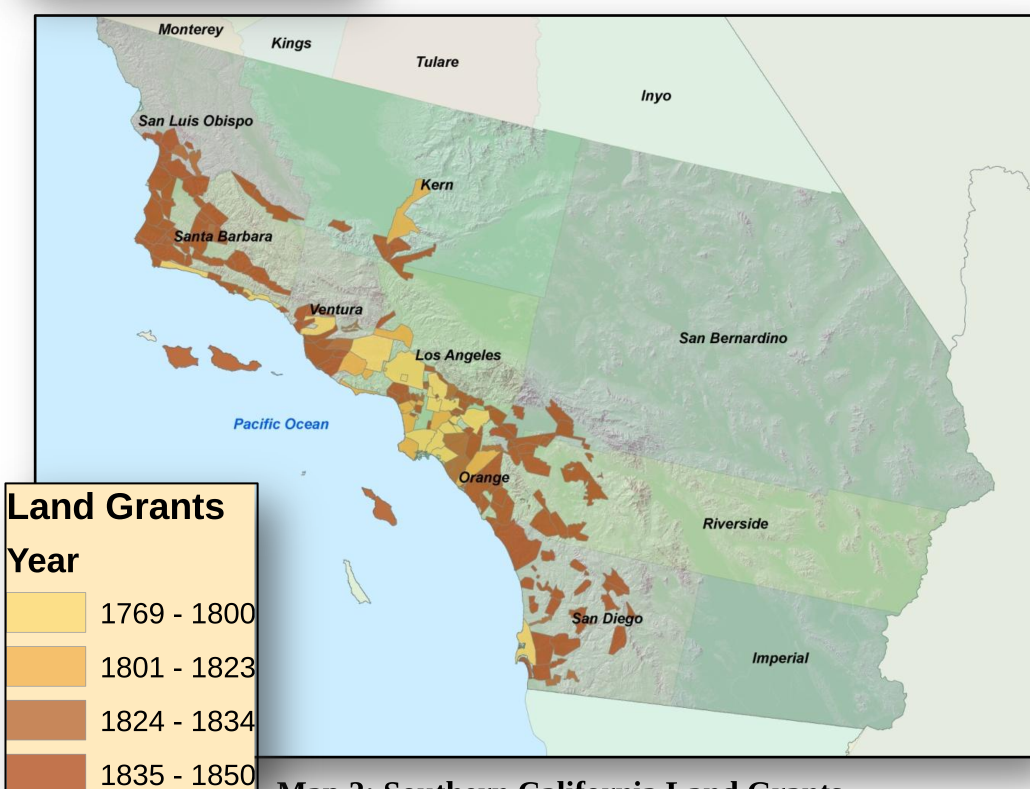
Treatment Method	Weather/Period	Sq Meters	Hectares	Acres	Amount Reduction
No Treatment	Moderate/1	10,537,273	1,054	2,604	
Limited Grazing	Moderate/1	6,018,295	602	1,487	42.89%
Oak Treatment	Moderate/1	3,087,492	309	763	70.70%
Combined	Moderate/1	3,049,044	305	753	71.07%
No Treatment	Moderate/2	17,844,929	1,784	4,410	
Limited Grazing	Moderate/2	8,286,749	829	2,048	53.57%
Oak Treatment	Moderate/2	4,110,580	411	1,016	76.97%
Combined	Moderate/2	3,807,855	381	941	78.66%
No Treatment	Extreme/1	17,798,038	1,780	4,398	
Limited Grazing	Extreme/1	6,764,484	676	1,672	61.99%
Oak Treatment	Extreme/1	3,554,094	355	878	80.03%
Combined	Extreme/1	2,286,050	229	565	87.16%
No Treatment	Extreme/2	44,067,600	4,407	10,889	
Limited Grazing	Extreme/2	26,043,975	2,604	6,436	40.90%
Oak Treatment	Extreme/2	19,969,109	1,997	4,934	54.68%
Combined	Extreme/2	5,417,457	542	1,339	87.71%

	CWPP Area Buffer			Study Area Buffer	
Fuel Type	TotalAcres	VegAcres		TotalAcres	VegAcres
Urban	3991.54			1590.57	
Agricultural	0.67			0.67	
Open Water	19.35			9.79	
Bare Ground	194.15			114.98	
GR1 grazing	988.32	988.32		354.05	354.05
GR2 grass 1 foot	480.15	480.15		188.15	188.15
GS1 grass/shrubs 1 foot	3765.81	3765.81		1240.74	1240.74
GS2 grass/shrubs 1 to 3 feet	3098.85	3098.85		1087.07	1087.07
SH2 Moderate Shrubs 1 foot	20.24	20.24		11.12	11.12
SH7 Very High Load Shrubs 4-6	1745.35	1745.35		777.71	777.71
TU1 Low grass/shrubs/litter	168.58	168.58		53.60	53.60
TU5 Very High Load litter/small trees/shrubs	18.46	18.46		4.67	4.67
TL2 Low Load Broadleaf Litter	958.08	958.08		309.35	309.35
TL3 Moderate Load Conifer Litter	72.28	72.28		27.80	27.80
TL4 Small downed logs	22.02	22.02		5.78	5.78
TL7 Large Downed Logs	40.48	40.48		8.45	8.45
Total Acres	15584.32	11378.61		5784.49	4068.49

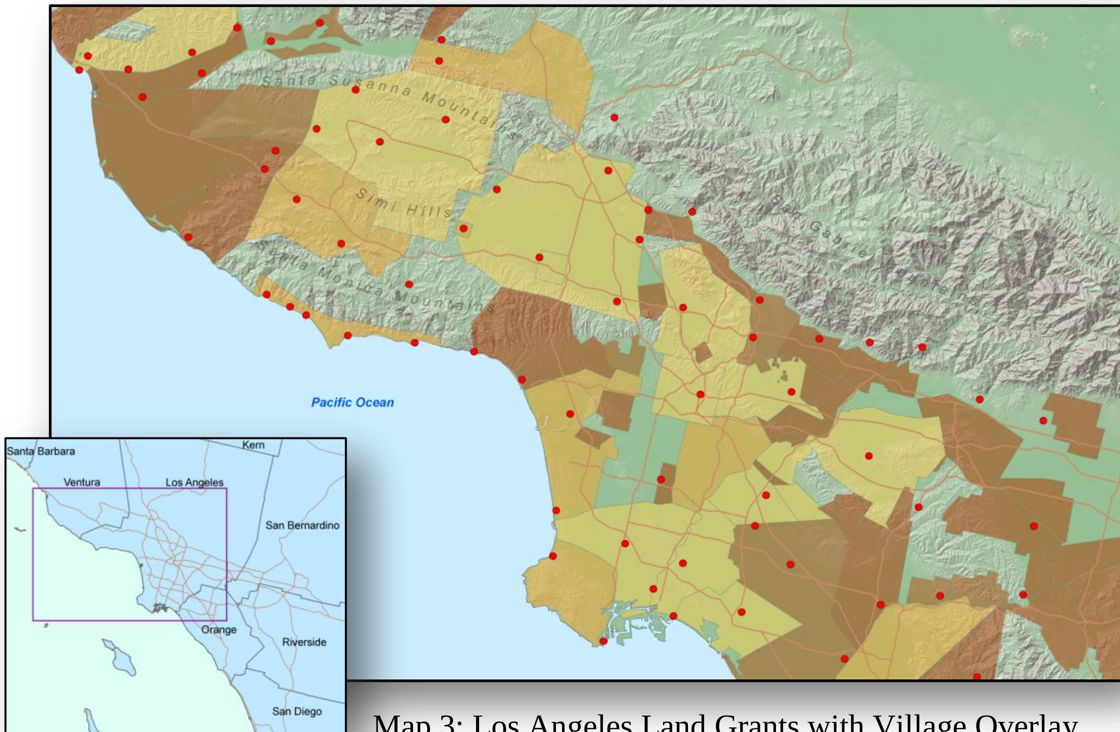
Table 18: Longcore Analysis

Map Appendix

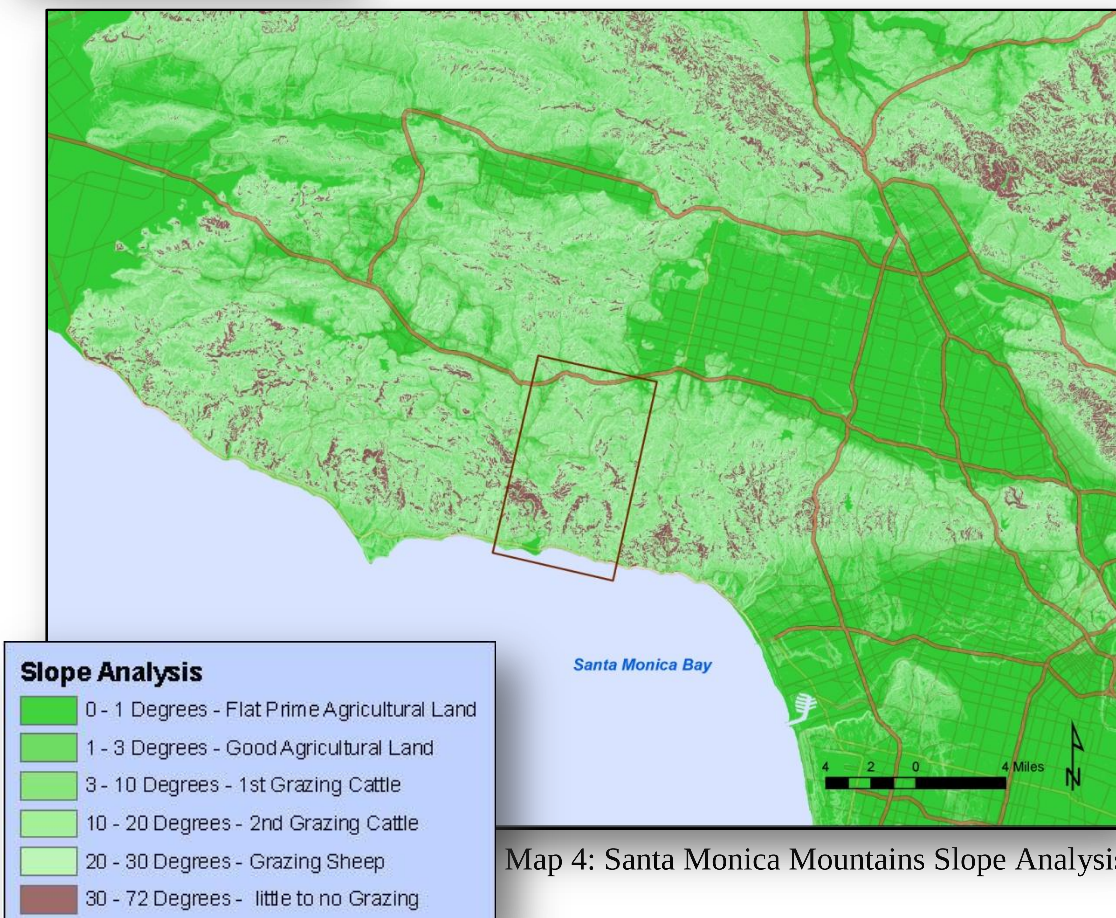
Map 1: CWPP Planning Area



Map 2: Southern California Land Grants

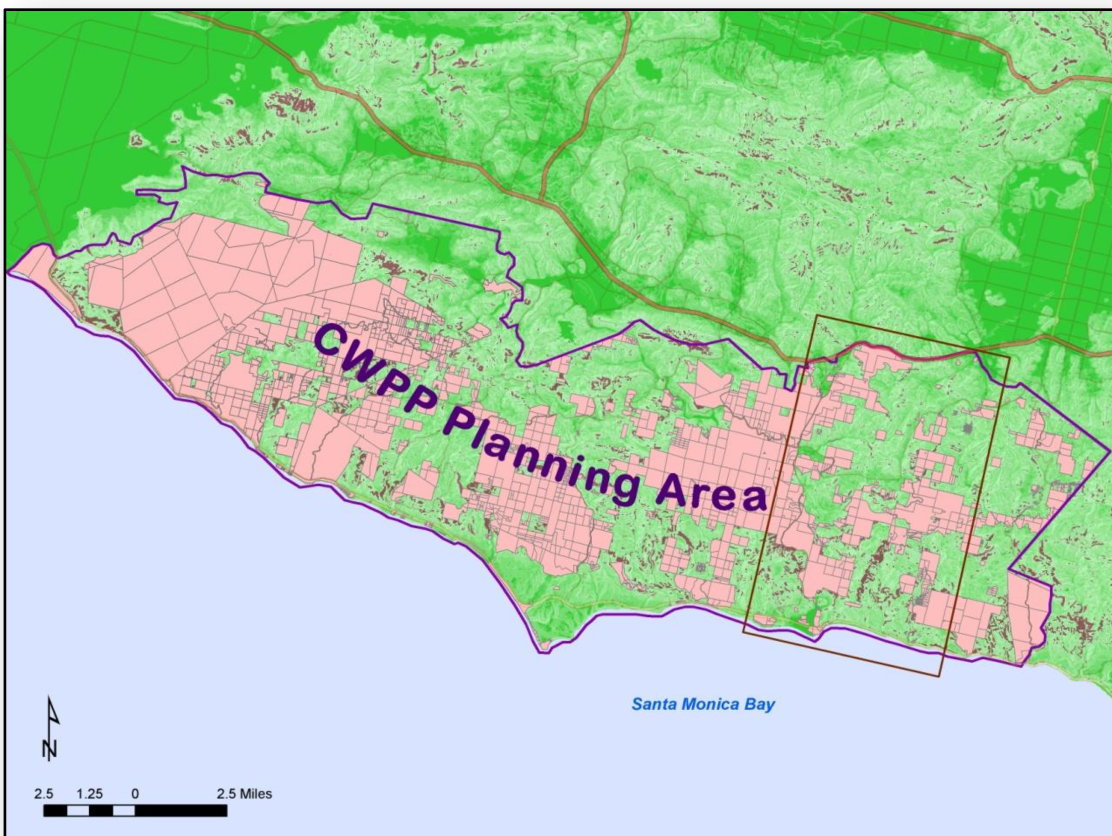


Map 3: Los Angeles Land Grants with Village Overlay

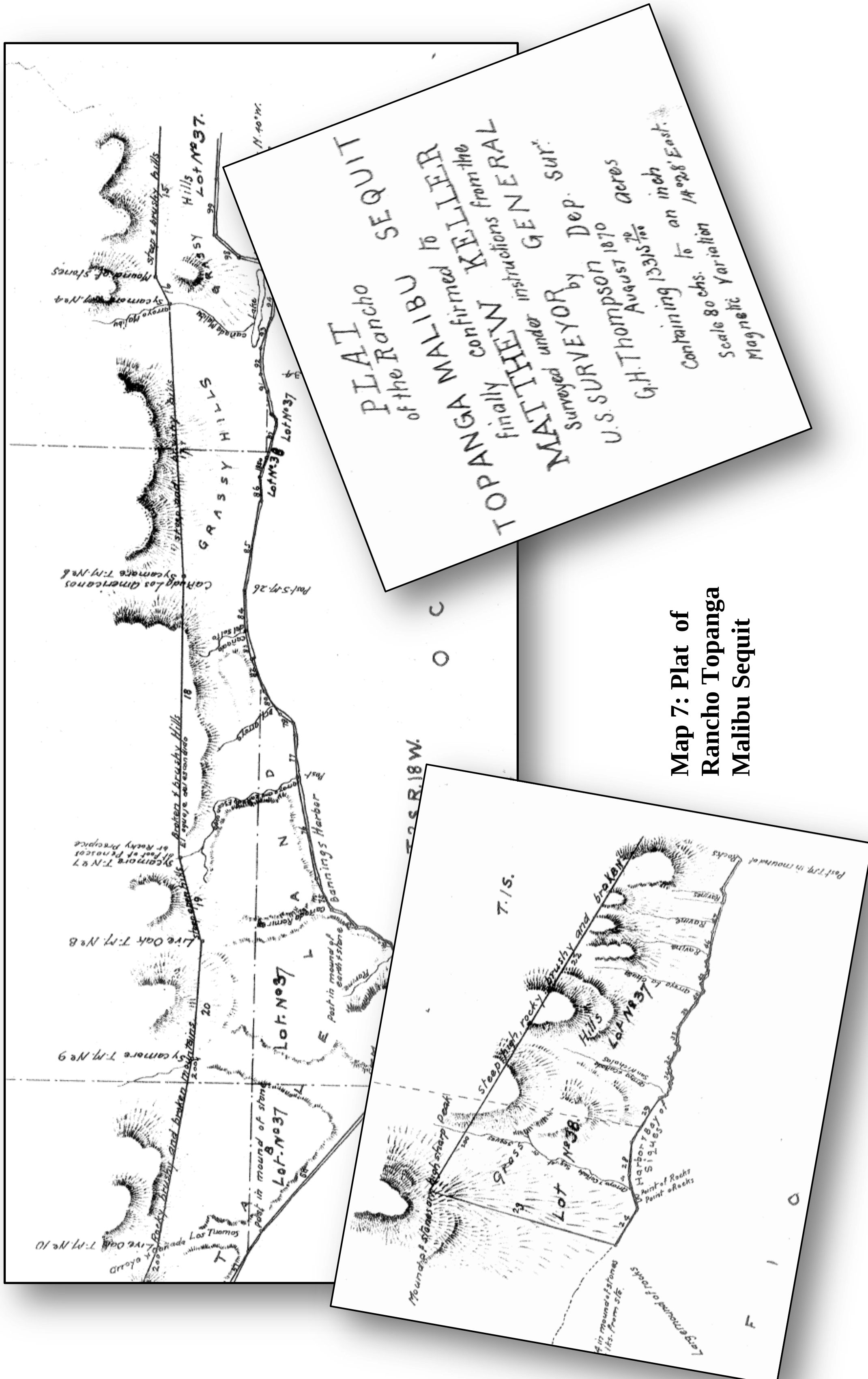


Map 4: Santa Monica Mountains Slope Analysis

Map 5: Primary Study Area with 1850 Ranchos & Public Lands (pink)



Map 6: Current Public Land within CWPP Planning Area



Map 7: Plat of Rancho Topanga Malibu Sequit

Map 8: Los Angeles Region Tribal Villages