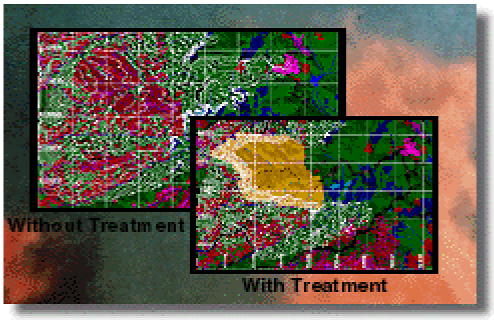


Modeling the Effects of Prefire Projects on the Old Gulch Fire Using FARSITE

June, 1997

Introduction

FARSITE is a computer based model of fire spread that utilized spatially resolved data to simulate fires occurring over areas of heterogeneous fuels, topography, and weather (Finney 1996). In as much as changes in fuel characteristics can be reflected both in nature and extent, FARSITE offers a unique opportunity to evaluate the effects of fuel management projects while leaving all other factors (topography and weather) constant. These comparisons can show what kinds of alternate outcomes might be likely in the presence or absence of various fuel modifications being subjected to a given fire scenario.

In this paper we examine the effects of two existing fuel management projects on potential outcomes from the Old Gulch Fire that occurred August 16-20, 1992 in Calaveras County. This fire consumed over 17,000 acres of grass, brush, and timber, destroyed 170 structures. Costs of suppression totaled almost 12 million dollars, and estimates of additional resource damage were placed at almost 17 million dollars. Both of the aforementioned fuel management projects were believed to have significantly reduced final fire size, and costs and losses from this fire. We have generated side-by-side comparisons of fire simulations for these two projects to explore how the FARSITE model can be used to validate the anecdotal effects of these projects. In addition, we have looked at the potential impact of one more project that indicates how various fuel management projects might be linked in space.

Model Inputs, Assumptions, and Setup

FARSITE uses spatial information describing fuels and topography to predict fire growth and behavior when subjected to information regarding ignition location and temporal data relevant to weather. That is, given where and when a fire occurs, the model will perform a simulation of the fire's growth for a specified duration of time. Various model assumptions and parameters can be set to simulate fire conditions of particular interest. In the case of this analysis, where fuel modifications were either known or supposed, the analysis centers around comparisons of alternate fire outcomes in the *absence* of these projects. Additionally, the model makes basic assumptions that are important to recognize, and is subject to user defined parameters such as length and frequency of calculations that affect model outputs and interpretation. Given their importance, we will briefly examine each of these.

Fuels

Once an ignition occurs, fuels provide the necessary energy source for fire propagation. In wildland fires, the vast majority of this energy comes from live and dead plant materials. Current means of modeling fuels are based on a mathematical model of surface fire spread (Rothermel 1972) that uses amounts and arrangements of fuels by size class (diameter), chemistry of the materials, and moisture contents. In general, vegetation type and structure shows significant correspondence with surface fuel characteristics, such that if information is known about vegetation, inferences in regard to fuels can be made. Areas that are grasslands and low density oak woodland can be grouped into grass models, brush types can be grouped into various brush models depending on age and composition, and forested types can be grouped based on composition, stand density, stand history (thinned, burned, etc.) into various forest litter/understory fuel models.

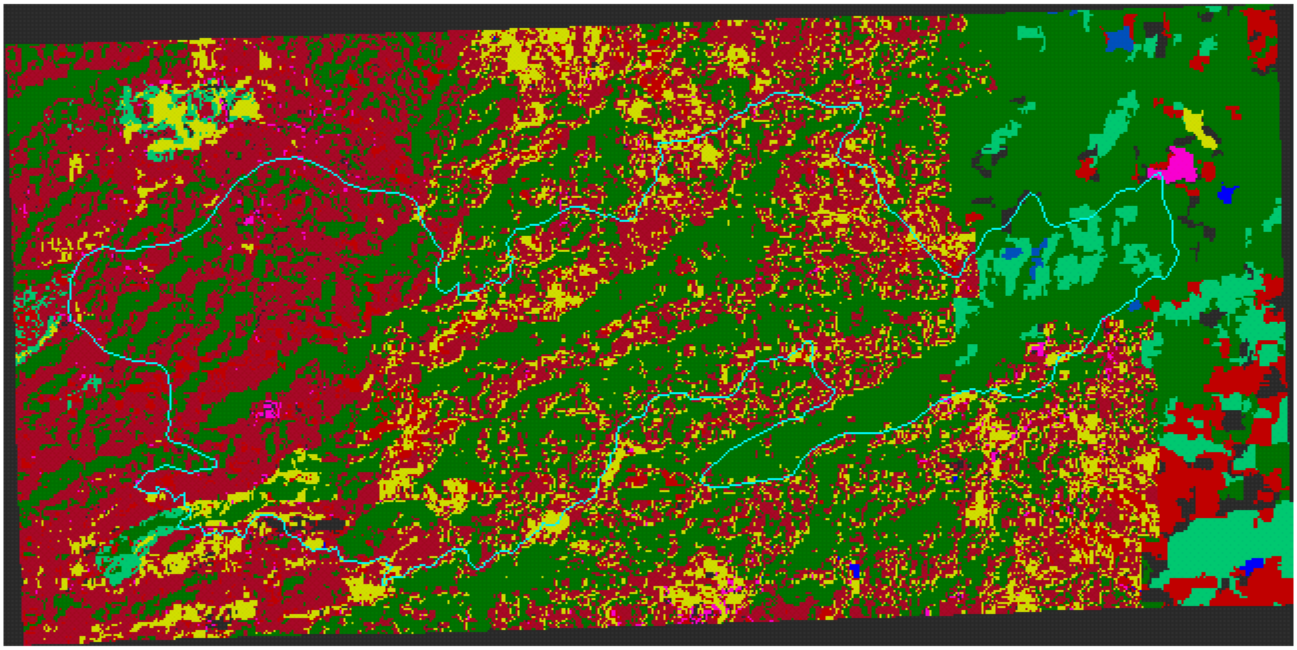
Additional fuel model data is required for modeling involvement of aerial fuels in lands that support trees. Although this element of fuel modeling is only in its infancy, crowning and spot fire mechanics are extremely important in assessing extreme fire behavior, as was exhibited widespread during the Old Gulch Fire. Consequently, additional inputs regarding tree density, vertical fuel continuity, and aerial fuel loads were made to allow crown fire modeling. FARSITE is the only currently available model that allows for spatially explicit torching, crown fire, and spot fire development. As will be evident in the analysis, and explicit in the graphical outputs, this element is fundamental to assessing fuel management effects.

In this analysis, we have used fuel Geographic Information System (GIS) coverages being developed as part of the CDF Fire Plan’s assessment database, where the best available vegetation coverages were used to create maps of surface fuel models. A variety of surface fuel models are reflected in the landscape, ranging from sparse grass to mature chaparral, to dense conifer timber litter with understory. Some other types included young plantations and immature brush. Also present throughout the landscape are areas of wildland-urban interface, where structures are a primary concern both as a resource and as an integral part of the fuel complex. Baseline fuel models used in the analysis prior to adjustment to reflect the fuel management projects are shown in Figure 1. Custom fuel models were developed to reflect the particular changes associated with the two projects. In each case, the underlying fuel models were altered to show reduced fuel loads, greater surface fuelbed compaction, and reduced aerial fuels.

Topography

Topography influences fire both by the influence of slope and the influence of landscape aspect relative to the sun, which in turn affects fuel moisture dynamics. Additionally, as FARSITE makes elevation adjustments in calculating weather inputs based on fixed data from weather stations, elevation data is also required. We obtained spatial coverages of slope, aspect, and elevation at 30 meter cell resolution from a Digital Elevation Model (DEM) obtained from the U.S. Geological Society.

Figure 1. Map of surface fuel models of the Old Gulch Fire area, prior to changes from fuel treatments. Grass fuels are shown in yellow, brush and chaparral fuels in reds, forest fuel types in greens and blues, and areas of mixed wildland/urban interface areas in magenta. The final perimeter of the Old Gulch Fire is shown in light blue. The fire area represents approximately 17,000 acres, while the total size of the landscape is roughly 44,000 acres.



Weather

FARSITE utilizes temporally recorded weather data that comes from standard Remote Automated Weather Stations (RAWS) that record basic weather data at fixed intervals. We obtained RAWS data for two nearby stations for the month of August 1992. Using recommendations from the field, we used one weather station (Green Mountain) for the first two days of the simulation, and the other (Esparanza) for the remainder of the simulation period. Key inputs are time and level of maximum and minimum temperature and relative humidity, and hourly reading of wind speed and direction. These temperature/air moisture data are then subjected to elevation adjustment based on adiabatic lapse rates. The wind profiles, however, are assumed constant across the landscape until a new hourly reading is recorded. Thus, during a fire simulation, the effects of changing weather are based on actual weather stream data occurring during the period of the wildfire.

In general, the period of the Old Gulch Fire was very hot and dry, with moderate winds out of the west. Although not the most extreme fire weather that occurs in the area, conditions of limited resources in conjunction with heavy fuels and very steep terrain resulted in very severe fire behavior, including widespread crown fire and long-range spotting. These two features make fire perimeter containment extremely difficult.

Fire Behavior Assumptions

FARSITE makes a number of assumptions about fuels and relationships to other inputs. Fundamental to these assumptions are the notion that fuel models are continuous and homogeneous across all cells with equal values. That is, any characterization of fuel models has no inherent measure of spatial variability, and as such are simplifications of reality. Some elements in the real fuel bed occur at spatial scales that we could not pick up in the coverages (e.g. roads).

Another fundamental model assumption is that the fire growth is unconstrained: that is, actions taken by the fire service to limit fire spread are not modeled. The only means by which restrictions in fire growth can be modeled is by the use of surface fire barriers that effectively preclude any surface fire advancement through those barriers. This function was used to calibrate the model by importing the final fire perimeter, and turning the perimeter into a fire barrier. These barriers, however, are subjected to being breached by burning brands (spots) flying over the barrier.

The final critical limitation in the model involves a lack of fire to fire interactions, which tend to cause under-predictions of fire behavior in areas such as tight canyons, where interactions between nearby flame fronts often act as a chimney, resulting in substantial increases in spread and intensity.

Taken together, these model assumptions radically simplify the extremely complex nature of fire growth and containment. The simulations presented only model the apparent effects of altering fuel conditions, and do not realistically incorporate the interactions of alterations in fire behavior with the likely changes in suppression operations and tactics that would accompany these changes. Furthermore, a number of issues relating to both resource availability and deployment that were highly significant in this fire's outcome are not treated in the analysis. Specifically, as the fire became established in the middle reaches of Indian and San Domingo Creek watersheds, suppression activities were deemed largely independent of fuel conditions due to steep slopes and inaccessibility.

Taken together, what the simulations tend to show is only the unconstrained changes in fire growth that results from alteration of fuel conditions. Actual fire growth, containment, final size, and impacts are estimated based on these outcomes, but are based on simplified fire/fuel relationships with no integrated assessment of fire service activities.

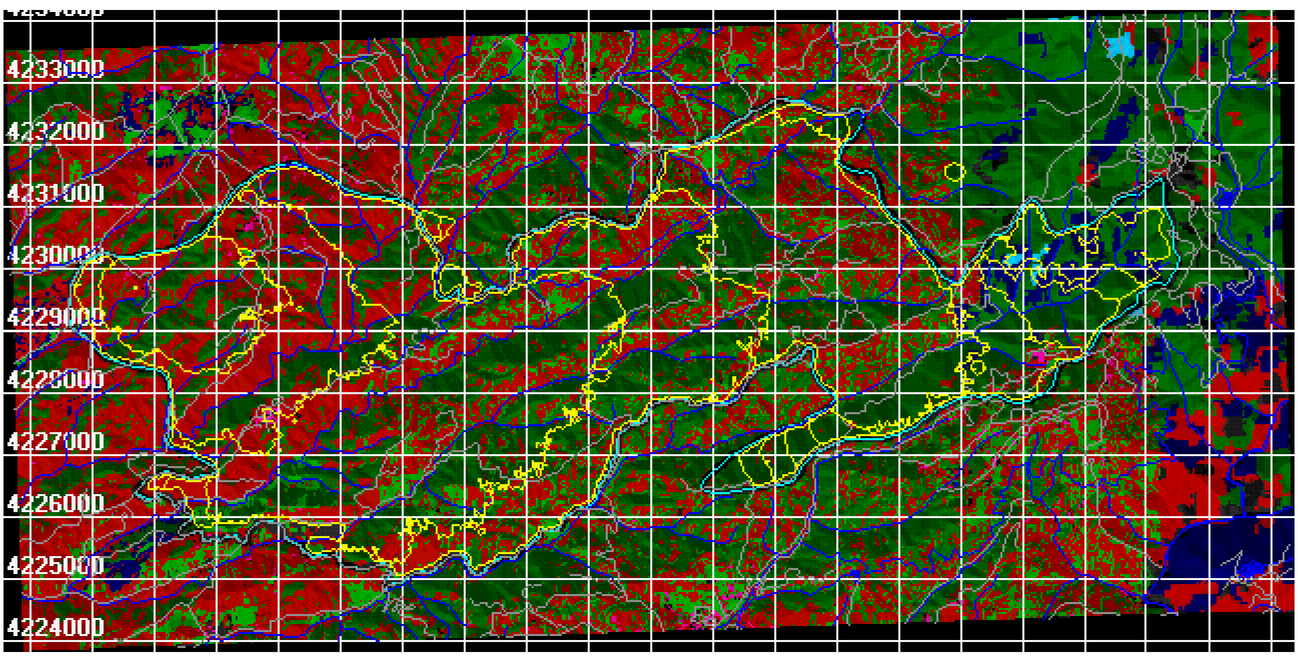
Parameters

Model parameters that determine how often calculations are made (i.e., time-steps) and the spatial distance check for recalculations are important assumptions in regard to changing conditions. We used 30 minute time-steps and a 350 feet distance check in all simulations. Visible time perimeters were set for each particular scenario, and are detailed in the appropriate discussion section. All simulations enabled crown and spot fire development to occur.

Model Calibration

The entire Old Gulch Fire was initially modeled to calibrate the fuel, weather, and fire spread adjustment factors to allow for realistic outputs and valid interpretations (Figure 2). We compared known fire perimeters at different times throughout the fire's duration to those simulated by FARSITE. Further, we restricted the bounds of the fire by creating a fire barrier based on the final fire perimeter. Isolated spot fires were exhibited throughout the fire's simulated growth. The modeled fire progression shown in Figure 2 is based on the same duration as the wildfire, and although the precise pattern of growth differs, the general scale and temporal correspondence with known points of interaction is relatively close. The basic elements of parameterization used in this calibration simulation were utilized for all subsequent simulations. These included level of spot fire development, fuel model dependent adjustment factors, and all base fire environment inputs (fuels, weather, topography). Although these variables possibly contained errors, the outputs from the calibration were judged reasonable for the purposes of these comparative analyses.

Figure 2. Calibration simulation of Old Gulch Fire, August 16-20, 1992. Light blue boundary indicates actual fire perimeter; yellow lines indicate 12 hour increments of modeled fire spread. The grid squares represent 1 square kilometer (247 acres). The yellow lines indicate 12 hour time progressions of the fire originating on 8/16/92 at the far left of the fire.



Simulations

1. Skull Ranch Project CFIP

Due to large levels of insect mortality, a California Forest Improvement Project (CFIP) – a combination of thinning and mechanical and fire slash treatment -- was undertaken between 1990 and 1992 on a privately held ranch that was encountered during the Old Gulch Fire. This "Skull Ranch" project was approximately 1200 acres, and resulted in significant reductions in fuels such that changes in fire behavior exhibited in the treated areas was thought to have materially led to the containment of the eastern front of the fire. It should be noted that this particular project represented much greater than normal hazard reduction when compared to other forest improvement projects on California's private timberlands. Consequently, caution should be taken when extrapolating these results (both real and modeled) of changes in fire behavior associated with CFIP areas.

In this case, crown fire in adjacent untreated stands approached the project area, and dropped to a low intensity surface fire that was contained by fire crews. In the absence of this project, fire managers believed that the fire would have crested through a drainage and moved directly toward the town of Arnold, where very high fuel loads and steep terrain would have likely led to a significantly larger fire that inevitably would have resulted in large losses associated with structure damage.

We have modeled the effect of this project by comparing two 24 hour simulations with and without the project, and comparing outputs (Figures 3a and 3b) . Fuel changes in the project included alteration of the preexisting fuel models to a low density pine type with light surface fuels and an absence of ladder fuels. This type of fuel complex would generally reflect well executed understory treatments in coniferous stands, where surface fuel loads are light, ladder fuels are not a concern, and tree canopy densities too low for crown fire behavior. Achieving these kinds of conditions requires effective thinning from below (smaller diameter trees) and wholesale reduction in activity fuels resulting from harvest activities. Consequently, a combination of mechanical and prescribed fire treatments are often utilized to realize these types of reductions in hazard.

Both fire simulations were initiated with the exact same fire front, representing the advancing eastern edge of the wildfire on August 18. Both fires showed rapid advance during the initial hours, with isolated spotting and some crown fire in many portions of dense timber immediately to the west of the Skull Ranch project.

The FARSITE run with treatment simulation clearly shows that as fire encountered the project, rate of spread and flame length both showed significant decreases in frontal fire behavior, with the net effect being to limit the frontal growth and directing most of the fires advance resulting from flank fires on both north and south portions of the fire perimeter (Figure 3a). This simulation resulted in a total fire size of 4,100 acres for the 24 hr period.

The simulation with no treatment exhibited high fire behavior into and through the Skull Ranch area, eventually extending east into the upper San Antonio Creek drainage below Arnold and south toward Hwy. 4 in the vicinity of Hathaway Pines (Figure 3b). This simulation resulted in a net fire size of 6,600 acres – an increase of 61% over the size of the fire with the treatment in place. In addition, the implications for these comparisons loom large given the impending threats posed by the fire to the community of Arnold. This drainage lies on a combination of private and National Forest land where extensive areas of mixed-conifer fuels pose significant hazard – extreme fire behavior, poor accessibility, difficulty of control all synergistically contributing to a dim outlook for this portion of the fire front.

Had the Skull Ranch Project not been in place at the time of the wildfire, the model indicates that the fire front would have marched unimpeded as an intermittent crown fire, overrunning Arnold during the next burn period of 8/20. This is supported by accounts of fire managers, who believed that had this portion of the fire front not been contained, an additional 5-10,000 acres would have burned, including the town of Arnold, with an assessed valuation of 1.6 billion dollars. The reduced fire activity on the heading front allowed direct attack, and relieved resources to work on other portions of the fire. In addition to increasing firefighter safety in this area, the project mitigated damage to timber resources, as is evident in post-fire comparisons between adjacent treated and untreated stands.

Figure 3 (a and b). Simulations with (above) and without (below) Skull Ranch CFIP project. The white grids indicate 1 square kilometer (247 acres). The gold color indicates the project area, while the magenta area in the upper right indicates the town of Arnold. In addition to reduced fire spread in the treatment area, fire behavior as indicated by flame length showed significant reductions to levels associated with direct attack capability. The white lines indicate 1 hour time periods.

FIGURE 3a.

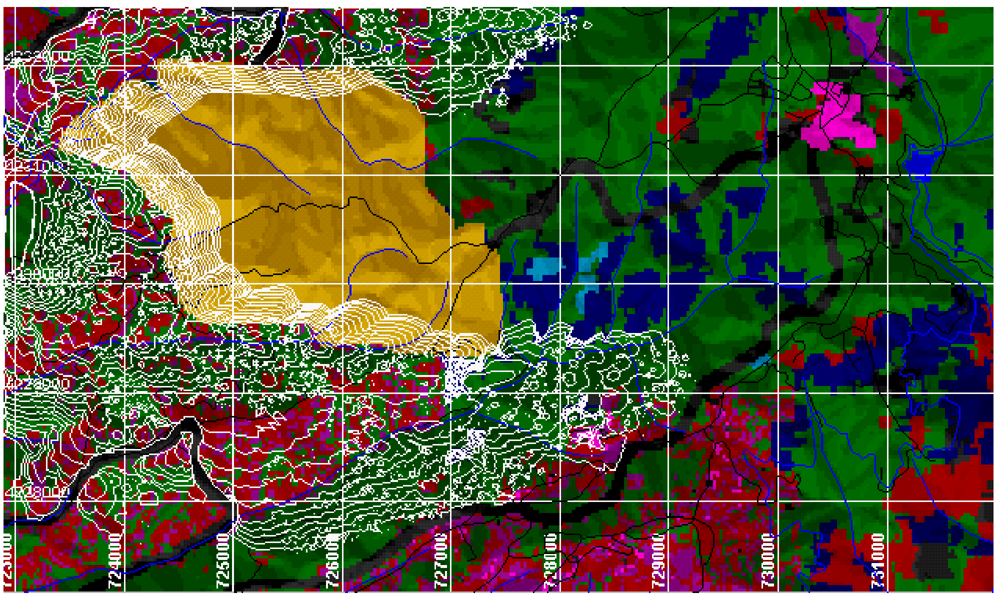
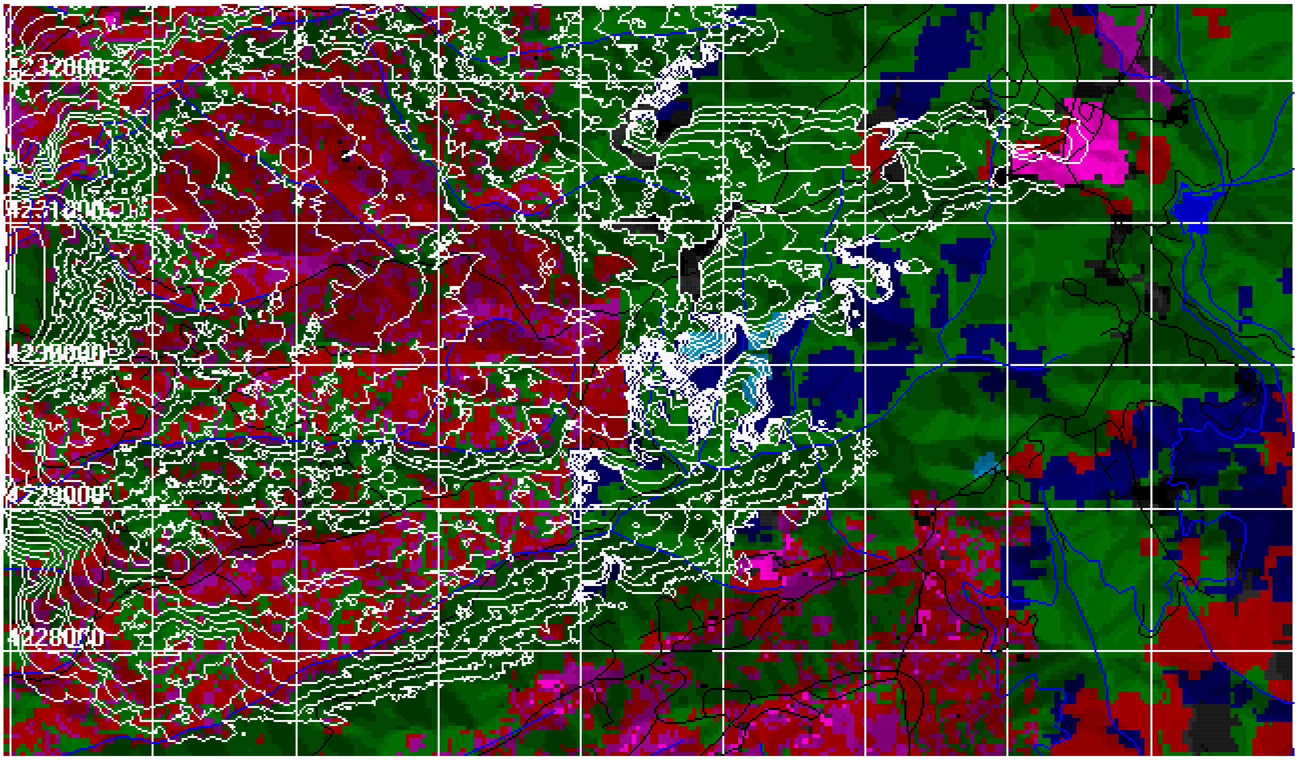


Figure 3b.



2. Forest Meadows Defensible Space Project

A short time after the fire interacted with the Skull Ranch project, its southern front began to encroach into the upper reaches of the San Domingo Creek drainage immediately adjacent and north of Hwy. 4. This area has scattered residences in and amongst a wildland fuel complex of brush and pine dominated timber. Eventually, the fire crossed the creek and made a dramatic crown fire run upslope toward the community of Hathaway Pines. Despite attempts to save these structures the extreme fire behavior of this portion of the front resulted in the majority of structures lost in the fire. The fire then proceeded to spot across Hwy. 4 in the region of the Forest Meadows development. Fortunately, this area had been the site of a recent effort for inspections for fire safe standards for homes in high fire hazard severity areas, as laid out in Public Resources Code 4291. It is estimated that 99% of the residences in the subdivision were in compliance with these regulations, and the fire behavior immediately became a moderate surface fire, that due to low fuel volumes and fuel discontinuity, was quickly contained before it was able to fully destroy any homes in the area. Although spot fires continued to light on the southern side of the slope, these were quickly attacked by ground and air resources that were not required for structure protection in the subdivision.

We have modeled this fire front over an 8 hour period beginning with the fire in the canyon and running up the slope adjacent and through the subdivision. Alterations to the base fuel models to reflect the 4291 compliance included reduced crown cover, decreased ladder fuels, reduced surface fuel loads, and increased live fuel moistures to reflect the affects of irrigation on the landscape vegetation in Forest Meadows. We believe that these changes accurately reflect the fuel conditions encountered by the fire in this critical area.

Simulation with the changes outlined above indicates that despite a very intense crown fire on the slope below Forest Meadows, and numerous spots being deposited within the subdivision proper, once the fire front made its way into the subdivision, both rate of spread and intensity were reduced significantly. The fire was quickly contained in this area due to discontinuous fuels and excellent access. In a similar fashion, the simulation indicates that based on predicted fire behavior during this time period, the fire would not have extended beyond the subdivision (Figure 4a). Total fire size for this model run (excluding the size of the initial fire front at the beginning of the simulation) was 680 acres.

The simulation without the changes brought about by the 4291 inspection indicates that the crown fire run made on the north side of the highway would have continued unabated through Forest Meadows, with a dramatic level of spot fires being generated up to 1 mile ahead of the fire front, up and over the ridge and into the Stanislaus River Canyon (Figure 4b.) This south slope is steep, inaccessible, and is dominated by high hazard chaparral fuels with intermittent tree presence that would have exacerbated the problem by torching and casting numerous burning brands. Should a free burning fire make its way into this portion of the landscape, features of the fire environment such as fuels and aspect result in very severe fire behavior, as is evident from the rapid expansion of the fire on the lower left portion of Figure 4b. Fire size for the 8 hour period totaled 1,880 acres, or almost triple the size of the simulation with the treatment in place.

Figure 4 (a and b). Simulations with (above) and without (below) the Forest meadows PRC 4291 inspection. The magenta area in Figure 4a indicates the area treated. The white lines indicate 1 hour time steps in the fires progression. The white squares represent 1 square kilometer (247 acres).The first perimeter (upper left) indicates the initial fire front position at the start of the simulation.

FIGURE 4a.

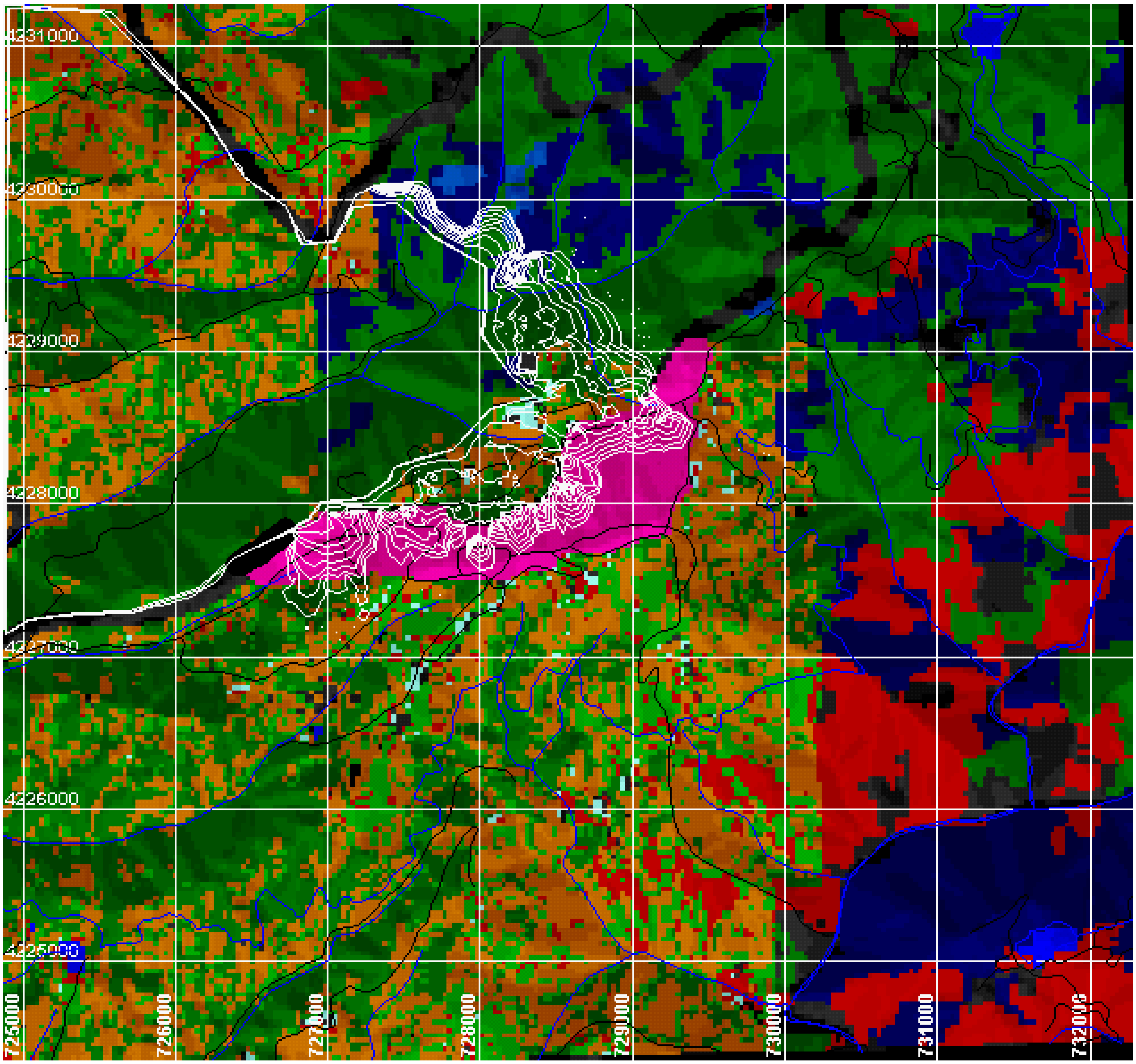
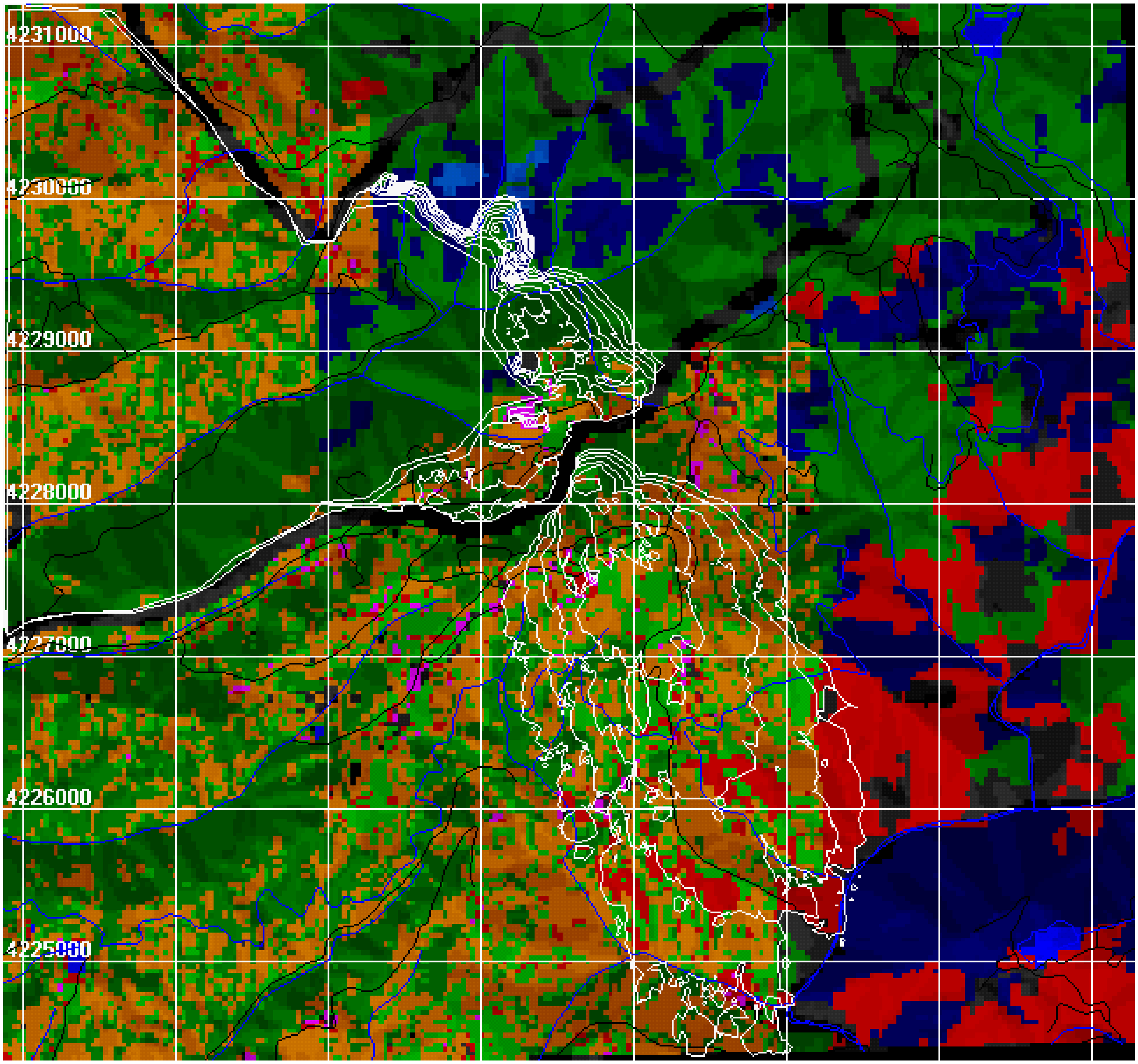


FIGURE 4b.



The findings of these simulations support the belief expressed by the Ranger Unit Chief, that had the fire successfully established itself in the Stanislaus drainage, the fire would have not been contained for many days, likely burning up canyon to the west-northwest all the way to Calaveras Big Trees State Park, some 8 miles away. We estimate that had this occurred, final fire size would have exceeded 50,000 acres.

3. San Domingo Creek VMP

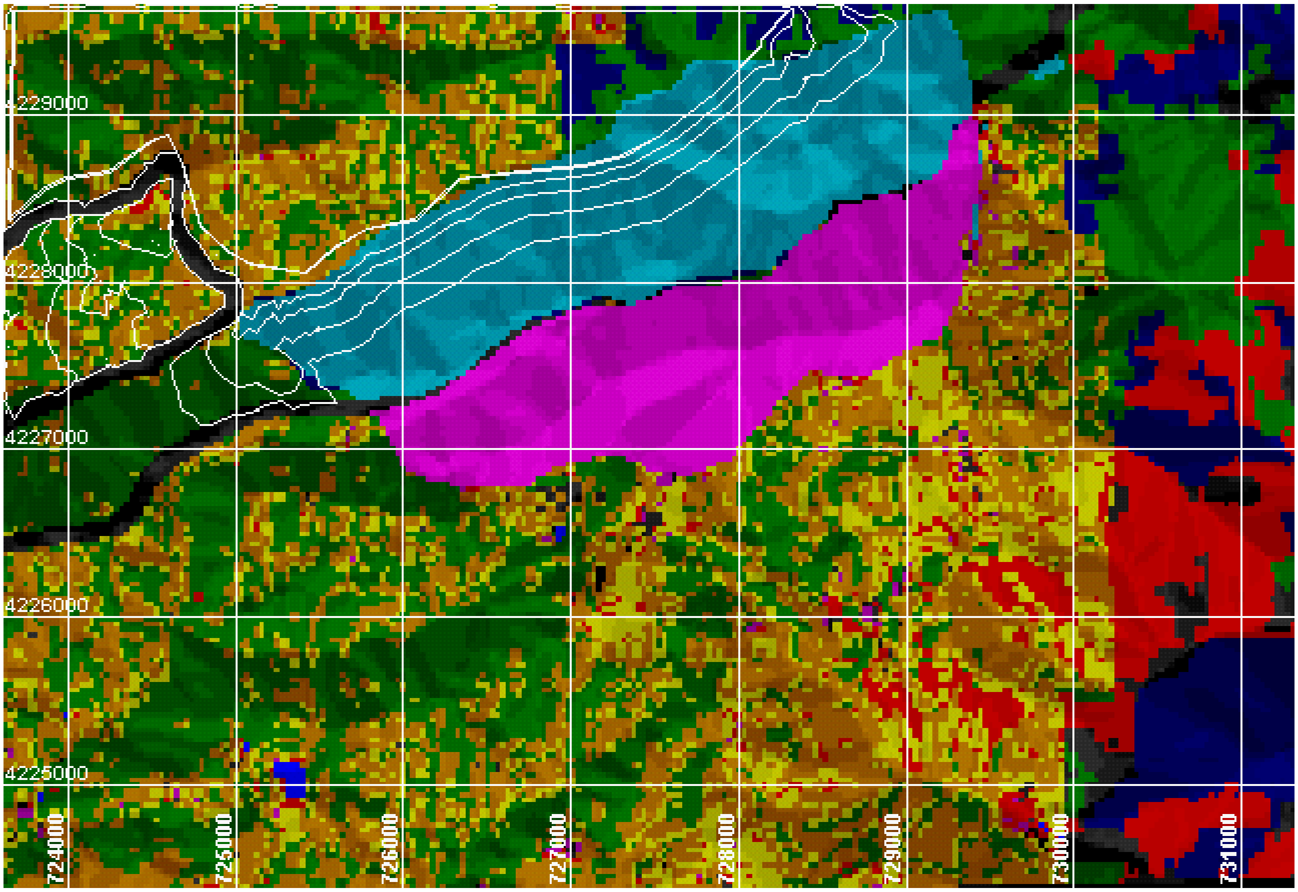
This analysis centers around the assessment of a potential fuel management project in the area where extreme fire and high levels of structure loss were reported above, namely, in the drainage opposite Forest Meadows. Although the scattered ownership patterns of this area would have created difficulty in terms of implementation, we explore this scenario to investigate how strategic placement of multiple projects can act in concert to reduce potential costs and losses associated with wildfire. Where areas of high hazard, high risk, and high assets are clearly identified, strategic multiple projects are an effective means of realizing these goals.

We modeled the effects of a Vegetation Management Program prescribed fire on the south slope of San Domingo Creek, opposite the Forest Meadows area. Changes in the fuel complex were quite similar to those of the Skull Ranch Project: reduced surface and ladder fuel loads, some crown thinning, and a break-up of the horizontal continuity of the these conifer litter fuels. Although this area also included numerous structures, we have assumed that they would not appreciably influence fire behavior, particularly when subjected to reduced hazard resulting from the VMP. Practical considerations for areas such as these would probably dictate extensive mechanical work in the immediate area of the structures to provide for protection of assets from the broadcast prescribed fire. Thus, not only would wildland fuels be managed, but in doing so, treatment of residential areas would also be required.

We simulated a 16 hour fire duration, corresponding to an overlapping period as that used in the Forest Meadows simulations. The same simulation settings and initial fire position were used, but used 4 hour time steps to show fire growth. As was evident in the early development of both with and without simulation shown in Figure 4, the fire behavior on the south slope of San Domingo Creek not only dictated effects on those areas, but also significantly determined how the fire made its way into the Forest Meadows/Stanislaus Canyon area.

The simulation of the project is shown in Figure 5. Clearly, the combination of the proposed VMP and the in-place prc 4291 compliant subdivision result in an area of significantly reduced threats from wildfires, particularly those burning upslope from the north, as was the case in the Old Gulch Fire. The reduced fire behavior in the VMP indicates that little or no spot fires would result from fires burning in this area, and that the opened canopy would allow direct attack by both ground and air forces. The slow rate of spread evident by the closely spaced perimeters indicates a high likelihood of control and little potential damage to assets within treated areas. Also evident is the fact that fuel management projects are only as good as the areas treated and the ability to use reduced fire behavior in those zones to free other resources to untreated portions of the fire front. The western edge of the fire circumvents the VMP, and quickly expands upslope to the western edge of Forest Meadows. If allowed to continue, this simulation would likely cross Hwy. 4, skirt the Forest Meadows project, and make its way into the Stanislaus River Canyon.

Figure 5. Simulations with San Domingo Creek VMP. Area extent of the project is shown in aqua. The magenta area indicates the extent of the Forest Meadows Project. The white squares indicate 1 square kilometer (247 acres). The white lines indicate 4 hour time steps in the fire progression. The first perimeter (upper left) indicates the initial fire front position at the start of the simulation.



Summary

Modeling the two in-place and one hypothetical pre-fire fuel management projects clearly demonstrates multiple benefits to CDF and the citizens in and around the fire area. We have summarized these benefits as a table of paired comparisons for the three projects (Table 1). In each instance we used the model to calculate size and fire intensity, and draw inferences in regard to firefighter and public safety, expectant final size and costs of containing the fire. Although these figures represent only estimates of alternative outcomes, they are based on expert opinion and costs of similar fires, and consequently both the trend and magnitude of the benefits are well grounded.

In each instance, the projects conferred significant benefits in terms of reduced fire size, lower cost of suppression, and increased firefighter and public safety. In as much as the fire size was effectively reduced, we can also infer lower damages resulting from the fire. In the case of the San Domingo Creek VMP, although the net reduction in fire size is relatively small, the expected reduction in damages would be quite high, given the fact that the additional area not burned in the fire was an area of very high structure loss.

Conclusion

The relative effectiveness of any given fuel management project is only as good as the fire scenario (fire location, weather stream, adjacent fire behavior) encountered and the suppression forces used to contain the fire. As suppression capability is currently outside the realm of FARSITE, we have held fire scenarios constant across fuels treatments, and interpreted the differences in outputs as a function of changes in fuel characteristics. In actuality, fire service decisions are going to be based on changes in fire activity when fires move into treated areas. Fuel management zones are routinely used as safety zones for firefighters and as points of anchor for both direct and indirect attack on adjacent portions of the fire front.

As an example, with fire behavior largely mitigated by the VMP shown in Figure 5, a logical tactic to tie the fire in on the west side of the front would be to clip the fire at the far left during the first 8 hours of the period, before it is able to reach across the creek and move rapidly upslope through untreated fuels. The amount of line required to successfully limit surface fire growth in this area is very small, and given the low fireline intensity exhibited in the treated areas, would likely be amenable to direct attack. In this sense, we can see how fire control measures would be linked directly to changes in fire behavior resulting from fuel management operations.

We believe that models such as FARSITE -- although limited by assumptions, model simplifications, and lack of complete system complexity -- still offer sound means of quantifying potential benefits of fuels management projects as they affect potential fire behavior. If we believe that we are able to both accurately reflect these fuel changes, and place them in context with likely fire scenarios, the outputs are robust. Further, when the interpretation of the outputs tend to support sentiments echoed by seasoned fire managers with a wealth of experience and knowledge of fire behavior and the interactions inherent in putting out fires, our confidence in these findings become stronger. As we move into a period of greater model validation, increased model capability, and application to a wider range of situations, we will have even more power to assess how prefire projects will likely influence threats from wildland fires.

Table 1. Summary of comparisons of simulations in regard to modeled and inferred benefits arising from fuel management projects.

Treatment run	DURATION (hrs)	increase in fire size (acres)	direct attack of fire front (y/n)	estimate of containment size (acres)	increase safety to fire crews and public (y/n)	estimated final suppression costs ($)
Skull Ranch w/o project	24	6,620	n	30,000	n	20 million
Skull Ranch w/ project	24	4,114	y	17,000	y	11.9 million
Forest Meadows w/ o project	8	1,882	n	50,000	n	35 million
Forest Meadows w/ project	8	680	y	17,000	y	11.9 million
San Domingo Cr. w/o project	16	1,827	n	17,000	n	11.9 million
San Domingo Cr. w/ project	16	758	y	14,000	y	9.8 million

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