CHAPTER 5: FIRE MANAGEMENT

5.0 Introduction

Fire is part of an important cycle of natural processes in both plant communities and watersheds. Historically, fire has played a significant role on the watershed lands now owned by the District, both in the forested areas on Ben Lomond Mountain, and in the sandhills plant communities of the District's Olympia Wellfield.

In forested areas, fire has historically contributed to a patchy forest age structure. Patchiness increases the overall health and resilience of the forest through time. Fire regimes vary according to climate, geography, vegetation types, and management practices. The fire regime of the past hundred years has emphasized fire suppression.

Ongoing climate change is an increasingly serious concern for watershed managers. Scientists have reported that the warmer and windier conditions corresponding to a doubling of carbon in the atmosphere produce fires that have burned more intensely and spread faster in Northern California (see Paragraph 5.8, Modeling fire).

Climate change is likely contributing to increased frequency and severity of wildfires locally, despite fire suppression efforts. Potential impacts to watershed resources from three large Santa Cruz County wildfires in 2008 are discussed in a post-fire study which brings to light many concerns for watershed managers should wildfires continue to increase as a result of climate change (see Paragraph 5.1, 5.1 Historical fire regimes in the Monterey Bay Area).

Drier inland forested areas are more prone to fire than moister coastal forests. Forests in areas of high wind are prone to windthrow, which create a significant fuel load.

Forests that are predominately redwood *(Sequoia Sempervirens)* are able to resist the effects of all but the most intense wildfires (Agee, 1993). Because it is the driest time of year, critical fire weather typically occurs in July through October. However, CalFire historical files for the Santa Cruz Mountains indicate that extreme fire conditions, including low humidity and high winds, have frequently occurred from August through early January. For example, in January 1961 six fires were recorded, several of which covered more than 1,000 acres (CalFire, 2008). Typically, redwood forests in the region also include Douglas fir (*Pseudotsuga menziesii*), tanoak (*Lithocarpus densiflorus*), Pacific madrone (*Arbutus menziesii*), and California bay (*Umbellularia californica*). Redwoods are not fire dependent; that is, they can survive and regenerate without fire.

In terms of fuel, redwoods are relatively free of volatile oils and resins, making them somewhat fire-resistant (Lindquist, 1974; as cited by Agee, 1993). Redwoods thrive in coastal areas with summer fog, which helps to lessen fire hazard. In mature upland stands, low intensity fires generally do not kill the overstory conifers, but will kill the tanoaks and other trees (Agee, 1993). Moderate severity fires that scorch the crowns of overstory conifers will generally kill mature Douglas firs, but not redwoods, which will re-sprout and grow a new crown (Agee, 1993).

Sandhills chaparral communities have undergone the most dramatic shift in structure due to plant succession in the absence of fire. Aerial photographs during the past 60 years have revealed large increases in woody vegetation and concomitant reductions in open sand areas during this period of fire suppression. The resulting increase in canopy closure reduces the abundance of open sandy habitat required by important sand chaparral plant species. Research suggests that plants cannot complete their life cycles in the dense leaf litter and low light of the closed canopy environment (McGraw, 2004).

Canopy gaps important for maintaining plant diversity are likely also important for the sandhills fauna, which is impacted by canopy closure due to fire exclusion. Animals may rely on the gaps in the canopy which provide habitat conditions dissimilar from the closed canopy environment including a greater availability of sunlight (e.g. for thermoregulation) and a higher diversity of plants which may provide a variety of food sources not found in the closed canopy (e.g. flowering plants for pollinators, seeds of herbaceous plants for granivores, etc.). Indeed, shrub encroachment due to fire suppression in sandhills chaparral communities is cited as one likely cause for the likely extirpation of the Santa Cruz kangaroo rat from the Bonny Doon Ecological Reserve and Wilder Ranch sandhills sites during the past 20 years (Bean 2003).

With respect to watersheds, major wildfires are important aspects of bed sedimentation, erosion and aquatic habitat management throughout the Coast Ranges (Hecht and Kittleson, 1998). Fire suppression and the resulting absence of wildfire over the last few decades increase the chance of a major fire, which could seriously alter surface hydrology and sedimentation (Balance Hydrologics, 2007).

5.1 Historical fire regimes in the Monterey Bay Area

Wildfire has long been both a natural occurrence, as well as a land management tool in the Santa Cruz Mountains, since the earliest inhabitants arrived between 30,000 to 10,000 years ago (Balance Hydrologics, 2007).

The year 2008 was a significant year for wildfires in Santa Cruz County. In May, the Summit fire burned 4,270 acres in the Browns, Corralitos, Soquel, and Uvas Creek watersheds (State Emergency Assessment Team (SEAT), 2008). In August, the Martin fire burned 520 acres at the Bonny Doon Ecological Preserve in the San Vicente Creek and the Laguna Creek watersheds (SEAT, 2008). SEAT reports conduct rapid assessments on burned areas of wildfires, as well as downstream of burned areas to determine if emergency rehabilitation treatment is needed to minimize risk of threats to human life or property, to minimize or prevent deterioration of water quality, loss of soil productivity due to erosion, or degradation of wildlife and botanical habitat, and cultural resources.

The SEAT report (2008) found that the principal concern in the aftermath of the Summit Fire was an increase in the potential for in-channel floods, hyper-concentrated floods, debris torrents, and debris flows. The primary mechanisms for these problems were found to be:

1. The loss of mechanical support of hillslope materials provided by vegetation and vegetative litter;
2. The increase in runoff resulting from reductions in interception and infiltration from the simplification of surface runoff patterns;
3. The loss of mechanical support along stream channels where riparian vegetation was burned.

Stephens and Fry (2005) provided a literature review tracing the history of fire in the Santa Cruz Mountains, and documented fire history by analyzing ring counts on live trees, downed logs, and stumps. Native inhabitants burned scrub and grasslands to foster the growth of seed-bearing annuals, and to facilitate acorn gathering (Balance Hydrologics, 2007). Logging operations from the late 1800s to the early 1900s relied heavily on fire to reduce slash piles, and to clear land for conversion to grazing and home sites. Fire scars on old growth redwood stumps throughout the watershed serve as historical evidence of these practices (Balance Hydrologics, 2007).

Greenlee and Langenheim (1990) distinguished five different historical fire regimes in the Monterey Bay area, which they based on field research they conducted in Big Basin State Park:

- Lightning Regime – up to 11,000 before present (BP)
- Aboriginal Regime – 11,000 BP - 1792 A.D.
- Spanish and Mexican Regime – 1792 – 1848
- Anglo Regime – 1848 - 1929
- Recent Regime – 1929 - present.

5.1.2 Lightning Regime

During the lightning fire regime, humans were not yet part of the ecosystem, and lightning accounted for all of the fire ignitions. Over a 50 year period, lightning fires were estimated to cover approximately 37 percent of the redwood forest, over approximately 20 percent of the land surface of Santa Cruz County. The mean fire interval (MFI) in the redwood forests was approximately 135 years (Table 5.1).

5.1.3 Aboriginal Regime

Upon arrival of humans, lightning was no longer the main source of fire. People used fire as a management tool. Greenlee and Langenheim (1990) suggest that one of the primary disturbances to vegetation communities resulted when humans arrived and practiced their local fire regimes.

Native Americans were nomadic, depending on the seasonal availability of foods. They burned oak savannah and coastal prairie to increase the productivity and collection of acorns, bulbs and other edible plants. The mean interval between fires shortened as a result (Table 5.1). To avoid grizzly bears, humans did not often venture into the redwood or mixed evergreen forests (Greenlee and Langenheim, 1990). However, some of these fires would spread into the forest.

Prior to the arrival of European man, forest fires were mostly low intensity ground fires that did not burn into the conifer live crowns. Fires set by Native Americans would burn through the forest often enough to prevent the accumulation of high fuel loads on the forest floor or the occurrence of dense ladder fuels that would carry flames into the canopy. During extreme fire weather, crown fires would still occur, but they would be infrequent events (Agee 1993).

5.1.4 Spanish Mexican Regime

During the Spanish Mexican Regime, the Spanish primarily burned chaparral, in order to increase grazing areas on their ranches. Traditional use of fire by the native Ohlone was made illegal.

5.1.5 Anglo Regime

During the Anglo fire regime, loggers burned to reduce slash, to ease the removal of downed logs, and to convert logged land to other uses. Greenlee and Langenheim (1990) describe fires from logging practices during this era:

> Since control lines were not used, fires frequently escaped. Where these human-caused fires burned under extreme weather conditions in heavy fuels, they were not usually stopped by a change in weather or by minor barriers.

Newspapers from this time described these fires as large, intense conflagrations, which frequently became crown fires (Greenlee, 1983). Fires often escaped control; by 1888 the State Forester considered escaped logging fires to be a major problem (Anonymous, 1888). Fire scars dating from the Anglo regime indicate that the entire inland portion of the county was logged and burned at least once and, in many places, two or three times. In contrast to the Aboriginal and Spanish regimes, fires during the Anglo regime generally occurred in the inland rather than in the coastal zone, and were larger, more frequent and more intense than previous lightning fires.

According to historical records, Santa Cruz County has one of the lowest numbers of recorded lightning fires in California (Keeley, 1981, as cited in Greenlee and Langenheim, 1990). Between 1893 and 1979, only 101 lightning storms were recorded for the County, igniting 34 fires (Greenlee and Langenheim, 1990). Ninety-one of these storms occurred during the moist winter season, causing only one fire. The remaining 10 storms caused the remaining 33 fires (Greenlee and Langenheim, 1980 as cited in Greenlee and Langenheim, 1990).

5.1.6 Recent Regime

As the watershed became increasingly developed, fire suppression became an accepted management goal. Land managers were advised to eliminate fire in old-growth forests and to be more careful when burning cut-over lands:

> The virgin redwood forest has been irreparably damaged by past fire; current fires aggravate the damage and on cut-over land they materially reduce the value of the land for new tree growth (Fritz, 1931; as quoted in Stephens and Fry, 2005).

According to Stephens and Fry (2005), “This early viewpoint was biased towards the utilization of redwood trees for lumber.” Still, from 1929 to 1979, some 3,765 fires burned approximately 53,000 acres, approximately 19 percent of the County’s land base (Greenlee and Langenheim, 1990). Ninety-two percent of these fires were less than 10 acres (Greenlee and Langenheim, 1990).

Fire suppression altered the natural processes of fire, reduced habitat variability, and impaired natural mechanisms necessary for ecosystem health. Fire suppression and clear-cutting altered forest structure and removed the patchy mosaic of various plant communities. The resulting build-up of ignitable fuel material on the ground increased the risk of a catastrophic fire.

Fire suppression affected other vegetation types in the watershed even more severely than it affected redwood and mixed conifer forests (Greenlee and Langenheim, 1990). In the sandhills, fire suppression is drastically altering the community structure of this rare ecosystem, potentially endangering it existence. McGraw (2004) conducted research to test the response of sand parkland vegetation to manual removal of pine needle litter from the soil, safely mimicking the effects of fire. Her results showed a positive response from native annual vegetation to this management technique.

Changes in the frequency and severity of wildfires will alter the composition, structure, and function of redwood forests. Fires suppression, practiced since the late 1920's, has increased the density of tan oaks and other hardwoods in the forest understory. It has likely cut off the recruitment of large snags and large down logs, two elements that play important roles in old-growth forest ecosystems.

Climate change and the build-up of forest fuels caused by Sudden Oak Death disease may cause the fire frequency "pendulum" to swing to the other extreme, as there is expected to be an increase in the frequency and severity of wildfires (U.C. Coop. Ext. 2008, Westerling and Bryant 2008). One possible scenario foresees more crown fires of an intensity severe enough to kill all the Douglas-firs and understory trees and burn the redwoods so severely that they won't sprout from the trunk and will only survive as stump sprouts. If this occurs, all large live trees will be lost from the stand. If severe fires re-occur frequently enough, old-growth conditions may never be re-established without human intervention, as the first conifer to achieve old-growth characteristics is Douglas-fir and it takes at least 175 years to reach that state.

Table 5.1 Mean fire intervals (MFI) in various vegetation types by historic fire regime in the Monterey Bay area

Fire regime	Vegetation where burning concentrated	Vegetation where burning incidental	Recorded or calculated MFI (yr)[1]	Probable MFI (yr)[2]
Lightning		Prairies		1-15
		Coastal sage		1-15
		Chaparral		10-30
		Oak woodland		10-30
	Mixed evergreen			30-135
	Redwood forest		135	
Aboriginal	Prairies		1-2	
	Coastal sage		1-2	
		Chaparral	18-21	
	Oak woodland		1-2	
		Mixed evergreen		50-75
		Redwood forest	17-82	
Spanish		Prairies		1-15
		Coastal sage		1-15
	Chaparral		19-21	
		Oak woodland		2-30
		Mixed evergreen		50-75
		Redwood forest	82	
Anglo		Prairies		20-30
		Coastal sage		20-30
		Chaparral	10-27	
		Oak woodland	50-75	
	Mixed evergreen		7-29	
	Redwood forest		20-50	
Recent		Prairies		20-30
		Coastal sage	155	
		Chaparral	155	
		Oak woodland	225	
		Mixed evergreen	215	
		Redwood forest	130	

[1] Recorded or calculated MFI data are derived from historic documents, fire scars, or published data.

[2] Probable MFI data, due to a lack of historic or physical evidence, are derived from data from literature.

Source: Greenlee and Langenheim, 1990.

5.2 Fire in the San Lorenzo River watershed

The San Lorenzo watershed contains substantial areas of fire-adapted vegetation, reported to burn at historical intervals of typically 40 to 80 years (Hecht and Kittleson, 1998). Fire suppression has been the predominant management strategy in the San Lorenzo River watersheds since the era of slash burning. CalFire is responsible for fire suppression and management in State Responsibility Areas (SRAs) and the Santa Cruz County Fire jurisdiction. Other fire districts, including Boulder Creek, Felton, Ben Lomond, Branciforte, Zayante, University of California at Santa Cruz, Scotts Valley and City of Santa Cruz, are responsible for fire management in their own jurisdictions within the watershed.

Several fires occurred in the 1930s and 40s, and a large fire known as the Sawmill Fire burned in the 1950s (Balance Hydrologics, 2007). In 1959, a fire in the Loch Lomond watershed burned about 1,000 acres on both sides of the lake. Evidence of this fire can be seen on the east side of Loch Lomond, where residual burned snags tower above the living trees. The Love Creek fire burned in 1970. No major wildfires have occurred in the watershed in the last three decades (Balance Hydrologics, 2007). Numerous small fires have occurred, but they have had little effect on reducing the overall fuel load (Balance Hydrologics, 2007). Therefore, there is concern among local resource managers that fire suppression has created a fuel build-up that will result in a watershed-scale fire, if the conditions are right (Balance Hydrologics, 2007). (Refer to Section 5.4, Forest Management and Fire and in the Santa Cruz Mountains).

5.3 Potential impacts to water resources from wildfire

Most water purveyors drawing upon surface or spring supplies should anticipate extended turbidity events following a large fire in their watersheds. Planning should focus on exploring potential alternative sources of supply during the months or years following the fire, and for protecting diversion or distribution facilities from post-fire erosion and slope stability (Balance Hydrologics, 2007).

5.3.1 Expected aftermath of a high intensity fire at the watershed scale

The SEAT report (2008) described the threats to water quality in the aftermath of the 2008 Summit fire in the forested areas of southern Santa Cruz County. The report stated:

> Water resources located within or near the fire perimeter are at an increased risk to the threat of flooding, debris torrents, and debris flows. The risk appears to be greatest to the City of Watsonville water supply. Watsonville maintains water intakes on Corralitos and Browns Creek (SEAT, 2008).

The report also found threats to wildlife, botanical resources and fisheries, due to the increased threat of flooding, debris torrents, and debris flows. Threats were greatest to listed species and species of special concern.

A major fire in the San Lorenzo River watershed could have serious consequences for the watershed health and water quality, the following areas:

- Alteration of surface hydrology and sedimentation
- Chemical impacts from fire retardants
- Habitat degradation and loss

5.3.1.a Alteration of surface hydrology and sedimentation

A major fire would cause alteration of surface hydrology and sedimentation in any or all subject water supply streams (Balance Hydrologics, 2007). First, sediment input into streams within the watershed would be increased for years, due to the loss of vegetation and canopy. High intensity fires burn organic matter within the soils. Since this organic material helps to hold soils together, burning increases the susceptibility of newly exposed soils to erosion (Spence et al., 1996). Burning can also cause soil to become hydrophobic, increasing runoff and erosion (Spence et al., 1996). According to the 2007 watershed sanitary survey:

> Elevated levels of turbidity are likely to persist from several months to several years following an extensive fire. Only part of the time will levels remain elevated about 10 to 30 NTUs (nephelometric turbidity units), a rule-of-thumb threshold range above which reliable water treatment becomes more challenging (Balance Hydrologics, 2007).

Creation of temporary roads and firebreaks to control fires can be a source of persistent sedimentation and turbidity if not properly abandoned following fire events. Reseeding burned slopes, mulching exposed soils, and the use of other erosion control techniques will reduce, but in no way eliminate the significant erosion likely to follow a wildfire (Balance Hydrologics, 2007). In addition, reseeding with non-native plants has potential impacts to native plant community regeneration.

5.3.1.b Chemical impacts to water quality from fire retardants

Fire retardants may also have adverse effects on water quality. Historically, retardants used by CalFire have included borate salts and bentonite clay in water. Borate salts are long lasting, but they are also phyto-toxic and soil sterilants. Bentonite clay in water is less persistent. Use then shifted to ammonium-based fire retardants, which accounted for nearly all chemical retardants used to control wildand fires. When these chemicals are applied directly to stream surfaces, they may cause fish mortalities (Buhl and Hamilton, 1998) and alter aquatic conditions by elevating nitrogen and causing eutrophication downstream (Camp, Dresser & McKee, 1996). More recently, a powder-based product (AquaGel-K) has become the dominant material applied by CalFire aircraft (CalFire, as documented in Balance Hydrologics, 2007). The active ingredient in this gel fire retardant, 2-propenoic acid, is practically non-toxic to aquatic organisms and the material degrades readily in sunlight. It also has enhanced reflectivity, which increases its effectiveness in combating initial outbreaks of fire (Balance Hydrologics, 2007).

The fire suppressant foams applied by fire trucks and helicopters may also have adverse impacts on water quality, and are more toxic to aquatic biota than ammonium-based fire retardants (Gaikowski and others, 1996 as cited in Balance Hydrologics, 2007). Application requires leaving a buffer between the spray zone and live streams (Balance Hydrologics, 2007).

5.3.1.c Habitat degradation and loss

Sedimentation and erosion in the aftermath of a major fire could have devastating impacts to fisheries and wildlife habitat. Steelhead and coho salmon are already listed as threatened or endangered, due in part to sedimentation in their natal streams. The impacts of fire retardants would also further threaten the survival of these fish, and other aquatic species. A fire that destroyed the forest canopy would also impact bird and mammal species.

Recovery of habitat in streams of the San Lorenzo River watershed following a high intensity fire would be expected to take 3 to 5 years (Hecht and Kittleson, 1998).

A catastrophic fire creates conditions to which native species are not adapted. The higher intensity and/or severity of a catastrophic fire could have devastating impacts on native species, which may be adapted to less intense fire conditions.

5.3.2 Expected aftermath of a high intensity fire on District-owned lands

The SEAT report (2008), which described threats to the City of Watsonville's water quality in the aftermath of the Summit Fire could be instructive to the District.

Potential pollutants generated from a fire in residential areas upstream of the District's water intakes on Foreman and Clear Creeks could have significantly more impact on water quality than pollutants generated solely from a forest fire.

The District's ground water sources located in the sandhills areas are especially prone to catastrophic fire. Because the sand soils are so porous, any residues left from the fire or chemicals used in fire fighting have the potential to readily enter the aquifer and thus contaminate the region's water supply. State Parks plans to increase prescribed burns in the pine sandhills areas of the Majors Creek watershed (Balance Hydrologics, 2007).

Generally, most of the expected impacts discussed at the watershed scale could also be expected for the District's watershed lands. However, because elevated turbidities persist much longer in reservoirs than in streams, the District's major surface water sources from local tributaries would probably have a shorter recovery time than the surface water source at Loch Lomond.

5.4 Fire management jurisdictions and practices

In rural areas, outside the jurisdiction of local fire districts, fire management within the San Lorenzo River watershed is the responsibility of the California Department of Forestry and Fire Protection (Cal Fire), Felton Headquarters (Camp, Dresser & McKee, 1996). The agency is equipped to suppress wildland fires throughout the watershed.

Local fire districts take primary responsibility for fighting domestic and commercial fires within their jurisdictions. At the county level, the county fire marshal is responsible for the coordination between neighboring fire districts, particularly during first alarm response. The county Office of Emergency Services provides communication and warning services to area residents and fire districts (Balance Hydrologics, 2007).

The stated fire management objective of the County General Plan is "to protect the public from the hazards of fire through citizen awareness, mitigating the risks of fire, responsible fire protection planning, and built-in systems for fire protection and suppression."

The Santa Cruz County Fire Department and the Office of Emergency Services participate in the development of fire-related development standards and post-fire restoration efforts, in addition to the review and updating of the countywide Disaster Contingency Plan and Critical Fire Hazard Maps.

Prescribed burning by the state Department of Parks and Recreation at Henry Cowell Redwoods State Park and Big Basin State Park is conducted to minimize the potential spread of a major fire either into or out of the parks. Prescribed burns are also used to promote fire-tolerant native vegetation threatened by invasive non-natives (Balance Hydrologics, 2007).

Balance Hydrologics (2007) described prescribed burning within the watershed, in order to address the potential catastrophe of a watershed-scale wildfire:

> Prescribed burning is done by the California Department of Parks and Recreation at Henry Cowell Redwood State Park and in Big Basin Redwoods State Park. These prescribed burns are done for two primary reasons: (1) vegetation management within Park boundaries and (2) to reduce the likelihood of fires passing over the Park boundaries. Use of prescribed burns is expected to increase over the next five years with the parks (Tim Hyland, personal communication, as documented by Balance Hydrologics, 2007). Many large forest landowners maintain networks of fire trails and roads on the properties. The County, and a number of community organizations including the former Fire Safe Council, attempt to extend appropriate measures to willing owners (Balance Hydrologics, 2007).

While fire suppression remains the primary fire management goal, Cal Fire's Vegetation Management Program staff (VMP) regularly work with landowners, including State Parks, on prescribed burns in the watershed. VMP staff also regularly work with other landowners, including the Los Cumbres and the Indian Trails homeowners associations, on vegetation management projects. In addition, the SCCRCD staff assists landowners with fire trail maintenance projects throughout the watershed.

Other agencies and landowners of large tracts of watershed lands could utilize prescribed burns as a management tool. More public education about fire prevention and management is needed to assist landowners in managing private property and to prepare for a large fire.

5.5 Forest management and fire in the Santa Cruz Mountains

Commercial timber harvesting in the Santa Cruz Mountains, which focuses on cutting of large and/or mature redwoods for their commercial value, is often presented by local foresters as a method of reducing fuel load and fire hazard. However, many scientists have refuted these claims. According to Montague (2006):

> Mature coast redwood stands usually will not support a crown fire without a heavy accumulation of ground fuels. Thinning of these mature Douglas fir and coast redwood trees to reduce the potential for a crown fire is not economically sound. The closed crowns and local fog conditions maintain the ground fuels to a much higher live and dead fuel moisture condition; therefore, producing a low fire spread and intensity. To open up the normally dense crown cover to more sunlight and solar heating will reduce live and dead fuel moistures, thereby increasing fire spread, fire intensity and flame lengths.

It is important to note that the goal of a commercial timber harvest plan is to realize revenues from timber; hence, a commercial timber harvest plan emphasizes the removal of large trees with high timber value, which are also the most fire-resistant trees. In contrast, thinning the forest to reduce fuel load emphasizes the removal of smaller ladder fuels. These smaller trees have relatively little timber value.

It should be noted that much of the area that burned in the 2008 Summit fire had been recently logged, including the property known as Grizzly Flat, owned by the City of Watsonville. In the mid-1990s, the city conducted a 120 acre commercial timber harvest plan at Grizzly Flat that removed many of the biggest and oldest redwood trees, just above the city's water intake on Corralitos Creek. Opponents to the timber harvest plan argued unsuccessfully that the logging would threaten the city's water quality (Herbert, 1995).

Omi (2006) stated that lopping and distributing fuels may increase fuelbed continuity and spread rate, depending on extent and quality of execution.

Analyzing the potential impacts of fire from a proposed a 1,000 acre timber harvest plan in the Santa Cruz Mountains, Montague (2006) stated:

> Timber harvesting techniques used in the region's selective harvesting regime, including cable, helicopter and tractor yarding, create activity fuels which will burn at a much higher rate of spread, fire intensity and produce longer flame lengths than if 100 year-old Douglas fir and coast Redwood stands are left in their current state. Activity fuels debris from timber harvesting activities such as road clearance (stumps and tree debris), treetops and limbs left on the ground, down and broken undergrowth brush and young trees (sapling and pole size trees). Activity fuels created by the various recommended timber harvesting techniques tend to increase overall fuel loading and fire intensity (Montague, 2006).

Montague (2006) recommended the following forest management regime as more appropriate than the proposed selective harvesting:

> What would be more appropriate for reducing and/or minimizing fire spread and intensity in the coast redwood and Douglas fir stands is to reduce ground fuel loading rather than crown removal. This can be accomplished by hand labor, mechanical means and/or the use of prescribed fire. Thinning out the understory ground fuels will do more to reduce fire spread and intensity than crown removal by timber harvesting (Montague, 2006).

Commenting on the same proposed logging plan, Stephens (2006) reported:

> Removing forest canopy by thinning this forest would not effectively reduce potential fire behavior and effects, especially in areas where redwood is the dominant species. Redwood foliage is not particularly flammable and there are few records of crown fires in redwood forests.

According to Stephens (2006), the most effective way to lessen potential fire intensity in redwood forests is by reducing woody surface fuels, and the best method for reducing woody surface fuels in redwood forests is by using prescribed fire:

> Experiences in prescribed burning in redwood forests demonstrate the sensitivity of this forest type to changing weather conditions. A minimum relative humidity of 50 percent is needed to successfully burn redwood litter (Finney, 1991; Stephens and Fry, 2005). It is possible to burn under higher humidities into the early evening for approximately 30 minutes, but once relative humidity increased to 60 percent, burning is no longer possible. Redwood responds very quickly to relative humidity changes. With heavy fog in the morning, it is possible to burn by 2 p.m. in the same afternoon if off-shore winds are present (Stephens, 2006).

According to Swanson Hydrology and Geomorphology (2001), logging increases fire risk for several reasons. First, harvesting typically removes the biggest trees, which are the least combustible, and which provide shade. Thus, timber harvesting enables increased penetration of solar radiation to the ground, which can reduce fuel moisture and humidity. Increased sunlight also encourages significantly faster understory growth, along with higher levels of stored chemical energy. This increased understory growth, in turn, "increases continuity of the vertical and horizontal fuel array." When the relatively large trees are cut, and replaced by smaller ones, the average height to the base of the tree canopy is also reduced, enabling transition from understory to crown fire. After logging, even-aged stands of small conifers result with uniform, dense canopies that also increase fire severity (Frost and Sweeney, 2000). Finally, logging slash can greatly increase dead fuel loads, and the increased hazard of crown fires may persist for many years following logging.

5.5.1 Forest management and fire in the San Lorenzo River watershed

Swanson Hydrology & Geomorphology (2001) characterized vegetation and assessed its role as potential fuel on the City of Santa Cruz watershed lands, which are located in the San Lorenzo River watershed. By analyzing data from local sources, they characterized vegetation in various areas as "fairly dense growth of young redwood," low density Douglas fir, chaparral, hardwoods, and knobcone pines. Following repeated logging by the city of Santa Cruz, Tunheim (1994) measured redwoods and Douglas fir, finding that they were predominantly 12 - 24 inches in diameter at breast height Swanson Hydrology & Geomorphology (2001) stated that, "it is clear from the timber data that the vegetation of the watersheds has been greatly modified by timber harvest and related activities. This will profoundly affect potential fire behavior."

Swanson Hydrology & Geomorphology (2001) documented the effects of timber harvest on subsequent fire behavior with empirical evidence from other forested areas. Citing Agee (1993) they found that, in Pacific Northwest forests that have been logged, excessive densities of Douglas fir can occur during early stages of regeneration. This growth not only hinders successful reestablishment of redwoods, but also creates a post-harvest fuel structure that may be conducive to stand-replacing wildfires for many decades. The authors also cited a comprehensive analysis of forest management in the U.S. (Aber et al., 2000), which concluded that forests with logging are more vulnerable to fire, and suffer greater consequences after fire, in terms of tree mortality and post-fire sedimentation, when compared to unmanaged forests. The authors found an apparent "consistent relationship between logging and increased negative effects related to fire."

Hydrology & Geomorphology (2001) found that, considering all of these factors together within the City of Santa Cruz watershed lands, that the area did have the potential for crown fire when weather conditions are favorable to combustion. The authors attributed recent changes in fuels more to timber harvesting than other factors. They found that "only riparian areas and pockets of late seral forest may currently retain a natural tendency to support surface fire or mixed fire severity" on city watershed lands. They also found it likely that similar scenarios exist in the Newell Creek watershed, upstream from the city's land.

5.5.2 Forest management and fire on District lands

While CalFire staff has assessed District lands for fire hazard severity (Figure 5-1), the District has not retained a fire management consultant to assess its forested watershed lands on Ben Lomond Mountain for fire hazard severity or for risk of ignition. The District's forested properties have not been recently logged, and most are approaching late seral stage. Thus, they may be less vulnerable to fire than the city of Santa Cruz watershed lands, though as Figure 5.1 indicates, almost all of the District's service area, on the west side of the San Lorenzo River, is rated by CalFire as high fire hazard.

5.6 Assessing fire hazard and risk

The District has not yet mapped and analyzed fire hazards more precisely than CalFire's broad maps, in order to conduct a wildfire risk analysis and develop specific emergency response readiness for fire.

Fire hazard assessment is based on the physical conditions of an area making it likely to burn over a 30 – 50 year period, without considering modifications such as fuel reduction efforts (CalFire, 2007). Risk, on the other hand, is the potential damage a fire can do to the area under existing conditions, including any modifications such as defensible space, community-based fuel modification or fire beaks, building construction, irrigation or sprinklers (CalFire, 2007).

In 2007, CalFire's Office of the State Fire Marshall revised its maps that identify wildfire hazard in areas, including unincorporated areas of Santa Cruz County, for which the State has financial responsibility for wildland fire protection. Figure 5.1 shows CalFire's 2007 map of fire hazard severity zones for Santa Cruz County.

CalFire has mapped three hazard ranges: moderate, high and very high. Wildfire hazard areas are areas of significant fire hazard based on fire history, potential fuel over a 30- to 50-year period, blowing embers, terrain, and weather. Note that most of the District's watershed land, on the west side of the San Lorenzo River, is shown as high fire hazard.

The 2007 fire hazard maps will be used to implement new wildland-urban interface building standards adopted by the California Building Standards Commission. The new building codes establish ignition-resistant construction for roofing, walls, decks, windows, and other building elements for homes in the wildland-urban interface based on the area's fire hazard severity zone classification (CalFire, 2007).

Swanson et al. (2002) emphasize that fuel characteristics have only moderate impact on fire hazard, which is strongly influenced by ignition patterns and weather conditions. Estimating fire hazard, in terms of lives and residential structures, requires assessment of local topography, adjacent fuels, the potential for structures to ignite, and the existence of escape routes from dwellings and neighborhoods.

According to invasive plant removal specialist Ken Moore, the invasive populations of French broom on District property at the Olympia Wellfield have increased the risk of catastrophic fire (Moore, 2007).

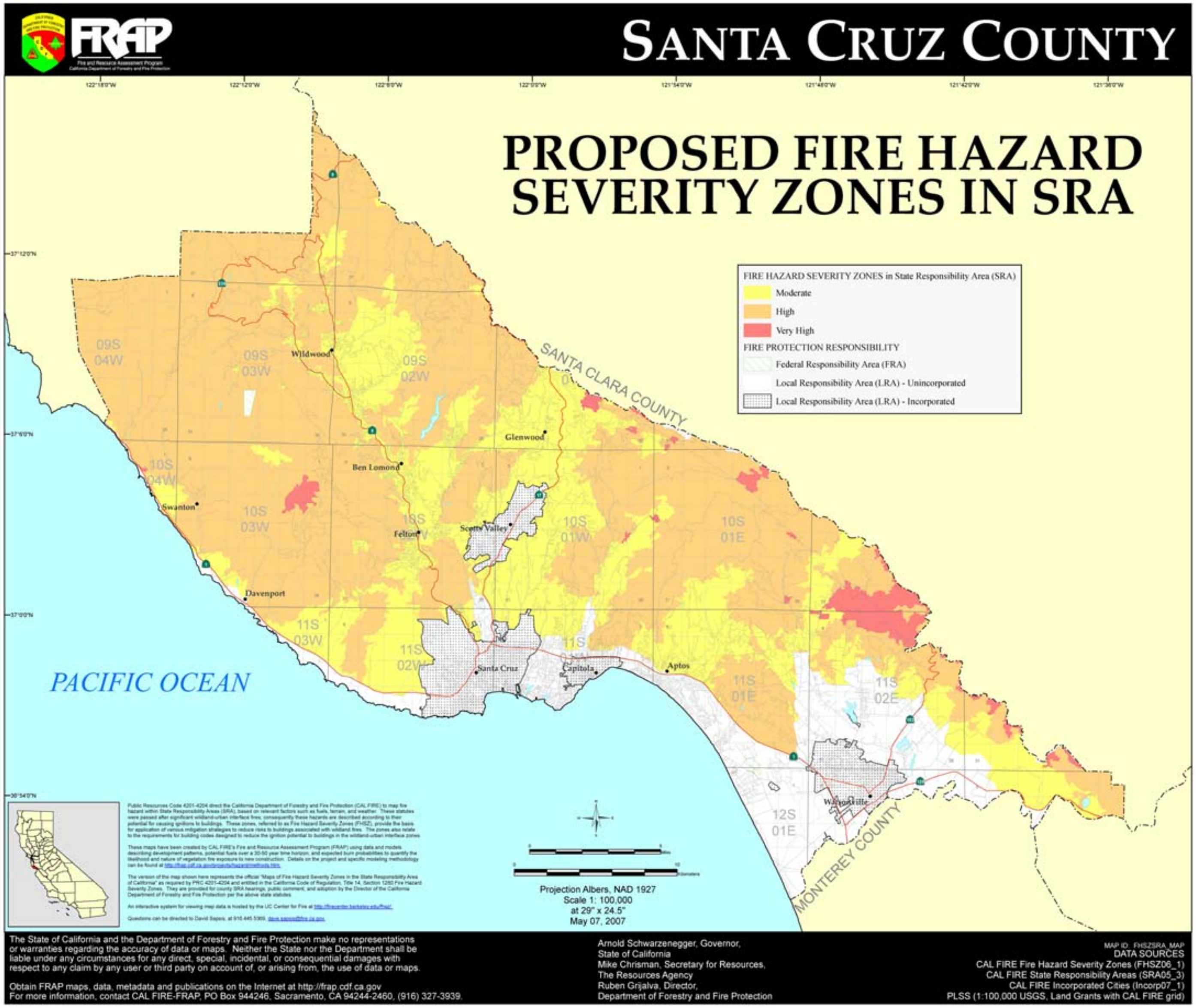
5.6.1 Sources of ignition

Lightning ignitions are infrequent in the Santa Cruz Mountains (Greenlee and Langenheim 1990). Probability of a human ignition may be substantial on the City of Santa Cruz watershed lands, especially with increased human recreational use (Swanson et al. (2002).

District lands where recreational access and trespass occur, such as the Olympia watershed, may be more vulnerable to fire ignition, especially areas invaded by French broom (Moore, 2007; personal communication).

Swanson et al. (2002) found it far more likely that a fire would ignite outside City of Santa Cruz watershed lands, and then spread to city lands. With modern fire suppression, most fires are contained at a small size so that large fires are improbable. Weather conditions will infrequently reach their optimum for supporting wildland fire. When an ignition occurs during these conditions, fuels characteristics and suppression efforts have little impact on large fire dynamics (Moritz, 1997).

Figure 5.1 Cal Fire's proposed fire hazard severity zones for Santa Cruz County.



Omi (2006) found the fire hazard assessment of a 1,000 acre proposed NTMP (non-industrial timber management plan) upstream of Lexington Reservoir to be misguided because it focused on fire hazard in the redwood stands in the harvest area instead of the more flammable chaparral within the Los Gatos Creek watershed.

> The potential for long-term damage to watershed values is arguably much greater in the chaparral zones than in the redwood stands within the NTMP. Notwithstanding the commercial value of redwood stumpage, the fire risk analysis should focus instead on the vegetation types comprising the entire upper watershed rather than the trees within the NTMP. The report is misleading insofar as it builds an apparent rationale for timber harvest under the guise of wildfire hazard reduction (Omi, 2006).

5.6.2 Weather conditions leading to increased fire hazard

Weather data are needed to identify thresholds in fire hazard and appropriate responses. It would be beneficial to know daily weather conditions (e.g., temperature, wind speeds, and humidity) that could generate fire conditions too intense for effective suppression, if an ignition were to occur (Moritz, 1997). The District can collect and monitor these data during fire season.

The conditions leading up to the 1959 fire in Newell Creek included a relatively wet winter, followed by an early dry-out period in spring/summer. These circumstances resulted in an early fire season, starting with unusually high biomass accumulation and very low fuel moistures.

Swanson Hydrology and Geomorphology (2002) found that the most significant fire hazard on the City of Santa Cruz watershed lands were located near the southeast corner of the Newell Creek parcel, bordering on the community of Lompico:

> Just over the ridge from Lompico is a U-shaped ravine extending down to Loch Lomond. If fire were to run up this ravine under extreme weather conditions, convection-driven flames could crest the ridge with concentrated energy. In firefighting lexicon, this topographic effect is called a ‘chimney.’ The 1959 fire started near this area where the Loch Lomond Dam was being constructed, but it did not spread into the community of Lompico. Under circumstances of offshore winds and/or more extreme fire weather, the outcome may have been different (Swanson et al., 2002).

The following account of the 1985 Lexington Fire came from the Santa Clara County Fire Department website (2007) provides another example of the importance of weather conditions in assessing fire hazard:

On Sunday, 7 July 1985, the Lexington Fire was reported to be burning about a quarter of an acre on the southeast side of Lexington Reservoir between the boat ramp and Soda Springs Road. Brush Patrol 3 and Engine 3 were first on the scene. The companies stretched hose lines up both sides of the fire in an effort to control the blaze. But, because of the terrain, wind and high temperatures, the fire was soon out of control. There was concern in the early hours of the fire that it would blown north through the canyon and into downtown Los Gatos, but this disaster was averted. The Lexington Fire continued to burn in a southeasterly direction despite all efforts to halt its progress. Throughout the next week, local firefighters and those from around the state battled night and day to control the blaze that consumed 14,000 acres, 42 homes, and caused the evacuation of 4,500 people and approximately $7 million in damage. After days of hard work, little rest, and constant danger to personnel, the fire was stopped at Loma Prieta Road off Summit Road. Fortunately, there was no loss of human life.

Historical data indicates that the Lexington wildfire spread primarily within the various chaparral patches and the ground fuels within the coast redwood and Douglas fir stands rather than the mature tree crowns. Untreated natural fuels, as demonstrated by the Lexington Fire, are also known to support wildland fire intensity and spread. However, the principal carrier of fire was the large tracts of native brush (chaparral), the dead and dying broken tree tops from a prior year heavy snow storm and the various dead and live ground fuels (brush, tree saplings and poles) lying beneath the mature tree stands (Montague, 2006).

5.6.3 Increased hazard from Sudden Oak Death and invasive species

Swanson et al. (2002) reported additional increases in dead fuels on the City of Santa Cruz watershed lands, due to the death of tanoak and coast live oak from *Phytophthora ramorum, a* disease that is widespread in the Santa Cruz Mountains. French broom (*Genista monspessulana*) infestations are quite flammable, increasing the risk of high intensity fire where it is present. This exotic shrub typically invades after a disturbance, such as logging or road-building, and flourishes in the disturbed understory of forests in the Santa Cruz Mountains. Where it flourishes, French broom increases fuel continuity into the canopy. It accumulates biomass more rapidly than native shrubs and exacerbates fuel loading. The District's watershed lands have not been surveyed for fire hazard, for Sudden Oak Death, or for invasive species such as French broom.

5.7 Water utility fire management plans

Many of the region's larger public water utilities that own thousands of acres of watershed property have extensive vegetation management or fire management plans (Marin Municipal Water District 1994, East Bay Municipal Utilities District 2000, and San Francisco Public Utilities District 2002). These plans assess the risk of fire, identify likely ignition sources, spell out fuel reduction practices, and describe emergency response procedures.

The City of Santa Cruz Water Department (SCWD) has an active fire management plan which involves annual coordination with CalFire – to ensure that Calfire has current maps, understands which roads are open, and that keys to gates have been issued. SCWD maintains fuel breaks on its property annually, and continuously maintains its watershed road system. SCWD also patrols these roads and maintains gates routinely to limit potential ignition sources, and to provide access to CalFire should they need it. Under severe conditions, SCWD prohibits all public access to its property (Berry, 2008).

The District routinely maintains the road system on District-owned watershed lands. While performing this maintenance, consultants routinely advise the District of any high fuel hazard areas where fire may be of special concern. The District operations staff knows the location of emergency access points throughout the watershed.

The District has not completely mapped its road system, emergency access points, or fire-fighting emergency fuel breaks and facilities. While emergency response procedures are generally defined for District operations, there is no formalized fire management plan.

5.8 Modeling fire

Models such as FARSITE (Finney, 1998 as cited by Swanson et al., 2002) can simulate fire spread and estimate fire intensity, flame lengths and spotting. The effects of suppression activities and fuel breaks can be incorporated into modeling scenarios, and likely ignition locations can be predicted. The city of Santa Cruz performed a cursory evaluation of fire hazard with respect to human lives and structures, and Swanson et al (2002) strongly recommended further evaluation.

Fried, Torn, and Mills (2004) estimated the impact of climatic change on wildland fire and suppression effectiveness in northern California by linking general circulation model output to local weather and fire records and projecting fire outcomes with an initial-attack suppression model. The warmer and windier conditions corresponding to a doubling of carbon in the atmosphere) climate scenario produced fires that burned more intensely and spread faster in most locations. Under this scenario, despite enhancement of fire suppression efforts, the number of escaped fires (those exceeding initial containment limits) increased 51% in the South San Francisco Bay area, 125% in the Sierra Nevada, and did not change on the north coast. Changes in area burned by contained fires were 41%, 41% and –8%, respectively. When interpolated to most of northern California's wildlands, these results translate to an average annual increase of 114 escapes (a doubling of the current frequency) and an additional 5,000 hectares (a 50% increase) burned by contained fires. On average, the fire return intervals in grass and brush vegetation types were cut in half. The estimates reported represent a *minimum* expected change, or best-case forecast. In addition to the increased suppression costs and economic damages, changes in fire severity of this magnitude would have widespread impacts on vegetation distribution, forest condition, and carbon storage, and greatly increase the risk to property, natural resources and human life. For more information about the potential impacts of climate change, refer to Chapter 7, Local Climate Change Assessment.

ACKNOWLEDGMENTS: CHAPTER 5

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