Acknowledgments

The California Board of Forestry wishes to acknowledge the efforts of individuals who played significant roles in the development of the California Fire Plan. Director Richard Wilson fully endorsed the Fire Plan and set the course by giving it the Department's highest priority. There are many individuals who played a part in developing this plan. Here are just a few of those who were the key players.

Jack Wiest stepped up to the task by providing leadership for the team. Wayne Mitchell assisted Jack with behind-the-scenes administrative details. Jack and Wayne were the consistent leaders needed for the duration. Loyd Forrest, Cathy Bleier, Greg Greenwood, Robin Marose, and the Fire and Resource Assessment Program staff contributed the primary planning framework, a key component that successfully tied together the various concepts. Don Rascon, one of the state's top fiscal experts, applied his expertise by shaping the plan into an acceptable document for presentation to the Department of Finance, Resources Agency and legislative fiscal committees. Hank Weston, Jerry Geissler and Wayne Mitchell led the Level-of-Service team that developed the LOS concept. Hank and Jerry were effective at communicating and ensuring the plan had practical application on the ground. The development of the prefire management focus was led by Doug Wickizer and Bob Irby. The field level planning concept involving stakeholders in the decision making process was organized by Bob and Doug.

Thank yous are in order for the assistance provided by Jon Kennedy, Gary Biehl, and Karen Barnette of the USDA Forest Service.

The early stages of the Fire Plan were directed by the Fire Plan Steering Committee. They included:

Jim Branham, Chief Deputy Director
Dean Cromwell, Executive Officer, Board of Forestry
Ken Delfino, Deputy Director for Resource Management
Jim Dykes, Deputy Director for Fire Protection
Cathy Bleier, Acting Chief, Fire and Resource Assessment Program
Bill Harrington, Assistant Deputy Director, Fire Control Operations
Lloyd Keefer, Region Chief, Coast-Cascade Area
Bob Kerstiens, Chairman, Board of Forestry
Jim Owen, Region Chief, Sierra-South Area
Elaine Vann, Deputy Director for Management Services
Doug Wickizer, Staff Chief, Forest Management

Jack Wiest, Staff Chief, Cooperative Fire Programs

All of the following team members contributed to the final product.

Jim Barron, Tulare Ranger Unit
Larry Benson, Riverside Ranger Unit
Marty Berbach, Forest Practice Program
Cathy Bleier, Fire and Resource Assessment Program
Clay Brandow, Fire and Resource Assessment Program
Pete Cafferata, Forest Practice Program
Joanne Cemo, Fire and Resource Assessment Program
Ron Childress, Lake Napa Ranger Unit
Dana Cole, Fire and Resource Assessment Program
Hugh Council, State Fire Marshal's Office
Dean Cromwell, Board of Forestry Staff
Pamela Duggan, Duggan and DeGraw, Editor
Helge Eng, Forest Practice Program
Loyd Forrest, Planning Consultant to the Board of Forestry
Dan Foster, Forest Management Program
Jerry Geissler, Tuolumne-Calaveras Ranger Unit
Gary Gilbert, Sierra Area Chief
Greg Greenwood, Fire and Resource Assessment Program
Russ Henly, Fire and Resource Assessment Program
Fran Henson, Board of Forestry Staff
Chuck Horel, Engineering/Technical Services
Carol Horn, Fire Protection - Cooperative Fire Protection
Robert Irby, Fire Protection - Fire Prevention Engineering
Robin Marose, Fire and Resource Assessment Program
Bob Martinez, Sierra-South Region
Ken Miller, Fire Protection - Cooperative Fire Protection
Rhonda Millwee, Fire Protection-Cooperative Fire Protection
Wayne Mitchell, Fire Protection-Operations Support and Research
Robert Motroni, Fire and Resource Assessment Program
Ken Nehoda, Forest Management Program
Steve Peterson, Lassen Modoc Ranger Unit
Tom Randolph, Forest Management Program
Don Rascon, Management Services
Donna Stadler, Board of Forestry Staff
Sharon Taylor, Board of Forestry Staff
Dennis Thompson, Kern County Fire Department
Rose Tilley, Management Services - Budget Office
Charlie Valenzuela, Kern County Fire Department
Bill Weaver, Fire Protection - Cooperative Fire Protection
Hank Weston, Nevada-Yuba-Placer Ranger Unit
Jack White, Cascade Area Chief
Jack Wiest, Fire Protection - Cooperative Fire Protection

This team deserves a big thank you from the Board of Forestry. Dedicated personnel (employees who all too often go nameless) keep the Department of Forestry and Fire Protection in the leadership role for wildland fire protection.

Robert Kerstiens, Chair
California Board of Forestry

California Board of Forestry Members

Robert J. Kerstiens, Chair

Bonnie Neely, Vice Chair

William E. Snyder

Nicole A. Clay

Robert C. Heald

Herbert E. Baldwin

Tharon O'Dell

Richard B. Rogers

Table of Contents

Charts and Tables

Executive Summary

The State Board of Forestry and the California Department of Forestry and Fire Protection (CDF) have drafted a comprehensive update of the fire plan for wildland fire protection in California. The planning process defines a level of service measurement, considers assets at risk, incorporates the cooperative interdependent relationships of wildland fire protection providers, provides for public stakeholder involvement, and creates a fiscal framework for policy analysis.

Goal and Objectives

The overall goal is to reduce total costs and losses from wildland fire in California by protecting assets at risk through focused prefire management prescriptions and increasing initial attack success.

Overall goal is to reduce total wildfire costs and losses.

The California Fire Plan has five strategic objectives:

- To create wildfire protection zones that reduce the risks to citizens and firefighters.
- To assess all wildlands, not just the state responsibility areas. Analyses will include all wildland fire service providers— federal, state, local government, and private. The analysis will identify high risk, high value areas, and develop information on and determine who is responsible, who is responding, and who is paying for wildland fire emergencies.
- To identify and analyze key policy issues and develop recommendations for changes in public policy. Analysis will include alternatives to reduce total costs and losses by increasing fire protection system effectiveness.
- To have a strong fiscal policy focus and monitor the wildland fire protection system in fiscal terms. This will include all public and private expenditures and economic losses.
- To translate the analyses into public policies.

Fire Plan Framework

Five major components will form the basis of an ongoing fire planning process to monitor and assess California's wildland fire environment.

Fire Plan key product is development of wildfire safety zones.

- **Wildfire protection zones.** A key product of this Fire Plan is the development of wildfire safety zones to reduce citizen and firefighter risks from future large wildfires.
- **Initial attack success.** The fire plan defines an assessment process for measuring the level of service provided by the fire protection system for wildland fire. This measure can be used to assess the department's ability to provide an equal level of protection to lands of similar type, as required by Public Resources Code 4130. This measurement is the percentage of fires that are successfully controlled before unacceptable costs are incurred. Knowledge of the level of service will help define the risk to wildfire damage faced by public and private assets in the wildlands.
- **Assets protected.** The plan will establish a methodology for defining assets protected and their degree of risk from wildfire. The assets addressed in the plan are citizen and firefighter safety, watersheds and water, timber, wildlife and habitat (including rare and endangered species), unique areas (scenic, cultural, and historic), recreation, range, structures, air quality. Stakeholders — national, state, local, and private agencies, interest groups, etc. — will be identified for each asset at risk. The assessment will define the areas where assets are at risk from wildfire, enabling fire service managers and stakeholders to set priorities for prefire management project work.
- **Prefire management.** This aspect focuses on system analysis methods that assess alternatives to protect assets from unacceptable risk of wildland fire damage. Projects include a combination of fuels reduction, ignition management, fire-safe engineering activities, and forest health to protect public and private assets. The priority for projects will be based on asset owners and other stakeholders' input and support. Prefire management prescriptions designed to protect these assets will also identify who benefits and who should share in the project costs.

Assess alternatives to protect assets from wildfire.

- **Fiscal framework.** The Board and CDF are developing a fiscal framework for assessing and monitoring annual and long-term changes in California's wildland fire protection systems. State, local, and federal wildland fire protection agencies, along with the private sector, have evolved into an interdependent system of prefire management and suppression forces. As a result, changes to budgeted levels of service of any of the entities directly affects the others and the services delivered to the public. Monitoring system changes through this fiscal framework will allow the Board and CDF to address public policy issues that maximize the efficiency of local, state, and federal firefighting resources.

These are Fire Plan framework applications:

- Identify for state, federal, and local officials and for the public those areas of concentrated assets and high risk.

- Allow CDF to create a more efficient fire protection system focused on meaningful solutions for identified problem areas.

- Give citizens an opportunity to identify public and private assets to design and carry out projects to protect those assets.

Focus on what public can do to reduce costs and losses.

- Identify, before fires start, where cost-effective prefire management investments can be made to reduce taxpayer costs and citizen losses from wildfire.
- Encourage an integrated intergovernmental approach to reducing costs and losses.
- Enable policy makers and the public to focus on what can be done to reduce future costs and losses from wildfires.

Chapter 1

Findings and Recommendations

The Board of Forestry's California Fire Plan findings and recommendations were developed by the Fire Plan working team. These findings and recommendations are summarized into three categories:

- Levels of Wildland Fire Protection Services
- Wildland Fire Protection Fiscal Issues
- Prefire Management to Reduce Wildfire Costs/Losses

Levels of Wildland Fire Protection Services

A primary Board of Forestry responsibility is set forth in Public Resources Code Section 4130, which directs the Board to classify all lands within state responsibility areas (SRA) based on cover, beneficial water uses, probable erosion damage and fire risks and hazards; to determine the intensity of protection to be given each type of wildland; and to prepare a fire plan to assure adequate statewide fire protection so that lands of each type be assigned the same intensity of protection. With the recent integration of the State Fire Marshal's office, the responsibility for the protection of structures included in Health and Safety Code Sections 13143, 17920.7, 17921, and 18930 is considered in the PRC 4130 evaluation.

Board of Forestry is responsible for preparing a Fire Plan to assure adequate statewide protection.

This California Fire Plan is the result. It is the Board's approach to assessing the level of wildland fire protection.

Findings

1. The history of California wildfires indicates that the following trends will continue.
   - Risk from wildfire to life, property, natural resources, and firefighter safety is increasing.

- Population will grow and more people will live and use wildland areas, especially in the Central Sierra and in the Southern California counties of Riverside, San Bernardino and San Diego.
- Topography and climate support ecosystems where large wildfires can be expected.
- Drought and fuel moisture conditions will be unpredictable but almost always dangerous in fire season.
- More structures will be constructed in areas that are very susceptible to wildfire.
- Historical legacy of narrow roads, difficult entrance, insufficient water supplies, flammable building construction and location that make many communities and homes wildfire-prone still exits.
- Public demand for wildland fire protection and other services will increase.

2. Deteriorating forest health, increasing fuel loads and other factors have led to more intense, destructive wildfires; unabated this pattern will continue.
3. Assets at risk will increase, especially watershed assets, because of the rapid rise in the demand for water to supply more people. Based on population projections, the potential for accelerating loss of protected assets, especially life and property, will be greater from disastrous wildfires.
4. Large wildfires do not respect political or property boundaries. Historically, a strength of California's firefighting agencies is found within a concept of mutual cooperation at the federal, state, and local levels of government. Day-to-day mutual aid for initial attack, as well as a statewide mutual-aid system for fire disasters, are the basis of this cooperation and coordination. The ability to rapidly mobilize, effectively deploy and support large numbers of specialized firefighting resources is essential to cope with large multiple fires. Hence, CDF, in cooperation with other fire agencies, must maintain infrastructure, including communications and capital improvements necessary to facilitate such a response.

Large wildfires do not respect political or property boundaries, thus cooperation among fire agencies is necessary. (Department of Forestry and Fire Protection photo)

5. Fire protection forces in California must have sufficient depth to respond to large, multiple wildfires and still prevent other small fires from becoming large damaging fires. CDF plays a key role in supplying and coordinating such forces; it should maintain and enhance this ability. The 1985 Fire Plan

includes a model to provide adequate depth of resources thatshow CDF needing 96 additional engines and 825 personnel for managing large fires using the Incident Command System. There is a greater need today as reflected in the California Fire Plan.

Recommendations

1. The Board of Forestry directs CDF to further develop and implement a new Fire Plan framework that includes:

CDF will implement a fire plan framework that includes LOS, assets, fire history and costs and losses.

- Level of service (LOS) initial attack success and major fire failure rates.
- Identification and assessment of assets protected, covering both commodity (economic) and non-commodity assets.
- History of wildfires by intensity levels, size and vegetation types. Identification and rankings of high-value/high-risk wildland areas for use by local, state, and federal agencies and the private sector for allocating prefire management and suppression resources.
- Severe fire weather rankings to relate probability that large damaging fires will occur by local area.
- History and projections of changes in total costs and losses of California's wildland fire protection system that can result from potential increases or decreases in local, state, and federal agency expenditures and private-sector investments.

2. CDF should identify options to expand its suppression force to meet the multiple, large fire scenario (such as the 1985 Fire Plan's proposal to retain, in a reserve fleet, 96 engines that were being replaced) and determine a cost-effective way to staff these engines with trained personnel in severe fire weather in targeted areas identified in the California Fire Plan assessment framework. The number of reserve engines should be increased to 100 for the California Fire Plan. This allotment would:

Create reserve fire engine fleet for multiple fire responsibility.

- Allow better management of SRA fires by minimizing CDF's dependence on the reduced federal agencies resources.
- Keep cost under control because of reduced ordering through the Office of Emergency Services, thereby better controlling emergency fund expenditures.
- Help limit the need to exceed maximum drawdown when there are large multiple fires, as now occurs.

3. CDF should assess and report back to the Board annually on what can be done during the next five years to reduce the impact in numbers and damage of large, disastrous fires in California annually.
4. CDF should use the new fire plan assessment framework at the ranger units and for creating local forums to obtain expertise and other input from citizens, community groups, local agencies and other stakeholders on assets protected. The questions of wildland resource assets and structure protection can be better addressed at the ranger unit community levels, in terms of level of service, benefits and financial responsibilities.

Create local stakeholder forums to improve fire protection.

5. The new fire plan assessment framework also should be applied to federal wildlands. The Board of Forestry has assigned its Resource Protection Committee to work with federal agencies that are primary participants in California's wildland fire protection system. The focus would be the complementary relationships of changes in federal agencies' budgets and policies that could affect California's total costs and losses from wildfires on federal, state, and local responsibility lands. Agencies, such as the USDA Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, US Fish and Wildlife Service, Environmental Protection Agency and Federal Emergency Management Agency should be invited to participate.

Wildland Fire Protection Fiscal Issues

Findings

1. Multi-year fiscal problems are occurring at all governmental levels, constraining the availability of funding to address the increasing workload, costs and losses of the Californiawildland fire protection system.
2. The increasing number of structures and people in California wildlands and the growing importance of the state's natural resources create a growing demand to fund additional wildland fire protection services for both the structures and the wildland resource assets.
3. The primary fiscal responsibilities for the initial attack responsibilities: (1) for federal wildland fire protection are the federal taxpayers, (2) for privately owned wildland fire protection are the state taxpayers, and (3) for structure fire protection in wildland areas are the local taxpayers. However, during the annual fire season, the state and federal taxpayers provide a minimum level of structural fire protection that is incidental to their primary missions of wildland fire protection. Similarly, in most wildland areas, local taxpayers provide year-round wildland fire protection on both state and federal responsibility areas that is incidental to the local government primary mission of structural fire protection.
4. Over the last decade, part of the increased costs for additional initial attack wildland resource protection and structural protection have been funded by local taxpayers through property taxes, fire district fees and volunteer firefighters. However, when a wildland fire overwhelms local resources and reaches a major fire status, both the state and the federal taxpayers pay for the costs of wildfires, structure protection, and the resulting disaster relief.

When wildfire overwhelms local forces, both state and federal taxpayers pay for resulting costs and losses.

5. For the local taxpayers, the following continue to increase: (1) the structural values and number of people being protected on wildlands, (2) the costs of wildland and structure initial attack fire suppression funded at the local levels, and (3) the losses from the extended attack and larger fires.

6. For state and federal taxpayers, the following will continue to increase: (1) extended and large fire emergency fund expenditures for wildland fires, (2) protecting structures during initial attack and extended attack fires, and (3) state and federal agency disaster expenditures for damages to wildland resources and structures.
7. Health and Safety Code Section 13009 allows for recovery of fire suppression costs which, when obtained, be placed back into the state's general fund rather than invested in a prefire management program.

Prefire management investments can reduce emergency fund costs.

8. There is a direct relationship between reduced expenditures for prefire management and suppression and increased emergency fund expenditures, disaster funding, and private taxpayers expenditures and losses. Reduction of prefire management or suppression resources allows more fires to become major disastrous fires. Major fires create additional suppression and disaster relief costs at all levels of government and increase citizen and business losses.
9. According to representatives of the insurance industry that insures structures in California wildland areas, (1) the insurer average costs and losses are about $1.09 for each $1.00 received in premiums, and (2) the urban dwellers are subsidizing the wildland homeowner through service-wide rating schedules.

Recommendations

1. To better evaluate future public policy changes, CDF should annually refine and update its comprehensive wildland fire protection fiscal framework to allow a more systematic assessment of the future costs and losses to California taxpayers. This fiscal framework should continue to include summaries of annual expenditures by local, state, and federal agencies; economic losses of the state's resources; and private-sector costs and losses.
2. To reduce the future total costs and losses to California taxpayers, the following actions and ideas should be considered to support a major new state prefire management initiative

To reduce costs and losses, expansion of the prefire management program should be considered.

   - Continue to implement the new CDF prefire initiative and the new Fire Plan assessment framework by September 1998.
   - Redirect fire cost recovery money from the General Fund to support an investment in reducing wildland fire hazards.
   - Provide a tax credit, as part of the governor's proposed tax-cut program, for private taxpayer investments in reducing wildland fire hazards in areas that have been identified under this fire plan framework that will reduce the state taxpayer's future suppression costs.

The Board and CDF will work with insurance industry to reduce taxpayer and citizen losses.

3. Get the insurance industry to develop an approach to reduce taxpayer and insurance underwriting losses.
4. Ensure a major federal prefire management initiative on federal wildlands in California. The purpose is to reduce total federal

taxpayer costs for wildland fire protection.

Prefire Management Program to Reduce Wildfire Costs and Losses

Findings

1. Suppression of fire in California's Mediterranean climate has significantly altered the ecosystem and increased losses from major fires and fire protection costs. Historical fire suppression has increased
   - periods between fires
   - volumes of fuel per acre
   - fire intensities
   - fire damage and losses
   - fire suppression difficulties, and
   - total taxpayer costs and losses.
2. With continued fire suppression in wildland areas, fuel volumes per acre will continue to increase, unless a substantial long-term program of fuel reduction is implemented.
3. Fuel loading problems are occurring on federal and state responsibility areas, as well as in wildlands within city limits, which are local responsibility areas.
4. Similarly, California's eight straight years of drought increased the dead and dying vegetation, the volumes of drier fuel per acre, and the acres with vegetation fuel ladders, all of which contribute to increased size and severity of fires resulting in greater costs and losses.
5. To address the long-term trends of fuel loading increases and population growth, CDF is implementing a prefire management initiative is needed that combines the existing vegetation management, fire prevention and engineering programs into a coordinated effort with the objectives of reducing fire hazards, improving the effectiveness of ignition management, and reducing losses and costs to California's Wildland Fire Protection System.

   A prefire management initiative is being implemented.
6. Prefire management can serve as a tool to reduce the overall emissions caused by wildland fires. Based on the annual average acres burned by wildfire from 1985-1994, wildfire is causing the emission of almost 600,000 tons of air pollutants per year.

   Wildfires cause an estimated 600,000 tons of air pollutants annually.
7. There are tradeoffs between taxpayer investments in prefire management and the related state and federal emergency fund (fire disaster) expenditures, ecological and natural resource losses, private citizen losses, and safety problems for civilians and firefighters during wildland fires.

8. With continued population-driven increases of people and structures in the wildlands, there are more life and property assets at risk in wildland areas, and increasing risks to ecological, economic and natural resource assets. This increases the values of wildland homes and other structures, as well as the number of wildland fires caused by people.
9. To reduce the wildland fire protection costs to taxpayers, development of wildfire protection zones and fire hazard mitigation measures (including ignition-resistant building standards) are needed as part of the local government planning and land-use decisions on permitting developments in wildland areas within incorporated cities and unincorporated areas.
10. A prefire management database is needed to provide more definitive risk assessment information to the public and the insurance industry, code officials, building industry and local fire jurisdictions. The objectives are to establish comprehensive minimums for wildfire protection zones, develop ignition-resistant building construction for improved reduction of fire hazards around wildland structures, and provide insurers and homeowners with information on reducing risks and support more equitable insurance rating for wildland structures.
11. The public doesn't sufficiently understand the risks and impacts of wildfires on natural resource assets, structures and people living and recreating in California wildlands. Agencies have not adequately communicated those risks. There is a false sense of security among wildland homeowners that they are not at risk if there are fire protection organizations, insurance policies for fire coverage, and the minimum fire prevention prescriptions are met.

Recommendations

CDF should develop a prefire management program for state responsibility areas and provide technical assistance to help local governments develop prefire management programs on local responsibility areas. The Board will encourage federal agencies to increase their funding for efforts on their lands and joint efforts in the wildland intermix.

In California's Mediterranean climate, the question is when, not if accumulated fuels will burn. (California Department of Forestry and Fire Protection photo)

1. CDF will develop prefire management data that will:
   - Support state, local and federal agencies' efforts to implement a coordinated prefire management program on California wildlands.
   - Provide the insurance industry with better fire hazard risk assessment data for underwriting,

rating and pricing fire protection policies in wildland areas. These are incentives to homeowners to invest in fire hazard reduction efforts.

2. To increase the market alternatives for using biomass materials removed from wildlands and to reduce future dependence on prescribed fire and vegetation management burns, CDF, in conjunction with other state agencies, should develop an assessment of future biomass marketing opportunities for California. It should include projections of potential market uses and actions local, state and federal governments could take to expand those markets.

3. The fire prevention education programs of local, state and federal agencies and private industry should be communicating the level of risk to the people who live in wildland areas. An evaluation should be made to determine the correct message to influence people to modify their behavior. That message should incorporate the standards for both vegetation management and ignition resistant building construction, as well as what citizens and businesses can do to reduce wildfire risks.

Fire prevention education programs should communicate levels of risk to people living in wildlands.

4. The Board of Forestry supports examining legislation that would condition state disaster relief on the development and implementation of prefire management programs on wildlands. The Board recommends that federal disaster relief be similarly conditioned.

5. To provide state funding for prefire management projects, legislation should be sponsored to provide that fire cost recovery funds collected by CDF be returned to CDF's budget for implementing the projects, as a means of reducing wildfire costs and losses.

6. Legislation should be sought to authorize local government to create special service districts for prefire management projects. CDF will prepare recommendations as part of its in-depth plan.

7. To remove a major obstacle to increased vegetation management burns, with their potential for reducing wildfire costs and losses, liability limits should be examined for conducting such burns in high-risk/high-value wildlands. The state's worker compensation program may be a model for needed changes.

8. Given the potential for prefire management to reduce the total level of air pollutant emissions from wildfire, the state, federal, and local wildfire protection and air quality agencies should jointly develop policies for reducing air pollutant emissions from California wildfires.

Chapter 2

Fiscal Framework

The Board of Forestry launched an assessment to determine wildfire costs and losses, all of which are paid for by California's citizens. The Board is incorporating its recommended solutions in its California Fire Plan, which is a policy document for guiding the California Department of Forestry and Fire Protection wildfire programs.

The plan includes a new fiscal framework for assessing and monitoring California's wildfire protection systems, and focuses on annual and long-term changes in wildfire costs and losses.

The California Fire Plan objective is to reduce total costs and losses from wildfire in California.

The new fiscal framework will allow state policy makers to systematically identify and assess the changes that affect the state taxpayers in terms of costs and losses. This new fiscal framework will also be used to monitor effects of new prefire management initiatives.

The California Fire Plan objective is to reduce *total* costs and losses from wildfire in California. In an era of shrinking public revenues, the increasing wildfire problem is creating new challenges for agencies to cooperatively make better use of their available resources. Wildland fire protection agencies are being asked to reduce the costs and losses from wildfires by taking initiatives to reduce the size, severity and damage from the large wildfires that occur in California annually. This requires allocating some resources to this objective and additional front-end investments to reduce the future total costs and losses to California citizens.

The state, local and federal wildfire protection agencies, along with the private sector, have evolved an interdependent system of prefire management and suppression forces. As a result, changes in budgeted levels of any of the entities directly affects the levels of wildfire protection services delivered to the public.

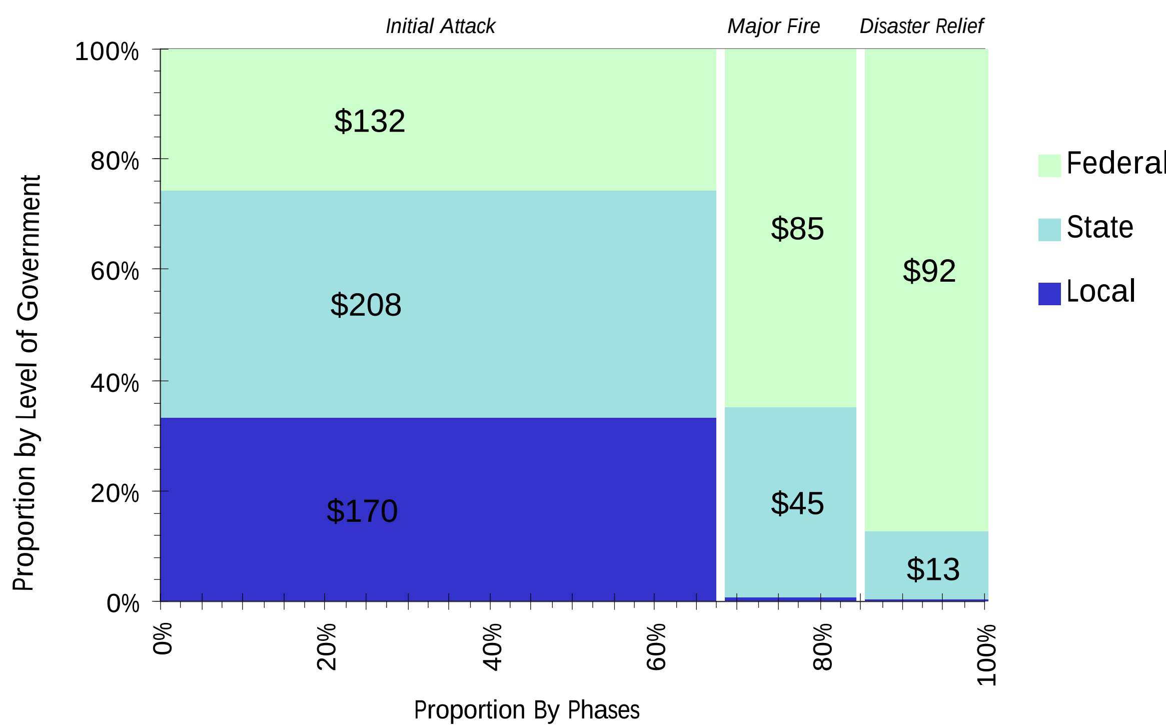
For example, the USDA Forest Service (USFS) recently made policy changes on the management of its emergency firefighting funds, reduced its initial attack fire suppression budget, and reduced budgets for other resource management programs. To deal with these changes, it proposes to cut engine staffing from five firefighters to three and to staff the engines five days a week instead of seven. Staff reductions in resource management programs mean fewer trained employees will be available for management positions on large fires. These cuts equate to a potential 20-50 percent reduction from the USDA Forest Service's 1994-95 suppression capability for California.

The suppression force available to fight large disastrous wildfires on public or private lands is significantly decreased. As a result, unless state and local governments or the private sector then increase their suppression forces, the level of wildland protection service delivered to the public is decreased. And more small fires will become large disastrous fires, thereby increasing the total taxpayer costs and citizen losses at all levels of government.

To assess the future success of CDF along with existing and potential changes in policies and fiscal allocations, the state must also periodically reexamine its relationship with the other sectors that make up the interrelated California wildland fire protection system. The relationship among the three government sectors can be assessed by addressing three questions concerning responses by each sector to California wildland fires:

- Who is responding to reported wildfires? Federal, state or local agencies?
- Who is responsible fiscally for the responses?
- Who is paying for the responses?

Chart 1. Wildland Fire Protection Agency Budgets



Traditionally, the state, federal and local fire protection agencies have evolved with the following program objectives:

- State Department of Forestry and Fire Protection — responsible primarily for protecting private or state-owned wildlands that have natural resource values as designated in the Public Resources Code, and for protecting certain state buildings.
- State Department of Forestry and Fire Protectionthrough the State Fire Marshal — responsible for developing minimum building standards that apply at both the state and local levels for all occupancies designated in the building and fire codes.
- Federal agencies, such as the USDA Forest Service, Bureau of Land Management, National Park Service and the Bureau of Indian Affairs — responsible primarily for wildland fire protection of federally owned wildlands.
- Local government fire districts (city and county fire departments) — responsible primarily for protection of homes and other structures in wildlands.

Most of the previous public policy discussion of state, federal and local roles have cited these primary responsibilities for making the initial attack responses when a fire is reported in a wildland area.

However, that kind of discussion is incomplete.*Chart 1, Wildland Fire Protection Agency Budgets,* on page 18 summarizes the estimated 1993-94 state, federal and local governments' costs of California's wildland fire protection system. The chart further identifies wildland fire protection phases — initial attack, major fires and disaster relief — for each level of government.

In the second and third stages, roles and responsibilities get blurred in terms of who is responding, whose responsibility is it and who is paying. Historically, disaster relief is provided by the state to local government when local firefighting resources are overwhelmed. Similarly, federal relief is provided to state and local government when those resources are overwhelmed.

During fire disasters, state and federal agencies protect homes and people as well as natural resources.

When a wildfire escapes the initial attack stage and reaches disaster status as a major damaging and costly wildfire, available state, federal and local resources are dispatched to contain the fire and provide disaster relief without differentiating among the primary initial attack roles. The firefighters make no distinction as to whether they are primarily protecting federal wildlands, state wildlands or structures; they protect whatever is in the way of the fire.

The Agency Budgets chart reflects the fiscal results of that approach. It identifies that annually, significant expenditures are made:

- By the state, federal and local governments to provide initial attack responses to wildland fires.

- By state and federal governments to fight wildland fires on private, federal and state-owned lands.
- By state and federal governments to provide disaster relief resulting from major wildland fires.

The chart shows that state, federal and local agencies spent an estimated $921 million on California wildfires in 1993-94. About $172 million of it was spent by 462 locally funded fire departments responding to wildland fires that are the primary responsibilities of the state and federal governments. The local agencies' responses were incidental to their primary initial attack responsibility for structures. In summary, local fire departments' expenditures for wildland fire initial attack responses were approximately 9percent of their total budget for structure fire protection; but cumulatively, the expenditures are significant statewide. The expenditures are significant locally funded expenditures for what is primarily a state (and occasionally a federal) responsibility.

Although data is not yet available, a significant effort is also expended by state (and to some extent the federal) agencies responding to protect structures in wildland areas during the initial attack phase. There are three primary reasons for state, federal and local agencies responding to their counterparts responsibilities, be it structure or wildland resources:

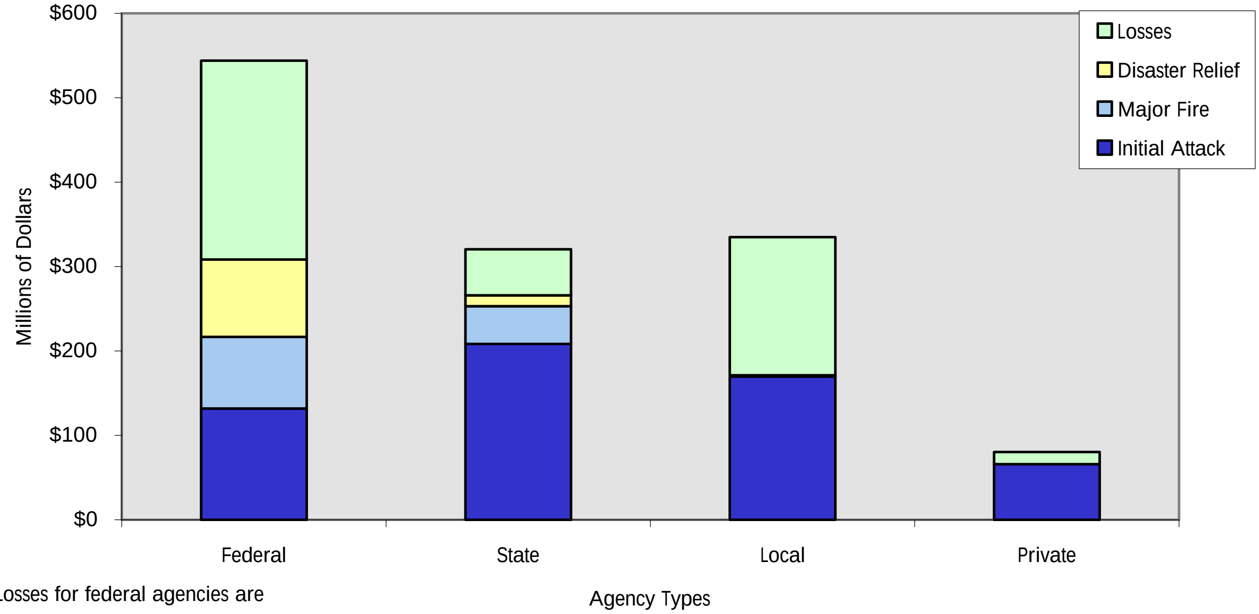
- Under a mutual-aid approach that reduces response times to all fires, whichever firefighting unit is closer responds to the fire.
- When natural resources, structures or people are threatened by wildfire, the public doesn't care whether the nearest firefighting unit is funded from their local, state or federal tax dollars. They expect the units to respond as quickly as possible.

The public doesn't care whether the nearest firefighting unit is funded from their local, state or federal tax dollars. They expect the units to respond as quickly as possible.

- A fire starting on private or federal wildlands, or in a structure on wildlands, if not quickly contained can threaten the other two resources, creating state, federal or local firefighting costs and losses.

To assess and monitor the total annual costs and losses from California's wildland fires, the annual costs of federal, state and local government agencies reflected in Agency Expenditure Chart are added to the annual losses and private sector costs. *Chart 2, California Wildland Estimated Suppression Costs and Losses,* reflects the total costs and losses from California wildland fires reflected in 1993-94 FY dollars. For losses, a 10-year history was used to derive average annual wildfire losses. Both the Agency Budgets chart and the total estimated Costs and Losses provide a fiscal framework that can be used by the state as well as the federal and local decision makers to identify and monitor trends among the sectors responsible for the total California's wildland fire protection system.

Chart 2. California Wildland Estimated Suppression Costs and Losses



Losses for federal agencies are estimates only due to insufficient data.

Chapter 3

Fire Plan Framework

Legislative Mandate

The Public Resources Code requires the Board of Forestry to develop a fire plan for the state responsibility wildlands that assures equal protection to lands of similar types. The California Fire Plan includes a new framework for a systematic assessment of the existing levels of wildland protection services, identifies high-risk and high-value areas that are potential locations for costly and disastrous wildfires, ranks the areas in terms of priority needs, and prescribes what can be done to reduce the future costs and losses.

The Board and CDF developed the new fire plan assessment framework that will identify where it is most cost effective to increase the level of wildland fire protection services to significantly decrease future wildfire costs and losses in those high-risk/high-value areas. CDF is implementing the new system in three pilot ranger units: Nevada-Yuba-Placer, Tuolumne-Calaveras and Riverside. In addition, CDF has made a budget change proposal (BCP) to expand the program to all 22 ranger units and six contract counties using this schedule:

Time Period	Task
November 1995—February 1996	Draft a regional vegetation zone map for the state. Design associated matrixes for setting up the LOS framework for the regional zone. Develop data sets, prepare prototype software systems, assemble products to take to the first test ranger units.
January—March 1996	Validate data sets, process and procedures in the first test ranger unit. Refine, revise and update CFES-IAM inputs as needed. Revise procedures as needed in preparation for going to the next two test units.
March—June 1996	Validate data sets, process and procedures in the next two test ranger units. Revise as needed in preparation for going to the remainder of the ranger units and contract counties.
June 1997	Produce state level of service map

Fire Plan Assessment System

This new California Fire Plan assessment system is reflected in *Chart 3, Fire Plan Assessment System* and described below.

Level Of Wildland Protection Services (LOS): The LOS rating (see *Chart 4, Level Of Service*) is a ratio of successful fire suppression efforts to the total fire workload, a method to measure initial attack success and failure rates throughout California wildlands.

The LOS rating is a new fire plan assessment system.

The LOS uses a Geographic Information System (GIS) that overlays a 10-year history of wildfires onto a vegetation type map and derives the average annual number of fires by size, severity of burning and assets lost. This data allows a LOS Success (and Failure) Rate calculation:

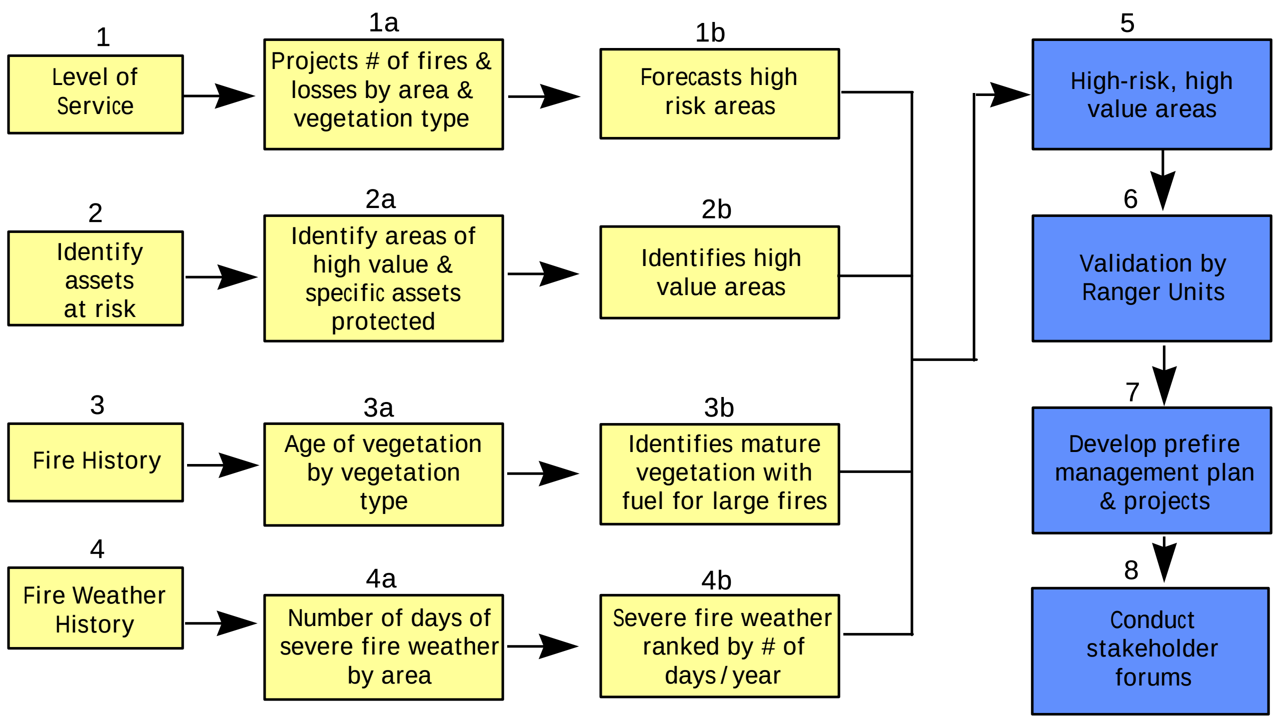
$$\text{SUCCESS RATE} = \frac{\text{annual number of fires that were small and extinguished by initial attack}}{\text{total number of fires}}$$

SUCCESS RATE = X percent

This results in an initial attack success rate in percentage of fires by vegetation type and by area. Similar areas can be compared locally, regionally or statewide using the GIS database.

Using the GIS databases, each wildland area of a community, ranger unit, region or statewide, can be ranked by age and type of vegetation to identify high-volume fuel areas that have accumulations of dead fuel with the potential for large *conflagrations*. Areas can be ranked by high, medium or low risk of potential as sites of large damaging *conflagrations*.

Chart 3. Fire Plan Assessment System

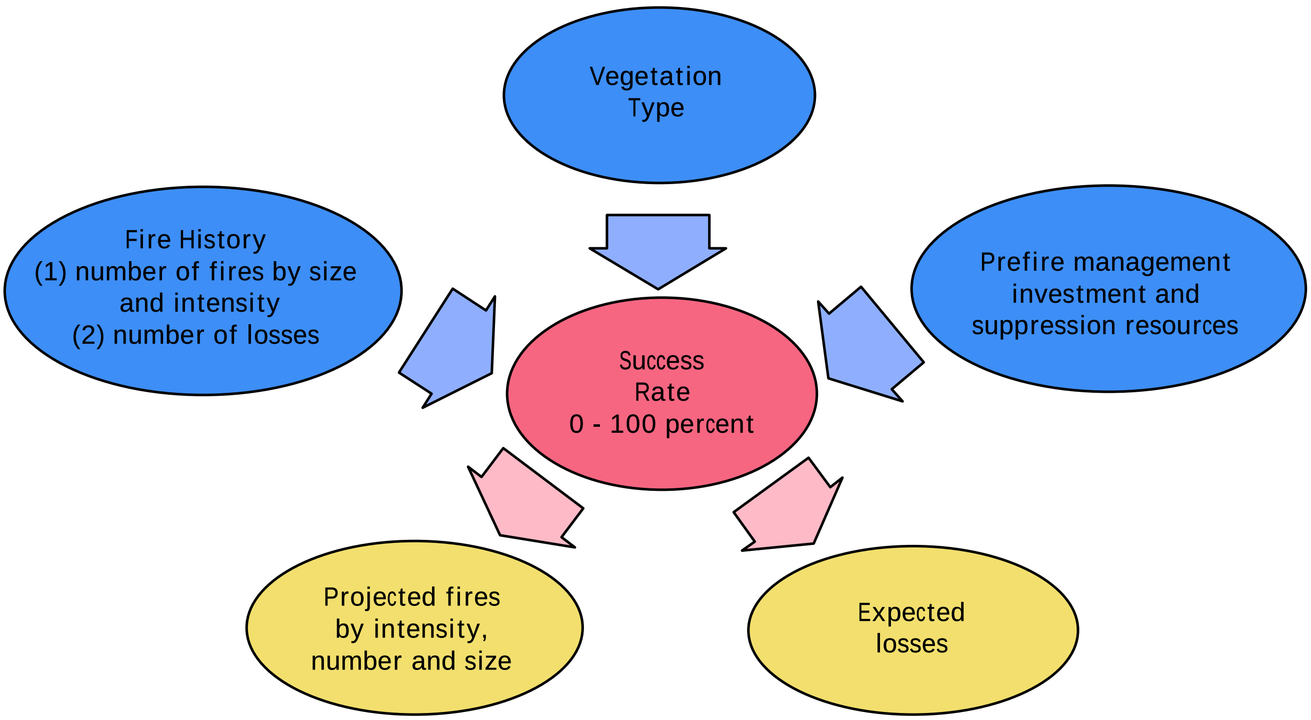


Assets at Risk: The assets at risk are the public and private assets that the wildland fire protection system is created and funded to protect. This framework identifies the following assets at risk from wildfires and delineates their economic and non-economic assets: timber, watershed, wildlife, unique scenic and recreation areas, range, wildlife, air quality, structures and people.

Assets are what the system protects.

- Using the GIS data, overlays of each asset are made on geographic maps of the state. This provides areas of individual and collective assets that are identified by community, ownership and protection responsibility.
- For each asset, relative rankings of high, medium and low values are made geographically.

Chart 4. Level of Service



Fire History: The GIS is used to overlay fire history data by vegetation type.

Fire history defines vegetation maturity.

- The fire history overlay results in identifying the age classes of vegetation and their related maturity stage. Each vegetation type has different maturity stages in terms of the volume of fuel per acre — as it progresses from green, high-moisture vegetation to a higher percentage of dead and dying vegetation with low moisture — and different stages in the development of fuel ladders to carry fires to the tops of trees.
- With the above data on vegetation age and maturity, the areas that have the potential for severe fires can be identified by vegetation type and geographical area.

Fire Weather History: The fire weather history is plotted on GIS maps.

- The fire weather history, in terms of average number of days of severe fire weather, is plotted and mapped by geographic area.

Fire weather history identifies severe fire weather days.

- Geographic areas are ranked by the average number of days of severe fire weather during peak fire season. This allows the identification of the higher risk areas in terms of probability of fires occurring during periods of severe fire weather.

Identify High-Risk/High-Value Areas: Based upon the analyses and the GIS databases described above, a ranger unit map is generated that identifies high-risk/high-value areas where large damaging wildfires are most likely to occur and become high-cost and high-loss conflagrations. These can be ranked from highest to lowest priorities for future resource allocations decisions.

Validate High-Risk/High-Value Areas by the ranger units: Most of the data used to generate the high-risk/high-value maps were developed from GIS overlays of databases for areas within ranger units. Much of this data needs to be validated on the ground by ranger unit personnel to assure that the high-risk/high-value and most likely to burn areas are properly mapped. Based upon this field review of the areas, modifications and corrections are input to the central GIS databases and revised maps are generated for use by the ranger unit and headquarters personnel in developing prefire management projects.

Prefire management projects decrease risks of high losses and suppression costs.

Identify Prefire Management Projects: The prefire management staff at the ranger units then develop a prefire management plan for the ranger unit. The prefire management plan includes specific projects for the high-risk/high-value areas that will *decrease the risks that a large fire in a specific area will occur, and create high costs to contain and high losses to the citizens*. The assumption used in developing the prefire management ranger unit plan is that a proposed prefire management project will reduce the costs and losses during periods of severe fire weather, which is when most of California's wildfire costs and losses occur. Thus, if a prefire management project is implemented, then the size and severity of a large fire burning in that specific high-risk/high-value area would be contained at a smaller size, would burn with lower temperatures and severity, would significantly reduce suppression costs and would result in significantly lower levels of losses.

Conduct Stakeholder Forums: The purpose is to acquaint stakeholders with the process; bring their expertise and knowledge to bear on the asset maps, which also identify areas of high, medium and low risk; to review the level of service in these locations, and to identify areas where the stakeholders consider the level unacceptable.

Stakeholders help set priorities on prefire management projects.

Ranger unit personnel will take the results of the above analyses into public forums with the following stakeholders:

- State, local and federal agencies with responsibilities for wildland protection in a specific area of the ranger unit, including USDA Forest Service, Bureau of Land Management, National Park Service; fire districts, county fire departments and other fire service cooperating agencies; local planning departments and county supervisors responsible for land-use planning.

- State, local and federal agencies with responsibilities for wildland assets at risk.
- Private and non-profit stakeholders that are concerned with the economic and non-economic assets being protected in a specific community within a ranger unit.
- People living in these wildland areas.


Input from the public is a critical part of the Fire Plan process. (Photo by Rob Allingham, Department of Water Resources)

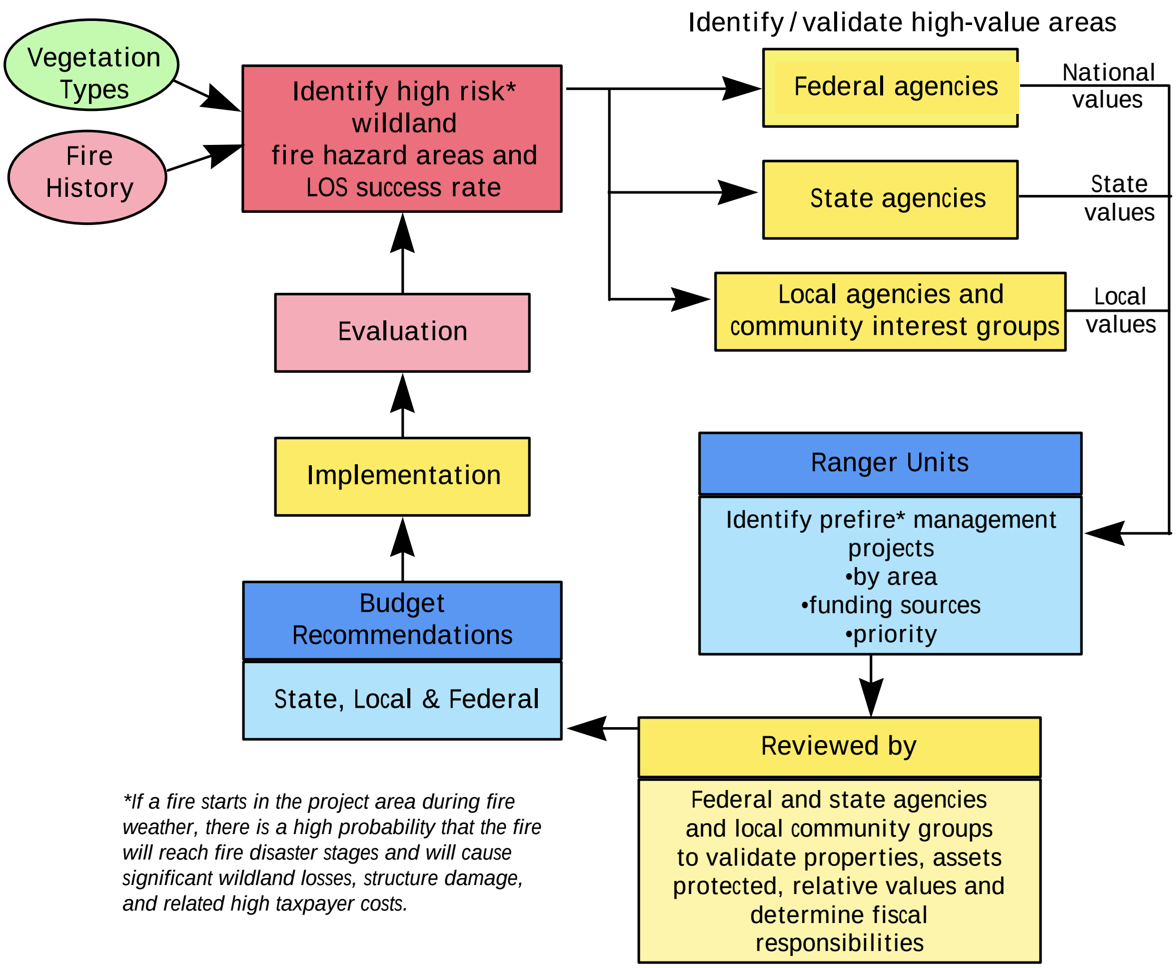
CDF will take the following information into these series of meetings:

- What can be done by the community to develop wildfire protection zones.
- The existing LOS for the specific community area in terms of historical numbers, size and severity of previous fires and those projected to occur with no changes in the LOS. This reflects the future success rates for preventing large disastrous fires.
- Identification of the high-risk/high-value maps, showing areas within the community, where large disastrous fires are likely to occur. The specific assets being protected and designated as high value areas within the community will also be delineated on the maps.
- Identification of the high-risk/high-value areas in the community with a ranking of the probability of fires occurring in severe fire weather.
- Prefire management plans with specific projects for reducing the risks and potential damage and suppression costs from disastrous fires.
- Identification of which assets are driving the need for prefire management projects and who is fiscally responsible for the assets at risk.

As reflected in *Chart 5, Wildland Fire Protection System*, the goal of this new framework approach is to identify for state, federal and local public officials and the public, those areas within the state responsibility areas that are high-priority areas in terms ofassets at risk, and with a high probability of large wildfires with associated costs and losses. This will allow the public and government decision-makers to focus on what can be done to develop wildfire protection zones and reduce future costs and losses in these areas. An important aspect of this new framework is that prefire management programs aimed ateducing wildfire risks to citizens and firefighters, andminimizing costs and losses be considered and compared for evaluating existing programs and alternatives for reducing costs and losses from large disastrous wildfires in California.

The goal is to identify high risk areas with a high probability that large fires will occur.

Chart 5. Wildland Fire Protection System



*If a fire starts in the project area during fire weather, there is a high probability that the fire will reach fire disaster stages and will cause significant wildland losses, structure damage, and related high taxpayer costs.

Chapter 4

Assets at Risk

Introduction

The primary purpose of wildland fire protection in California is to protect the wide range of assets found on California wildlands. These assets include life and safety; timber; range; recreation; water and watershed; plants; air quality; cultural and historic resources; unique scenic areas; buildings; and wildlife, plants, and ecosystem health. This section briefly describes these assets and discusses approaches to assessing their economic and non-economic values.

Knowledge of the types and magnitudes of assets at risk to wildfire, as well as their locations, is critical to fire protection planning. Given the limits on fire protection resources, these resources should be allocated, at least in part, based on the value of the assets at risk.

This analysis addresses two basic questions: What are the aggregate values of the assets at risk to wildfire? What are the losses, both economic and non-economic, in a fire? Where possible, estimates of values were made on a dollar-per-acre basis. The methodologies used, although exposed to some peer review, need further review and refinement that is part of the pilot projects in the three ranger units. Also, CDF is working with the Department of Fish and Game, State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co. and the East Bay Municipal Utility District and other stakeholders to refine our approaches to wildlife, plants, ecosystem health, watersheds and water.

The fire plan assessment framework will use three key techniques to relate each asset being protected to existing and potential levels of service and resource allocation priorities.

There are three key techniques for assets at risk: GIS maps, community meetings to validate assets and joint CDF/stakeholder funding.

- As reflected in the prefire management process descriptions in the appendix, CDF headquarters staff has developed GIS maps on assets at risk. From this data, CDF will produce ranger unit maps with overlays for each commodity and non-commodity asset protected. Each asset map will indicate whether the preliminary value of the asset in a given area is high, medium or low. These maps will be reviewed and refined at the ranger unit level.

- Separate community level meetings will be scheduled with the respective stakeholders for each asset at risk. The purpose is to acquaint the stakeholders with the process and to bring their expertise and knowledge to bear on the asset maps. In effect the stakeholders will be asked to evaluate the preliminary rankings for levels of service based on economic and non-economic values. This process provides a sort of Delphi technique of using expert and asset owner judgments where quantifiable data is not available
- CDF also will engage stakeholders in a process to identify who is willing to invest prefire projects that will protect the various assets. CDF's major reason for conducting prefire management projects is to reduce state suppression costs and disaster relief. Thus, CDF will allocate its state prefire project funds primarily on the basis of projects' potentials to reduce the suppression and state disaster funding costs that would occur in the project area under high-hazard fire conditions. However, where stakeholders are willing to provide funds to support prefire projects that would reduce the threat to assets at risk, CDF will consider undertaking such projects, even if the benefits in terms of reducing potential state suppression and disaster relief costs are less than might be achieved by other prefire projects competing for state prefire project funds.

Assets may be of value locally, statewide or nationally.

Detailed explanation of the quantification and valuation approaches for each asset may be found in the appendix. The table, *Assets at Risk Framework Summary*, at the end of this chapter depicts the framework developed for estimating fire impacts. Resource assets presented here are air quality, range, recreation on public wildlands, structures, timber, water and watersheds, cultural and historic resources, unique scenic areas, and wildlife, plants and ecosystem health. No attempt was made to place economic value on the loss of human life or unique scenic areas, although there are methodologies for estimating such values. Their true value to society cannot be measured.

For each resource, the assets at risk framework summarizes the asset value basis (i.e., the units in which fire impacts have been estimated) and the level of disaggregation (resource subtype and geographic area) of these values. The table also indicates the levels (local, state and national) at which the resources are valued. The manner in which "consumers" of a particular resource value it may differ from local to state to national levels. Some of the resources protected from fire in California even have international value. For example, the scenic Lake Tahoe Basin or the old growth redwood parks of the North Coast are considered of high value at the local, state and federal levels, as well as internationally.

The Lake Tahoe Basin, one of the state's most beloved natural resource assets, is facing extreme fire risks. (Photo courtesy of Department of Water Resources)

The rest of this section briefly discusses each asset at risk. (The appendix provides more detail.) It should be emphasized that calculations of economic assets are preliminary and often highly aggregated. The estimates will be refined as fire plan implementation moves to the ranger units

Air Quality

Air pollution from wildfires can affect, among other assets, visibility, human health, materials, vegetation, pollution rights and greenhouse gas accumulation. Quantifying impacts is difficult. First,there is insufficient data on the quantities of various pollutants that are emitted during wildfires of varying intensities burning in a wide range of fuels. Second, models of pollutant dispersion, though increasingly sophisticated, still leave much to be desired, particularly when trying to apply them to specific events rather than to longer-term emissions. Third, models estimating the impacts of various pollutant levels on human health have generally been geared toward examining chronic pollution levels, not episodic events such as wildfires. This area of empirical research has been almost ignored by the air quality agencies in California. There is an assumption that wildfires are "acts of God" and not manageable by man. However, this assumption is not true. As reflected in this fire plan framework, future wildfires are predicted and their losses, including levels of air pollutants can be managed before the fire occurs.

The estimated annual wildfire air pollutant emissions are 600,000 tons from CDF and USDA Forest Service fires.

As reflected in Appendix C, Table 3, the estimated annual wildfire air pollutant emissions are 600,000 tons from CDF and USDA Forest Service fires. This does not include Bureau of Land Management, Bureau of Indian Affairs, National Park Service or wildlands inside city limits fires. The estimated 600,000 tons of air pollutants annually are based on a ten year average of acreage burned by vegetation type annually. A joint initiative is needed between the Board of Forestry and the Air Resources Board to reduce air emission pollutants from wildfire. Estimates of air quality wildfire impacts have been developed for particulate matter, specifically PM10 (particulates 10 microns or smaller). Using economic impact models developed for the California Energy Commission combined with basic fuels and emissions models, dollar-per-acre estimates for air quality impacts were developed for 13 of the state's 14 air basins. For some basins, where industries can buy and sell rights to emit PM10 pollution, the value of these rights is also included. It should be noted that the Energy Commission models are not widely accepted. The wildfire air quality impact values estimated range from $1 per acre to $15,000 per acre burned, depending upon the fuel type and the air basin. While these estimates include some measure of all of the above air quality related values, there are additional non-commodity values that are not well represented (for example, air quality impacts to areas of unique scenic quality).

The overall strength of the methodology used to develop these estimates is uncertain. The base air pollution impact model used is not widely accepted. Further, estimates of pollutants released from the open burning of given fuel types and loadings are not well researched and are highly generalized. This is an area needing more research by the local, state, and federal air quality and wildfire protection agencies.

Range

Range is primarily vegetation as forage, estimated to be worth $138 million a year in California. The value of forage lost to fire is based on the cost of replacing that forage for two years through feeding oat hay or alfalfa to the livestock. It was assumed that the probability of an acre of rangeland burning is the same whether it is grazed or not. Ungrazed acres were assumed to have a zero replacement feeding cost. To calculate an average loss per acre burned, averages were developed of replacement feeding costs per acre by type of grazed rangeland as a percentage of all grazed and ungrazed acres.

Rangeland types and associated replacement feeding costs were disaggregated to eight regions, nine cover types and five ownership classes, allowing a fairly detailed analysis of fire impacts. At the fully disaggregated level, replacement feeding cost estimates ranged from zero to $114 per acre of rangeland burned. The weighted average cost statewide is estimated at $8 per acre.

Recreation on Public Wildlands

Fire adversely affects recreation values on public and private land alike; however, the lack of data regarding recreation on private lands allows estimates only for public lands. The bulk of recreation on public wildlands occurs in national parks and forests, Bureau of Land Management holdings and state park lands. Recreation on public wildlands in recent years averaged an estimated 112.1 million recreation visitor days per year. A recreation visitor day (RVD) is equivalent to 12 hours of participation in any recreation activity. Based on USDA Forest Service data, the estimated average market value is $13.26 per RVD for wildland recreation in the state.

Based on this conservative value, an annual average value of $1.5 billion per year for recreation was calculated for public lands in the state. The impacts of wildfire on recreation values were estimated to range from $5 per average acre burned (for the Bureau of Land Management) to $107 per average acre burned (for the state parks system). Of course, where the areas that burn are particularly scenic, visible, or accessible to the public, the value impacts will be significantly greater.

Structures

Average annual home losses to wildfire is $163 million.

Statewide, approximately one million housing units are within California's, including wildlands and wildland-urban interface areas. In total, these housing units have an estimated replacement value of $107 billion for the structures only. Based on fire records for 1985-94, an estimated 703 homes are lost annually to wildfire in California. Taking into account the value of dwellings, value of contents, other improvements, intangibles, uninsured losses, costs of disruption (lost wages, temporary housing, etc.) and insurance company transaction costs, the average loss per home burned from wildfire is estimated to be $232,000. Average total annual loss of California homes to wildfire is estimated at $163 million.

Timber

The timber assets at risk represent the economic value of standing trees for conversion to wood products, such as lumber. Trees that will not be converted to wood products, such as those found on areas administratively or congressionally designated as wilderness, do not have timber value. Timber values were estimated using USDA Forest Service statewide inventory data and stumpage values determined by the State Board of Equalization. The estimates were disaggregated to six regions or cover types and four ownership categories.

Using this approach, the standing value of California commercial timber is estimated to be $105 billion. The timber value lost during a wildfire depends on the intensity of the fire. For a moderately intense, stand-replacing fire, it is estimated that the timber value lost will range from $2,538 per acre in the northern interior to $8,823 per acre on the central coast, based on assumptions about volume loss and salvage values. Less intense or more intense fires would cause different levels of loss.

Water and Watersheds

Water and watersheds have both commodity values and broad environmental values. As a commodity, water produces electrical power and quenches the thirst of people, industry and agriculture. Water impounded behind dams also provides important recreational opportunities. As an environmental resource, water sustains plants, animals and aquatic ecosystems. The many benefits of water are referred to as "beneficial uses." The six million acre feet of water delivered annually to residential, commercial and industrial consumers have a retail value approaching $6 billion. The 24 million acre feet of water used by agriculture each year have a value of about $1.5 billion. In an average year, California produces about 40,000 gigawatt-hours of hydroelectric power with a value of approximately $1.6 billion. In-stream uses of water for maintaining aquatic ecosystem function have a huge but incalculable value as well.

Fire can have beneficial and detrimental watershed impacts.

Fire can have beneficial and detrimental effects on water and watersheds. By removing vegetation and exposing mineral soil, fire impairs the ability of a watershed to hold soil in place and to trap sediment. As a result, increased amounts of sediment are delivered to streams, reducing both commodity and non-commodity beneficial uses. On the other hand, by decreasing evapotranspiration, fire can increase, at least on a temporary basis, the quantity of water delivered to streams. However in the wrong place at the wrong time — such as the fire-flood cycle commonly experienced in Southern California — this increased run-off and its large sediment load causes costly damage to downstream assets such as homes, roads, debris basins and other infrastructure.

The actual water and watershedeffects that result from a wildfire vary greatly depending upon the size and severity of the fire, vegetation type, soil type, slope, proximity to a watercourse and other factors. Only a few general conclusions are drawn here regarding the economic impacts of fire on water and watershed resources. Large, intense wildfires can produce increased runoff worth from $3 to $12 per acre burned in the year after the fire. In addition to consumptive uses, this additional runoff can generate hydroelectricity. In one hypothetical example, $17.50 worth of hydroelectricity would be produced per acre burned in an intensive wildlife enhancement project during the first year after the fire. The value resulting from increased runoff will diminish rapidly as the burned area revegetates over the years following the fire. Fire-caused sedimentation can diminish reservoir capacity, costing $9 to $90 per acre burned in a large, intense fire. This risk is more imminent in reservoirs without large amounts of dead storage capacity, typically smaller reservoirs and reservoirs not originally designed to produce hydropower. Sediment removal after such a fire could cost $100 toas much as $1,000 per acre burned. Increased sedimentation also causes additional wear and tear on hydroelectric generation equipment, harms fisheries and has negative aesthetic impacts; none of those effects can be quantified easily.Fire and landslides triggered by lost vegetation are direct threats to water supply and hydro facilities, such as flumes borne on wooden trestles and canals on hillsides.Then there is the expense of watershed rehabilitation, such as reseeding or replanting vegetation or installing erosion controls: Reseeding grasses afterwildfire costs $30 to $200 an acre; planting tree seedlings costs about $200 per acre.

Sediment removal after such a fire can cost $100 to as much as $1,000 per acre burned.

Overall, it is clear that the economic costs of intense wildfire impacts on water and watershed are greater than the benefits derived from increased water flow. CDF is working with the State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co., the East Bay Municipal Utility District, and other stakeholders, to improve these preliminary characterizations and valuations of water and watershed impacts.

Wildlife, Habitat, Plants, and Ecosystem Health

One of the more challenging categories of assets at risk covers wildlife, habitat, plants, and ecosystem health. First, it is difficult to develop economic values for these assets. A number of economic techniques can be applied,but they are often expensive and subject to significant limitations. This difficulty arises in large part because of the ways in which these assets are valued. Aesthetic values in particular do not appear in a market form and are difficult to quantify, let alone determine a per-unit value. Second, fire can have markedly different effects on wildlife, habitat, plants, and ecosystem health. Large fires do not burn evenly and as a result produce a mosaic of vegetation and postfire plant community succession. Alternatively, at a smaller scale, an intense stand-replacing fire can reduce habitat heterogeneity and foster a uniformity of food and cover value particularly in areas of similar slope, aspect and soil type. Both outcomes may be positive, negative, or exhibit no particular effect depending on the degree of habitat patchiness, the wildlife and plant species of concern, and other topographic, climatic and biological variables influencing fire effects. Thus, consistent generalization of the effects of postfire habitat conditions and their implications for wildlife, habitat, plants, and ecosystem health is not yet possible. An individual species may be favored, negatively affected, or exhibit no particular response to the postfire environment.

While wildfire-caused modification of one habitat type into another may in many cases be "value-neutral," in other cases, such as the loss of habitat for a threatened or endangered plant or animal species, we may be very concerned about conversion of habitat type. One key example here is the California spotted owl, which the USDA Forest Service has identified as a sensitive species. Scientists have identified wildfire and its potential impacts on the species' mature forest habitat as one of the biggest threats to the owl.

Scientists have identified wildfire and its potential impacts on the species' mature forest habitat as one of the biggest threats to the owl.

Long-lasting negative effects of a wildfire in present day fire regimes are likely limited to:

- Localized stream habitats, late seral or climax forest habitats sensitive to fire effects and requiring long periods before re-establishment.
- Some seral habitats that through direct and indirect fire effects do not effectively regenerate.
- Areas occupied specifically by species with unstable populations that are negatively affected by fire occurrence.

Overall, it is not yet possible to specify both the biophysical and economic ramifications of the interactions between wildfire and wildlife, habitat, plants, and ecosystem health. A number of experts have indicated, however, that when one considers qualitatively the economic effect of wildfires on all species, fire regimes and wildland habitats at the scale of the state, it is likely that fire, at least over the short term, has had a net neutral if not beneficial effect. On the other hand, specific fires in specific places at specific times can have significant adverse impacts on particular plant or animal species and/or their habitat. Given the dynamic nature of vegetation, wildlife populations and ecosystems, these impacts are of the greatest concern for listed species, those near the lower bound of population viability.

Other Resource Values

Other, significant resource asset values have not been addressed above. These include historic resources, such as very old structures or places where important events occurred, and cultural resources, such as archaeological sites and unique scenic resources, such as Yosemite National Park or the Lake Tahoe Basin.

California has 85,000 recorded historic buildings, most of which are located in wildland areas. There are over 100,000 recorded archaeological sites in California. It is estimated that there is a like number of undiscovered or unrecorded sites in the state.

Historic and cultural resources cannot easily be valued economically since they are not generally exchanged in the market and are often unique. Further, many people get satisfaction simply from the knowledge that these resources exist and are being protected in perpetuity ("existence" and "bequest" values in the terms of economics), regardless of whether they will ever visit them personally. Similar considerations apply to unique scenic resources. These special resources may have value to people at the local, state, national and even international level, adding further difficulty to attempts to place an economic value on them. Measuring recreation values of the actual usage of unique, scenic areas captures only a small part of their total value to society.

Assets at Risk Framework Summary

esource	Asset Value Basis	Level of Disaggregation	Levels of Value*	Strength of methodology
fe and safety	Non-economic values are not quantified	By population density	National, state and local	High
r quality	Non-economic values of pollutants; average dollar impact from particulate matter (PM10) emitted per acre burned	Air quality basins (13), basic fuel types (2), and by air pollutant emissions	National, state and local	Low
ange	Dollar cost of replacement feed per acre of rangeland burned	Values by regions (8), cover types (9) and ownership classes (5)	State and local	High
ecreation on ublic wildlands	Average dollar loss per acre burned; non-commodity assets also exist	Statewide average by public ownership categories (5)	National, state and local	Low
ructures	Average dollar loss per home burned; non-commodity assets also exist	Statewide average	State and local	High
mber	Average dollar loss per acre burned	Values by regions (6) and ownership categories (4)	National, state and local	High
ater and atersheds	Range of economic impacts per acre for value of increased water yields; cost of sediment removal; loss of reservoir capacity; effects on hydroelectric generation; costs of watershed rehabilitation; non-commodity assets also exist	Statewide ranges of economic impacts	National, state and local	Low to medium
ildlife, habitat, ants and osystem health	Qualitative discussion of the tradeoffs in fire impacts	Statewide	State and local	Low
ther resource ssets, cultural d historic sources, unique enic areas	These non-commodity assets cannot be quantified adequately; descriptive enumeration only	Statewide (generically) or place-specific	National, state and local	Low to medium

*May or may not be cumulative.

Chapter 5

Prefire Management Initiative

Introduction

Over time, all California's wildlands *will* burn. However, various factors contribute to increased risks that fires will occur; that they will be larger, more intense and more damaging; that fighting them will cost more; and that they will take a higher toll (in economic and non-economic terms) on the people of California and, in some cases, on stakeholders from a broader arena, such as federal land and resources owned by all United States citizens.

The prefire management initiative includes a systematic application of risk assessment, fire safety, fire prevention and fire hazard reduction techniques.

CDF proposes a prefire management budget change proposal (BCP) to reduce wildfire damage fires andcosts of suppressing fires. The prefire management initiativeincludes a systematic application of risk assessment, fire safety, fire prevention and fire hazard reduction techniques.

The state's extreme diversity and complex pattern of land use and ownership require equally diverse and complex techniques to effectively manage the fire environment. Some options are the responsibilities of state, federal and local governments; others fall to private citizens or businesses; most are joint responsibilities. Custom strategies for each situation can be created through combinations of prefire management, suppression, and postfire management. They should lessen the costly impacts of future wildfires and offer alternatives to continually increasing suppression forces.

Some background: Vegetation in California's Mediterranean climate was dominated by a complex succession ecology of more, smaller and less damaging wildfires before European settlement began. The evolution of fire suppression since then has produced these results:

- Increasing life, property, resources and ecological losses.
- Difficulty of fire suppression, increasing safety problems for firefighters and reducing productivity by fire crews on perimeter lines
- Longer periods between recurring fires in many vegetation types by a factor of 5 or more. For Ponderosa pine vegetation areas on certain western Sierra slopes,

for example, the average period between fires is 175 years, where it once was 30 to 40 years.

- Increasing volumes of fuel per acre.
- Increasing fire intensities.
- Increasing taxpayer costs and asset losses.

Other factors also contribute to a complex fire environment prone to large disastrous wildfires:

- More people are living and recreating in wildland intermix areas. That adds to the demand for — and value of — finite natural resources in the wildland, and increases ignition sources, resulting in more fires.
- California's extended drought increased the dead and dying vegetation, the volumes of drier fuel per acre, and the number of days annually of lower humidity and fuel moisture.
- Continued set-asides of federal lands, without an aggressive prefire management program, limit fuels management and contributes to the annual fuel loading increases. (Supporting data on increased fuel volume is contained in the USDA Forest Service draft environmental impact report on the California spotted owl.)

Even when fires are not necessarily larger, they are burning more intensely. They are more costly to control and create greater risk of losses to the resources, improvements and people in wildland areas; examples include fire storms in the Oakland Hills (1991), Southern California (1993) and Marin County (1995). In the 10 days between October 25 and November 3, 1993, wind-driven wildland fires consumed over 189,000 acres of valuable Southern California watershed and wildlife habitat. It also damaged or destroyed 1,260 structures, claimed three lives and injured hundreds of people. The cost of suppressing these fires is estimated at nearly $60 million; the damage will exceed $1 billion.

This new fire environment requires the combination of new partnerships and strengthening old ones to provide a fire protection system that will ensure natural resource protection and provide for an acceptable level of public health and safety. CDF's new system emphasizes prevention and minimizing risk as well as trying to make better use of existing resources because of shrinking public revenues.

The prefire management initiative:

- addresses the components of fuel loading, fuel arrangement, land-use patterns, building construction standards and ignition management;
- gives priority to high-risk, high-value areas most likely to burn under severe fire weather conditions; and
- focuses effort by more aggressively emphasizing fire prevention, vegetation management, land-use planning and forest health programs.

Key Components of Prefire Management

Fire Prevention

CDF addresses fire prevention through its engineering, education and law enforcement programs. Their shared objective is reduced fire hazard and risk. This is more narrowly addressed in a planning process based on ignition management and loss reduction; it includes biomass harvesting, fire resistant landscaping, mechanical and chemical fuels treatments, building construction standards, infrastructure, and land use planning. The basic planning unit is the fire management analysis zone (FMAZ).

Ignitions are managed by preventing fires.

Ignitions are managed by preventing fires likely to exceed the capabilities of available attack forces and could result in large damaging fires. Loss reduction is integral to mitigating large and damaging fires. Significant improvement can be attained by reducing hazards (fuel buildups around structures and communities) and working with private industry to implement hazard reduction plans around residential developments in the rural-urban intermix areas.

Successful programs permit more effective utilization of CDF's initial attack forces and enhance firefighter safety.

An average of 30,000 acres a year have been treated with prescribed fire.

Vegetation Management

Since 1981, approximately 500,000 acres — an average of 30,000 acres a year — have been treated with prescribed fire under the vegetation management program. Prescribed fire has been the means of fuels management on virtually all that land. However, a program review has identified needed changes.

The typical vegetation management project in the past targeted large wildland areas without assessing all of the values protected. Citizen and firefighter safety and the creation of wildfire safety and protection zones are a major new focus of the new prefire management program.Now, increasing population and development in state responsibility areas often preclude the use of large prescribed fires. (They remain an option inless populated areas.)

The vegetation management program will shift emphasis to smaller projects closer to the new developments, and to alternatives to fire, such as mechanical fuel treatment. In some instances the program may be limited to simply providing

Prescribed fire projects such as this reduce risks to life and assets. (Photo courtesy of San Francisco Chronicle) wildland safety and protection zones around high value assets.

There also will be a new emphasis on quality over quantity of acres treated. Projects will be chosen that will provide the most cost-effective means of protecting assets at risk from major disastrous wildfires.

The Board of Forestry and the State Air Resources Control Board will develop a joint policy on the use of prescribed fire. The policy will recognize the value of prescribed fire in reducing the emissions of wildfire during the summer high-air-impact period.

Fire-Safe and Land Use Planning

Population increases create wildfire problems.

Population increases in wildland areas have raised strategic concerns about wildfire protection. Clearance laws, zoning, and related fire safety requirements implemented by state and local authorities need to address these factors:

❍ **Fire-resistant construction standards:** We can no longer view a wildland fire as affecting only watershed, wildlife and vegetation resources; we must now consider their effect on people and their structures. Further, this increase in people and structures have provided increasing ignition sources for fire which, due to their proximity, can spread into the wildland. Building construction standards that encompass such items as roof covering, opening protection and fire resistance are designed to both protect the structure from external fires and to contain internal fires for longer periods.

❍ **Hazard reduction near structures** (defensible space): The public image of defensible space as part of prefire management should be expanded to include such immediate benefits as improved aesthetics, increased health of large remaining trees and other valued plants, and enhanced wildlife habitat. The use of defensible space that provides landscape naturalness, along with its compatibility with wildlife, water conservation and forest health, should be emphasized.

❍ **Infrastructure:** Effective fire protection in the intermix cannot be accomplished solely through the acquisition of equipment, personnel and training. The area's infrastructure also must be considered during the formulation of development plans. Specific fire hazard areas should be evaluated and reasonable safety standards adopted, covering such elements as adequacy of nearby water supplies, routes or throughways for fire equipment, addresses and street signs, and maintenance.

The ultimate objectives for fire-safe planning and construction are (1) improve the ability of communities and other high value assets that will survive a large, high-intensity wildfire with minimal fire suppression effort and (2) provide for improved citizen and firefighter safety.

Forest Health

Years of aggressive fire protection and timber management have dramatically changed the character of California's forests. Pre-European Sierra forests were open, park-like pine and fir forests that were subject to frequent low-intensity fires. Current forests are smaller, younger, and more dense; they have high fuel loads and are prone to very intense fires. Developments have been superimposed in many of these forest types. The resulting fire problem, in critical fire weather periods, is a difficult control situation for any fire agency.

CDF resource management programs are aimed at keeping forest fuel values low enough that wildfire can be contained. Densities of dead and dying trees, understory vegetation and development must be managed. This includes advice to landowners on timber management, environmental protection, fuels treatments, prescribed fire treatments and development planning.

CDF is in the unique position to provide these services to forest landowners and communities. It also includes the proper treatment of stands during commercial timber harvesting. The Forest Practice Act and rules of the Board of Forestry have as their objective reducing the risks of wildfire costs and losses in timber harvest areas.

The objective is to service a large high-intensity wildfire without direct fire protection.

Prefire Management as Part of the Fire Plan

The prefire management initiative is a blend of existing CDF programs — fire prevention, land-use planning, vegetation management and forest health improvement, with risk assessment and systems analysis expertise. The initiative is being implemented in 1996 in the Nevada-Yuba-Placer, Tuolumne-Calaveras and Riverside ranger units. Beginning July 1, 1996, an additional 27 months will be required to expand the prefire management program to all 22 CDF ranger units and the six contract counties.

GIS maps will be provided for each asset at risk, with overlays showing level of service success and failure rates; hazards; asset values; and severe fire weather days by year. Each criterion will be summarized on the GIS maps and categorized for high, medium or low risk. After the risk areas are mapped, separate GIS maps will be generated that identify high-risk areas, for development of prefire management projects.

At the community level, representatives of all stakeholder groups for each asset at risk will be contacted and invited to a meeting. The purpose is to acquaint the stakeholders with the process and bring their expertise and knowledge to bear on the asset maps that identify risk levels. They will review the level of service that applies to the location of the assets. Areas where they find the level of service unacceptable will be identified on the hazard and risk maps for later use.

Ranger unit personnel will provide ground review and validation of the high-risk prefire management areas; maps will be corrected to reflect the need on the ground. New high-risk GIS maps will be generated for use in developing prefire management projects. Ranger unit staff will define

The fire management projects will reduce total costs and losses of a major fire burning through the area during a period of severe fire weather.

prescriptions for prefire management projects that will reduce total costs and losses of a major fire burning through the area during a period of severe fire weather. Budgets will be developed for the projects.

Ranger unit staff, with assistance from area offices, headquarters staff and stakeholders with specific expertise, will identify economic and non-economic assets protected and estimated reductions in costs and losses if the prefire management projects are implemented. Ranger unit staffs, with assistance of area office and headquarters staff, will identify the mix of state, federal and local government and prefire management projects will be ranked in priority, based on cost effectiveness and the priorities of the ranger unit chief.

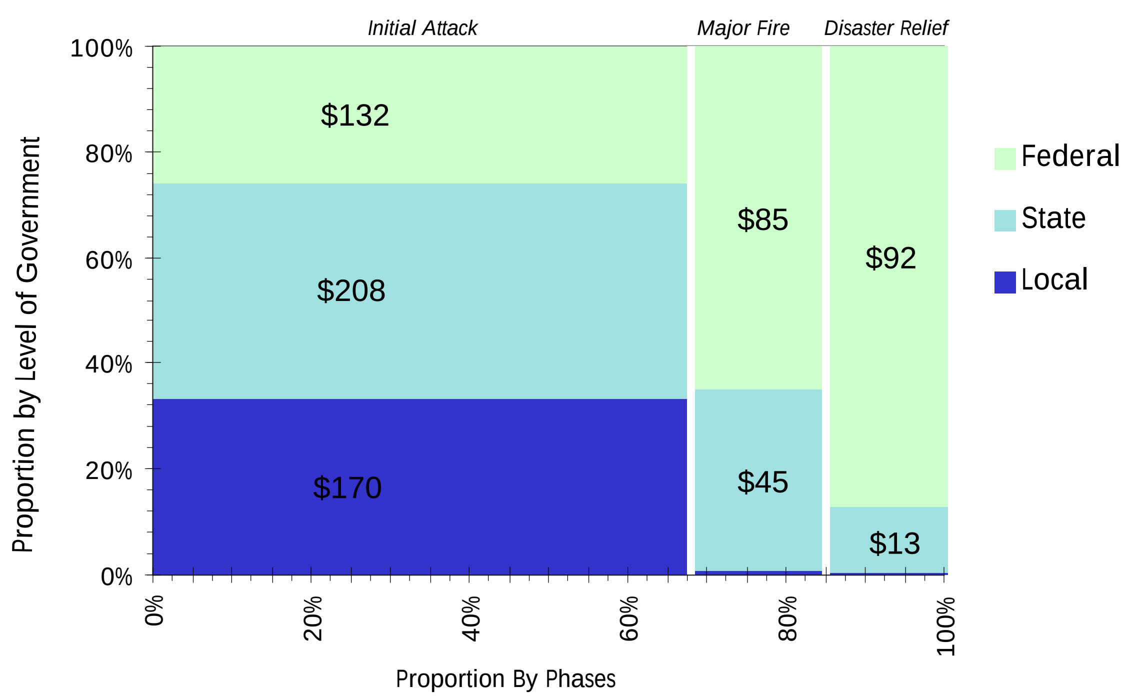
Additional meetings will be held with stakeholders when more than state funding is needed for the prefire management projects. Ranger units will then conduct community public hearings for the general public and stakeholders to review the assessment and proposed projects. After this final public input, the prefire management projects in the three ranger units will be aggregated at the state level for the budget change proposal and funding.

Final results of the fire plan process will be presented to the Board and monitored to use in adjustment of statewide policies.

Appendix A. Fiscal Framework Charts and Assumptions

Wildland Fire Protection Budgets by Level of Government by Fire Phase

	Millions of Dollars			
	Initial Attack	Major Fire	Disaster Relief	Total
USFS	$123	$ 77	$ 0	$200
BLM	6	4	0	10
NPS	1	3	0	4
BIA	2	1	0	3
FEMA	0	0	92	92
Other Federal	0	0	0	0
CDF	206	45	0	251
OES	2	0	0	2
Other State	0	0	13	13
	Initial Attack	Major Fire	Disaster Relief	Total
Total Federal	$132	$85	$92	$309
Total State	208	45	13	266
Total Local	170	1	1	172
Total	$510	$131	$106	$747



Explanation of Labels Used in the "Wildland Fire Protection Budgets" Chart

Wildland Fire Protection Budgets: includes all costs associated with wildland fire protection in California for local, state and federal government agencies.

Wildland: lands covered wholly or in part with flammable vegetation, requiring protection from fire and/or advancement of fire into areas containing other valued assets.

Fire Protection: all activities to protect wildland, and other assets at risk within wildland, from fire. This includes pre-suppression and disaster relief activities.

Fire Phases

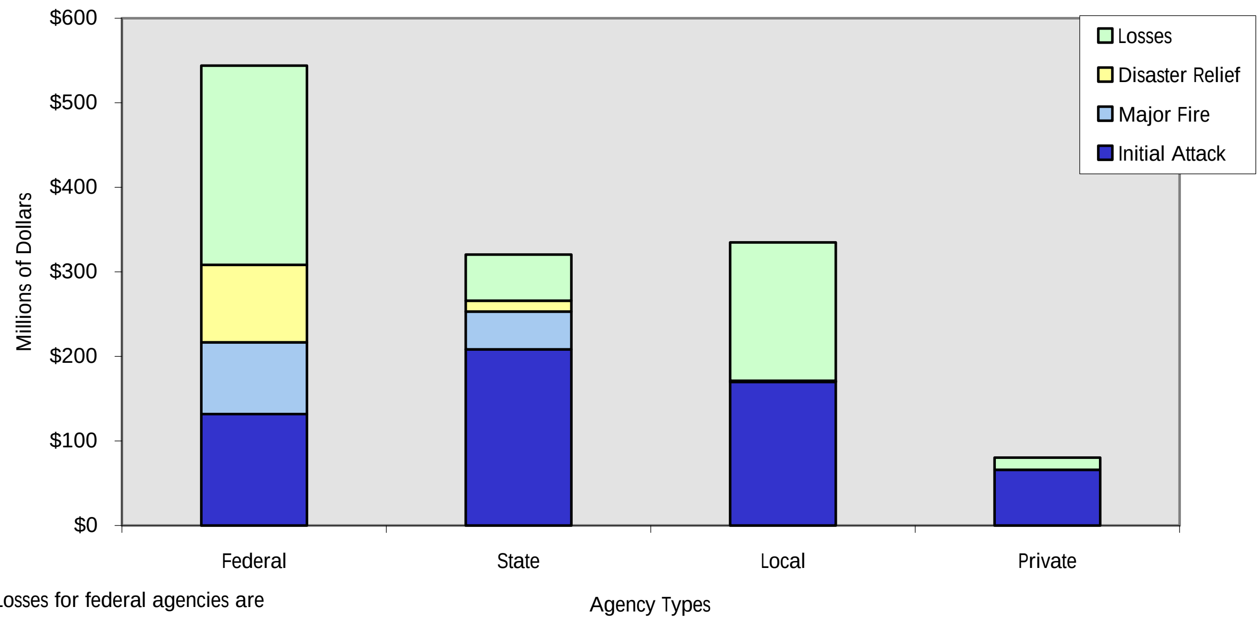
Initial Attack: includes all costs associated with pre-suppression and the control activities taken by resources on fires that are fires to arrive at a wildland fire.

Major Fire: includes all costs associated with control activities taken by resources on fires that are beyond the capabilities of the initial attack effort. For purposes of this chart, this includes the extended attack phase of a wildfire.

Disaster Relief: includes all costs to augment control efforts when a wildland fire has overwhelmed the capability of state and/or local governments to carry out the extensive emergency operations necessary to save lives and protect property.

Who Pays for Fire Protection Costs and Wildfire Damage

	Millions of Dollars				
	Initial Attack	Major Fire	Disaster Relief	Losses	Total
Federal	$132	$85	$92	$235	$544
State	208	45	13	54	320
Local	170	1	1	164	336
Private	66	0	0	14	80
Total	$576	$131	$106	$467	$1,280



Losses for federal agencies are estimates only due to insufficient data.

Explanation of Labels Used in the Suppression Costs and Losses Chart

Federal: includes all costs and losses associated with federal wildland fire protection and disaster management agencies in California. Generally this includes USFS, BLM, NPS, BIA and FEMA.
State: includes all costs and losses associated with state wildland fire protection and disaster management agencies in California. Generally, this includes CDF and OES.
Local: includes all costs and losses associated with local government fire protection and disaster management.
Private: includes costs and losses incurred by the private sector and not otherwise recovered from government assistance.

Fire Phases

Initial Attack: includes all costs associated with pre-suppression and the control activities taken by resources on fires that are fires to arrive at a wildland fire.
Major Fire: includes all costs associated with control activities taken by resources on fires that are beyond the capabilities of the initial attack effort. For purposes of this chart, this includes the extended attack phase of a wildfire.
Disaster Relief: includes all costs to augment control efforts when a wildland fire has overwhelmed the capability of state and/or local governments to carry out the extensive emergency operations necessary to save lives and protect property.

Appendix B. Level of Service Rating and Process

Background

The California Department of Forestry and Fire Protection (CDF) is a statewide resource protection agency. It is the largest multipurpose fire protection agency in the United States. CDF is directly responsible for wildland fire protection of over 31 million acres of California's privately owned watershed lands. In addition, the department provides full fire service protection to nearly 11 million acres under reimbursement agreements with local governments. The department responds to over 7,000 wildland vegetation fires onstate responsibility areas each year. Approximately 95 percent of these fires are contained at less than 10 acres.

The heart of CDF's fire protection program is an aggressive initial attack firefighting strategy. CDF commands a force of approximately 3,800 full-time fire professionals, foresters, and administrative employees; 1,400 seasonal personnel; 5,500 local government volunteer firefighters; 2,600 Volunteers in Prevention; and 3,800 inmates and wards. All of these people work aggressively to prevent and suppress wildfires.

CDF operates 1,027 fire engines, (338 state-funded engines and 689 local government funded engines), 103 rescue squads, 12 aerial trucks, 58 bulldozer units, 5 mobile communication centers and 11 mobile kitchen units. CDF also funds 82 engines and 12 bulldozers used to protect state responsibility areas in Los Angeles, Orange, Santa Barbara, Ventura, Kern and Marin counties. In addition to its ground attack capability, CDF maintains a significant fleet of aircraft that includes seventeen 800-gallon air tankers, one 3,000-gallon and two 2,000-gallon contract air tankers, 13 air attack planes, and 10 helicopters.

CDF doesn't fight fire alone. The department cooperates fully with federal and local government firefighting agencies and the governor's Office of Emergency Services. This cooperation is formally defined and authorized in interagency agreements with the federal agencies, in the State Master Mutual Aid Agreement, and in local mutual aid agreements. The department advocates and uses the Incident Command System to efficiently manage the diverse resources used in the firefighting effort.

Level of Service Rating

The legislature has charged the Board of Forestry and CDF with delivering a fire protection system that provides an equal level of protection to lands of similar type (PRC 4130). To do this, the department needs an analysis process that will define a level of service rating that can be applied to the wildland areas in California to compare the level of fire protection beingprovided. The rating should be expressed as the percentage of fires that are successfully attacked. Success is defined as those fires that are controlled before unacceptable damage and costare incurred.

California has a complex fire environment, with multiple climates, diverse topography and many complex vegetation communities. CDF data on assets at risk to damage from wildfire is incomplete. These factors combine to make it very difficult to develop a true performancebased fire protection planning system. CDF has resorted to prescription-based fire protection planning (travel times of firefighting resources to incidents, report times for the detection system, the same acreage goal statewide, etc.) as a way to overcome the complexity of the issues. Prescription-based planning is possible but tends to oversimplify some issues. Prescription standards also make it difficult to integrate the interrelationships of various fire protection programs, such as the value of fuel-reduction programs to reducing the level of fire protection effort required.

The following approximation method is proposed to overcome these shortcomings and allow CDF to proceed with a damage-plus-cost analysis of fire protection performance. This is a relative system, attempting to measure the relative impact of fire on the various assets at risk. At the same time, this process produces a level of service rating (LOS). The rating can be used to describe fire protection services to “civilians.”

The level of service rating (the score of successes in initial attacks) can be used to compare one area of the state with another, recognizing that the assets at risk may be quite different. This gives CDF a powerful tool for setting program priorities and defining the benefits of the programs. The level of service rating also provides a way to integrate the contribution of various program components (fire prevention, fuels management, engineering and suppression) toward the goal of keeping damage and cost within acceptable limits.

The level of service rating used in this plan is expressed as the percentage of incidents where initial attack effort succeeds. Successful initial attack is defined in terms of the amount of resources needed to suppress the fire and of fire intensity. It is that effort which contains the fire within an acceptable level of resource commitment, acceptable suppression cost and minimal damage to assets at risk.

$$\frac{\text{number of successful initial attacks}}{\text{(total number of initial attacks)}}$$

A matrix is used to define and display successful initial attacks in this framework. The matrix axes defines fire sizes and intensities. The body of the matrix contains the fire activity workload for the fire management analysis zone.

The general matrix has five columns for fires of different sizes and three rows for different intensity levels. The actual size classes and intensity levels are defined for regions of similar vegetation. Thedark shaded portion of the matrix indicates fires that would be expected to exceed budget (and some emergency fund) protection.

The lightly shaded portion indicates successful initial attack suppression, fires that are normally contained within allowable suppression cost.

Intensity	Spots	Small	Medium	Large	Exceed model simulation limits
Low					
Medium					
High					

In this matrix, the lightly shaded area represents fires that are successfully attacked and the dark shaded area represents the unsuccessful initial attacks. This designation of successful and unsuccessful matrix cells would remain the same for all fire management analysis zone (FMAZ) matrices.

Average annual fire activity in the FMAZ is entered into the matrix according to intensity and size of the fires. A ranger unit's fire reports are sorted and tallied by size, intensity and FMAZ. Data from 1985-1994 is used to calculate a 10-year average of fire activity. This workload is then used as a calibration measurement for the California Fire Economics Simulator-Initial Attack Model (CFES-IAM). The modeled results, after calibration, are entered into the matrix and used to calculate the current level of service. Modeled results are used so analysts can maintain consistency with results during later analysis of system changes.

For example, suppose one ranger unit's FMAZ modeled workload looked like this:

Intensity	Spots (0 - .25)	Small (.25 - 5)	Medium (5 - 25)	Large (25 - 300)	Exceed model simulation limits (+ 300 acres)
Low	19	5	2	0	0
Medium	18	9	3	1	0
High	16	8	5	3	1

The level of service rating is the proportion of successful initial attacks to total initial attack workload.

$$\frac{\text{number of initial attack successes}}{\text{(total initial attack workload)}}$$

In this example, the annual average fire activity totals 90, with 80 fires in the successful initial attack portion of the matrix. This produces an 89 percent level of service rating (LOS).

$$\frac{\text{number of initial attack successes}}{\text{(total initial attack workload)}} = \frac{80}{90} = \text{89 percent LOS}$$

The score of 89 percent would be used to describe the level of service. It could be compared to scores from other fire management analysis zones in various systems for setting priorities.

By the fall of 1998, the LOS procedure will produce a numeric score of the level of wildland fire protection service with the following characteristics:

- The score can be used to compare service levels in similar vegetation areas in California to help identify areas that are not receiving an equal level of service to lands of similar type.
- The score can be used to compare service levels in different vegetation areas in California to help set priorities for prefire management project funding.
- The process can discern which level of government is providing the service.

Additionally, when presented in different formats, the LOS rating can help explain CDF's initial attack fire protection system.

- Scores can be used to compare CDF's abilities from one FMAZ to another.
- The FMAZ can be mapped and colored or shaded to show levels of service.
- Scores can be used to help identify areas needing additionalprefire management program attention.

The contents of the matrices within a ranger unit can be combined graphically to show the composite workload within the unit.

LOS Rating Process

Areas, Maps and Models

The first step is to define regional areas of similar vegetation types in California. These zones are areas within an administrative (ranger) unit that have generally similar fire behavior and fire effects characteristics. The mapping process will use previously planned response areas as the basic mapping unit. This will ease later integration of the fire plan into operational procedures.

The next step is to define a matrix for the appropriate level of service for the regional vegetation zone. The fire size side of the matrix will be defined through interviews with the region's involved fire managers. The fire intensity side will be defined through an analysis of historic weather data for the zone. The LOS matrix is used to define inputs into the CFES model within each ranger unit.

The California Fire Economics Simulator-Initial Attack Model (CFES-IAM) is then used to model a ranger unit's fire workload. The results are used to calculate the current level of service in each fire management analysis zone in the ranger unit. Modeled results are used so analysts can maintain consistency with results during later analysis of system changes.

CFES-IAM also can be used to calculate the level of service by funding source. Ranger unit, regional and state-level maps can be generated depicting the total level of service and the level of service by funding source. The state-funded LOS map would be used to evaluate CDF's ability to provide an equal level of service to lands of similar type without consideration of other available local or federal firefighting resources.

An LOS rating map would be used as an input in defining areas of the state with high value, high hazard, frequent severe fire weather and low service levels. Ratings can be displayed in different formats to explain CDF's initial attack fire protection system.

- The LOS scores can be used to compare CDF's abilities from one area to another.
- The areas can be colored or shaded to show levels of service on a map.
- The LOS scores can be used to help identify those areas that need additional prefire management program attention.

The level of service rating as defined above uses history to validate the modeling system. The modeled system (CFES) includes the efforts of CDF, any other state-level efforts, local government and federal government efforts. As a calibration step, this balances fire growth modeling vs. production function modeling in the simulator.

The local and federal resources can be removed from the CFES model for a "what if" analysis of the state-funded system. The CFES program will "refight" historic fires as if only CDF resources were available. The result will rate the state-funded response capability. This rating can be used to compare state response capabilities in lands of similar type.

As per the Public Resources Code (PRC 4130), the Board of Forestry is to provide *an equal level of protection to lands of similar type*. Key questions are: What is the state-funded level of service? Are the levels equal on lands of similar type? This portion of the process defines a method for addressing that issue.

The Matrix's Fire Intensity Axis

CDF chose to use three intensity levels to provide consistency with operational procedures. The department uses three levels to define the potential fire workload expected on initial attack fires. The levels are an integral part of a complex response system, used to determine the correct amount of resources to dispatch for an initial attack. Staying with three intensity levels will facilitate integrating the strategic plan with tactical operational plans.

Current research indicates that fire intensity is an important element for estimating fire effects. (Many other parameters, such as duration of burning, flame length and consumption, also relate to damage.) The fire intensity axis of the matrix should capture the most important indicator for damage to the area in question.

As a practical matter, measurements of fire intensity are limited. The fire behavior portion of CFES uses the National Fire Danger Rating System modeling process. NFDRS produces four primary fire behavior parameters:

- **Ignition:** This component captures the factors that relate to ease of ignition of the fuel bed; generally, these are fine fuel moisture and temperature. The ignition component may work as a predictor of fire activity but, once a fire starts, isn't the best indicator for damage.

- **Spread:** This component covers factors — chiefly wind, along with fine fuel moisture — that affect how fast the fire burns. This can be a good indicator of damage in "light fuel" vegetation types like rangeland but not in broad conditions.
- **Energy release:** This is the energy released from the fuel bed as the fire actively burns through it (the smoldering stage doesn't count). It is heavily affected by fuel moisture, especially from living plants and large dead ones; it is not affected by wind speed. Usually a very good indicator of damage in "heavy fuel" vegetation types like forested areas.
- **Burning index:** This combines the energy released and the rate of spread, and is designed to relate well to flame length. The index can be a very good indicator of damage in "medium fuel" vegetation types like woodland areas. It can also work well in brush and chaparral.

Other NFDRS components and indexes incorporate fire workload (human occurrence, lightning occurrence and fire load indexes) and thus cloud the issue a little. The level of service rating process brings in workload later. The appropriate component for describing fire behavior in the vegetation type will be selected by the fire plan analysis team.

Intensity Analysis

Grouping FMAZs by similar vegetation and fuel types will provide more data matches on weather and fire reports for statistical analysis. There is much data to be collected and correlated.

Select appropriate weather stations: State and national fire managers have used the National Fire Danger Rating System (NFDRS) to collect weather data for over 20 years, first through AFFIRMS and now WIMS software programs. The data is stored in the National Fire Weather Data Library, in the National Computer Center, in Kansas City. It has been designed, recorded, formatted and saved specifically for historical analysis. More than 475 historic and active California weather stations are in this data set. Many of them may not have weather records for the 1985-94 analysis period; 118 of them do.

CDF also has data from about 200 remote, automated weather stations. It is formatted as hourly data and is not ready to be processed through the NFDRS historic analysis programs. This formatting can be done on selected stations to fill voids in the NFDRS weather station data set, but it will take some time.

Calculate fire danger indexes: These indexes can be calculated given the weather data for the FMAZ, the fuel type, slope class, climate and herbaceous vegetation type. The danger rating processor produces a data file of daily fire danger indexes. These indexes can then be linked to the fires that occurred in the area on each day.

Collect fire activity data: Fire activity data for 1985-94 is available for most zones. It covers the incident number, report date and time, arrival date and time, containment date and time, cause, size and location. The location information is based on public land survey data (section, township, range information). The public land survey can be converted to latitude and longitude with an acceptable level of accuracy (center of section); that allows a geographic information system to link fire reports to the appropriate fire management analysis zone.

Collect fire cost data: California's CALSTARS accounting database system has millions of spending records that can be tied to the originating incident and grouped by category. These cost totals can then be related to incident records in the fire activity database.

Merge fire report data with fire danger indexes: There are two ways to link the weather and fire reports. Both linkages will need to be performed for different portions of analysis.

- The data can be linked by weather day. Each record in the data set is a day with weather readings and fire intensity indexes. Fire business is summarized and linked as a yes/no condition. Typical fire business queries are: Did a fire occur on this day? Yes/No. Did a large fire occur? Yes/No. Was some level of expenditure exceeded? Yes/No. This linkage can be used to establish the predictive quality of the index and to set operational decision points. It also can be used to validate the fuel model and weather station selection. A further discussion of this analysis is part of the section describing the intensity axis of the matrix.
- The data can be linked by fire report. The fire intensity index for the day is attached to the fire report record. The same intensity level would be used many times if there were multiple fires on a day. This linkage will provide for the analysis of historic fire activity for the CFES-IAM model.

Compare indexes with fire business: The next step is to define the appropriate intensity level groups — low, medium and high fire intensity. The analysis effort will aim at finding the index, fuel model and/or weather station that best discriminates the types of fire business. Fire business is correlated with the intensity rating as:

- Low — little to no fire larger than the "spot size" in this index range
- Medium — some fire activity but no (or little) history of large or major fires in this index range
- High — history of large fires in this index range

Break points in the intensity level group can be determined by plotting the cumulative frequency distribution curves for all days, fire days, medium-size fire days and large fire days. Fire day definitions are:

- All days — any day with fire weather readings, regardless of fire business
- Fire day — a day with a fire, regardless of size

- Medium-size fire day — a day with a fire larger than “spot” size
- Large fire day — a day with a fire in the “large” or “major” size class

The break points can be found by plotting the distributions and finding the index level where medium-size fire days begin to show up and where large and major fire days begin to show up.

Combine intensity analysis: The intensity analysis will be done at the FMAZ level. The next step is to compare the intensity break points between similar FMAZs and calibrate them so that a single set of break points can be used for the similar FMAZs. This step will allow comparison of level of service ratings among similar FMAZs.

The Matrix’s Fire Size Axis

The fire size classes along the horizontal axis of the matrix reflect the general cost of fighting the fires. They also indicate the general impact on suppression organizations by the extent of resources they tie up and how long the resources are used. These impacts should be similar between fire management analysis zones of the same fuel type but can vary among zones of different fuel types.

Impacts on the initial attack suppression organization are an important element in planning. The matrix allows for a general grouping of fires along the horizontal axis in three size classes representing minimal resource commitment, extended time commitments and major resource commitment.

Small fires (up to a quarter acre or so) are those that have to be extinguished but don’t require a significant resource commitment. This size class includes fires that don’t spread, are suppressed by local citizens, or are otherwise not a problem.

The middle size classes define the small to medium fires that are modeled in the CFES-IAM initial attack simulator. These classes are used to reflect changes in initial attack strategy and use of tactical resources that affect the suppression system.

The last size class indicates the point at which the CFES-IAM initial attack model breaks down, where continuous fuel, weather and slope factors exceed the basic modeling assumptions for those components. This size can vary among FMAZs, subject to regional conditions.

Another important use of the size class breakdown is to provide categories of fires for assessing damage to assets at risk. One common definition of the matrix within similar FMAZs will allow different assets to be combined into a composite matrix and the matrices to be compared from one administrative unit to the next.

Defining Size Classes

Representatives from the field units responsible for fire protection in the FMAZs should be brought together for a structured interview session to define the acreage break points. Interview team members should represent each unit in question and include a mix of unit chiefs, operations officers, battalion chiefs, administrative officers, air attack officers and others knowledgeable in firefighting in the unit.

The interview team would review the FMAZs in question by examining photographs, maps and fire history data. The unit representative would be asked a series of questions:

- What acreage would account for most of the “non-serious” initial attack fires?
- What acreage accounts for routine initial attack with a short duration impact on initial attack drawdown?
- What acreage represents an upper limit of initial attack and the beginning point for extended drawdown, verging into extended attack?
- What acreage would describe the point where modeling assumptions of continuous slope, fuel and weather no longer are valid?

Team members would answer these questions individually without discussion. The answers would be tabulated and the team, as a group, would discuss them and agree on an acceptable single answer for each question for each FMAZ.

Defining the System Failure Threshold

System success is defined as fires that are managed without either adversely affecting the initial attack system’s ability to respond to other incidents or expending significant unallocated resources (emergency fund). CDF’s budget structure generally provides that initial attack activities be funded out of an allocated budget. The emergency fund exists to pay for managing wildland fires that escape initial attack. Consequently, fiscal data should show an acreage threshold that indicates significant impacts on the emergency fund.

The field team will evaluate the failure threshold by comparing the emergency fund costs by incident acreage and intensity level to establish the acreage threshold for system failures. The threshold can be defined as the point where significant e-fund expenditures begin. This will be reflected in the acreage side of the level of service rating matrix.

Multiple Major Incident Capability

CDF’s wildland fire protection system is based on a strategic concept of initial attack success. Initial attack failures are not only costly, but they also drain suppression resources from readiness and increase the possibility of more initial attack failures. Sufficient resources must be available to meet the workload demands of initial attack failures, the so-called “major fires.” The ability to staff and equip major incidents and still retain some initial attack effectiveness is called “depth of resources.” As a concept, depth of resources includes all suppression capabilities, from engines and people to financial flexibility, needed for incident management.

A depth of resources analysis is contained in the 1985 Fire Plan, Section 7270. The fire plan field team should review and refresh this analysis. Future generations of the fire plan may be able to refine this methodology.

The Fire Plan Field Team

A field team will be assembled to visit the ranger units; explain the planning process; review and validate prior field work on defining fire management analysis zones, representative fire locations, resource travel times, production rates, etc.; conduct acreage interviews; and otherwise assemble the information needed to complete the fire plan. The team will update field fire planning software and data files as necessary, and will train unit CFES coordinators on the latest version of CFES, other planning software and the fire plan framework and methodology. The team will also visit administrative units to complete those tasks.

A variety of roles and talents will be needed. The team should be led by a SFR IV or CDF administrator-level employee. Members should include people knowledgeable in fuels modeling, vegetation typing, firefighting strategies and tactics, local government and federal resources, statistical analysis, the CFES-IAM software program, and the fire plan framework and process.

A staff paper by the Level of Service Task Group, Fire Plan Working Team:
Jerry Geissler, Hank Weston, Wayne Mitchell, Larry Benson, Steve Peterson, Greg Greenwood
April 6, 1995

Appendix C. Assets at Risk and their Role in the Fire Plan

Introduction

The primary goal of fire protection in California is to safeguard the wide range of assets found across wildland areas. These assets include range, life and safety, timber, recreation, water and watershed, air quality, cultural and historic resources, unique scenic areas, life and safety, structures, wildlife, plants, and ecosystem health. This appendix to the fire plan describes these assets and discusses approaches to assessing their economic and non-commodity values. It also addresses how estimates of these asset values will be used in the fire plan process.

Knowledge of the types and magnitudes of assets at risk to wildfire, as well as their locations, is critical to fire protection planning. Given the limits on fire protection resources, these resources should be allocated, in part, based on the magnitude of the assets. At the margin, knowledge of assets at risk is also necessary to choose those prefire management projects which will provide the greatest benefit for a given amount of investment. For the department, the primary concern regarding prefire projects is the reduction of suppression costs; of secondary concern is reducing the fire risk faced by the various assets described here.

Thus, as a part of the overall fire plan process, assets will be addressed at two levels. First, generalized assets at risk will be estimated and summed across the state to indicate what areas contain highly valued assets. These assets will be overlain with a measure of likelihood of occurrence of a large damaging fire. These statewide assessments will be refined at the ranger unit level through a process that includes the participation of stakeholders in the various assets. Those areas with the highest combined asset values and fire risk will be targeted for prefire management projects, particularly where those projects would significantly reduce suppression costs should a fire start in the project area during high fire hazard weather. Second, as potential projects are identified in these areas, they will be subjected to an analysis of the degree to which the projects will reduce potential suppression costs and damage to assets.

The process of explicitly enumerating assets at risk also helps to identify who benefits from those assets. It is a premise of the fire plan that those who benefit from the protection of an asset should pay for that protection. Thus, asset stakeholders will be expected to provide financial support for those projects that provide significant benefits to their assets of concern while providing little potential for reducing suppression costs. For example, if a prefire management project primarily protects structures, local government and the affected homeowners should provide the primary financial support for the project. On the other hand, if a project primarily benefits wildlife in general, then the Department of Fish and Game, the U.S. Fish and Wildlife Service and/or a wildlife interest group should bear the major costs of the project.

The first, and major, part of this appendix addresses two basic questions: What is the value of the resources or assetsat risk to wildfire? What asset losses (economic and non-economic) result from wildfire? Where possible, estimates of asset values were made on a dollar-per-acre basis. The methodologies used, although exposed to some peer review, need further review and refinement. This will be done at the state level and as a part of the pilot projects in three ranger units.

Table 1 summarizes the assets at risk framework that has been developed for estimating fire impacts. Resource assets presented here includelife and safety, air quality, range, recreation on public wildlands, structures, timber, water and watersheds, wildlife and habitat, cultural and historic resources, and unique scenic areas. No attempt has been made to make economic estimates of the value of human loss of life or injury, although there are methodologies for estimating such values.

Table 1. Assets at Risk Framework Summary

Resource	Asset Value Basis	Level of Disaggregation	Levels of Value*	Strength of Methodology
Life and safety	Non-economic values are not quantified	By population density	National, state and local	High
Air quality	Average dollar impact from particulate matter (PM10) emitted per acre burned; non-commodity assets also exist	Air quality basins (13) and basic fuel types (2)	National, state and local	Low
Range	Dollar cost of replacement feed per acre of rangeland burned	Values by regions (8), cover types (9) and ownership classes (5)	State and local	High
Recreation on public wildlands	Average dollar loss per acre burned; non-commodity assets also exist	Statewide average by public ownership categories (5)	National, state and local	Low
Structures	Average dollar loss per home burned; non-commodity assets also exist	Statewide average	State and local	High
Timber	Average dollar loss per acre burned	Values by regions (6) and ownership categories (4)	National, state and local	High
Water and watersheds	Range of economic impacts per acre for value of increased water yields; cost of sediment removal; loss of reservoir capacity; effects on hydroelectric generation; costs of watershed rehabilitation; non-commodity assets also exist	Statewide ranges of economic impacts	National, state and local	Low to medium
Wildlife, habitat, plants and ecosystem health	Qualitative discussion of the tradeoffs in fire impacts	Statewide	State and local	Low
Other resource assets, cultural and historic resources, unique scenic areas	These non-commodity assets cannot be quantified adequately; descriptive enumeration only	Statewide (generically) or place-specific	National, state and local	Low to medium

*May or may not be cumulative.

For each of the resources, the table summarizes the value basis (i.e., the units in which fire impacts have been estimated) and the level of disaggregation (resource subtype and geographic area) of these assets. The table also indicates the levels, ranging from local to national, at which the resources are valued. The manner in which “consumers” of a particular resource value it may differ from local to state to national levels. Some of the resources protected from fire in California have value beyond national borders — for example, the scenic Lake Tahoe Basin or the old growth redwood parks of the North Coast. Again, it should be emphasized that the economic values that have been calculated are preliminary and are often highly aggregated. These estimates will be refined as fire plan implementation moves to the ranger unit level. CDF is working with the Department of Fish and Game, State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co. and the East Bay Municipal Utility District to refine our approaches to wildlife, plants, ecosystem health, watersheds and water.

The remainder of this appendix examines the manner in which generalized assets at risk will be summed across the state to identify those areas with the greatest total value of assets. These initial, coarse statewide assessments will be refined at the ranger unit level through a process that includes stakeholder participation. Finally, the appendix discusses the issue of how the costs of prefire management projects will be shared among those parties benefiting from them.

Air Quality

Introduction

Air quality is of particular importance in California, given our large urban populations and the state's topographic and meteorological characteristics, which often inhibit dispersion of air pollutants. This section examines economic values related to wildfire and air quality. Similar issues exist with respect to the air pollutants created by prescribed fires.

Suppression of wildfire provides a short-term benefit to air quality by reducing the amount of vegetative and woody material that would have burned if the fire were left unchecked. However, since fire is a natural part of California's wildland ecosystems, what we prevent from burning today may simply end up burning next year. Our success at fire suppression has resulted in a fuels buildup that contributes to the occurrence of large fires with their associated acute pollution events. Thus, our fire suppression system has in part replaced a natural background level of frequent light fires with less frequent, large, catastrophic fires. Further, large wildfires result in the burning of larger fuels that would be unlikely to burn under a natural fire regime, but instead would decompose. The result of these changes is likely to be higher net wildland fire smoke emission and the concentration of these emissions in space and time, relative to the more dispersed smoke emissions of the natural fire regime.

This report begins with a review of the mechanism of pollutant emission from wildfires and then examines the impact of such smoke emissions on a range of assets — visibility, human health, materials and vegetation, and pollutant rights. Finally, an overall estimate of marginal pollutant impact values is presented. Unlike for most of the other assets examined in this appendix, there is no meaningful way to describe the total value of the resources being protected from wildfire smoke emissions by wildfire suppression.

Fire Emission and Exposure Mechanisms

Wildland fires are categorized as an "area source" by air pollution agencies, since fires release pollutants over the area burned, rather than from a discrete "point source" such as a smokestack. There are many variables involved in determining the amount of various kinds of pollutants emitted in wildfire. These factors include fuel type and loading, moisture content, topography and weather. In general, flaming materials (such as would occur with dry vegetation or wood in daytime) produce fewer pollutants than smoldering materials (e.g., relatively moist material at night). Emissions from controlled burning are likely different than those from wildfire (Reinhardt et al. 1994).

The most prominent pollutants produced in wildfire are carbon monoxide (CO), nitrogen oxides (NOx), organic gases (OG), and suspended particulates (TSP). Of particular concern for human health are particulates smaller than 10 microns in size (PM10). Table 2 indicates Air Resources Board emission factors for wildfire. Although more research is needed, they are the best information available at this time. The USDA Forest Service recently developed a more sophisticated set of emission factors (USDA Forest Service 1995), which will be incorporated when they have been more fully documented.

Table 2. Emission Factors for Wildland Fires

	Grass and Woodland		Timber and Brush	
Pollutant	lb / ton	lb / acre*	lb / ton	lb / acre**
CO	101	202	260	3,900
NOx	0	0	4	60
OG	19	38	25	375
TSP	16	23	42	630

* assumes fuel load of 2 tons per acre
** assumes fuel load of 15 tons per acre
Source: California Air Resources Board

Table 3 shows the estimated total air pollutants emitted per year by CDF and USDA Forest Service wildfire[1], based on the factors presented in Table 2 and average annual acres burned from 1985-94. These numbers indicate that wildire is responsible for the release of significant quantities of air pollutants, totaling an average of almost 600,000 tons per year.

---

[1] *Does not include Bureau of Land Management, Bureau of Indian Affairs, National Park Service and wildfires inside city limits' acreage.*

Table 3. Estimated Annual Wildfire Air Pollutant Emission (1985-1994 average)

Pollutant	Grass and Woodland (tons of emissions)	Timber and Brush (tons of emissions)	Total (tons)
	CDF Fires		
CO	6,083	139,695	145,777
NOx	0	2,149	2,149
OG	1,144	13,432	14,576
TSP	693	22,566	23,259
Total	7,920	177,842	185,762
	USDA Forest Service Fires		
CO	4,457	319,125	323,583
NOx	0	4,910	4,910
OG	839	30,685	31,524
TSP	508	51,551	52,059
Total	5,803	406,271	412,075
	CDF and USDA Forest Service Fires		
CO	10,540	458,820	469,360
NOx	0	7,059	7,059
OG	1,983	44,117	46,100
TSP	1,200	74,117	75,317
TOTAL	13,723	584,113	597,836

Estimating the impacts of pollutants is difficult even for industrial point sources, since the sources and receptors are often distant from one another, with many intervening variables. For wildfire, the emission-to-impact chain of causation goes something like this. First, a fire occurs, emitting varying amounts of pollutants depending upon its size, the fuels burning, the moisture content of those fuels, topography, and meteorological conditions. Next, those pollutants are transported from the site of emission to potential receptors. The dosage of the pollutant (concentration and duration) received by the receptor will be strongly influenced by the transport distance and intervening meteorological factors. The actual impacts suffered by the receptor will depend upon susceptibility (e.g., for human receptors, age, asthma, chronic obstructive pulmonary disease, etc.).

Trying to attach economic value to the impacts of air pollutants is formidable. While some work has been done in this area, the results are limited and in many cases are difficult to translate to pollutants arising from wildfire.

Overall, the air quality impacts of smoke from wildland fire are important, especially given the fact that most air basins in the state are in non-attainment status for many pollutants, including those most closely associated with wildfire. According to RERI (1994) none of the state's 14 air basins were in attainment with state PM10 standards at the 1987 benchmark date; only half were in attainment with the weaker federal standard.

Resources Protected

Wildfire smoke emissions can affect visibility, human health, materials and vegetation, and pollutant rights. Each category is examined in turn. Finally, an overall estimate of marginal pollutant economic impacts is presented.

Visibility. Visibility relates to a person's ability to see objects in the distance and the manner in which pollutants decrease visibility. Air pollution can have significant, adverse impacts on the aesthetic assets of visibility (Chestnut et al. 1994). In the extreme, loss of visibility can affect public safety. The wildfire-related pollutant of greatest impact on visibility is particulate matter.

Analysts have defined two primary visibility categories, residential and recreational, with the former category providing the bulk of the related economic value (Chestnut et al. 1994). The values individuals place on improvements in visibility have generally been estimated through a survey method known as contingent valuation. While this method has its limitations, it provides the preponderance of the information available on the economic value of visibility.

Estimates of the value of visibility are usually based on a general improvement in air quality over the course of a year. It is not possible to translate these estimates into a value for loss of visibility for a single acute visibility impairing event such as a wildfire. Based on their own work and that of others, Chestnut et al. (1994) provide estimates of value for a 20 percent improvement in residential air quality. The estimate of value ranges from $112 per household per year to $224 per household per year, with $157 per household per year accepted as the central estimate (all figures are 1995 dollars).

For recreation assets, values for protecting visibility in parks is most often examined. Given the high level of outdoor recreation that occurs in California, and considering the presence of such unique and highly visited outdoor resources as Yosemite National Park and the Tahoe Basin, these assets, in aggregate, can be considerable. Individuals are expected to value not only the opportunity to enjoy good visibility during their own visits to parks, national forests, and other areas, but also the opportunity for others to enjoy that visibility now and in the future. Chestnut et al. (1994) found a total value of $16 per household per year for in-state residents and $9 per household per year for out-of-state residents for a 20 percent improvement in air quality (all figures are 1995 dollars). While these data indicate significant values for improvements in overall visibility in both residential and recreation areas, they cannot easily be translated to the acute visibility effects of wildfire.

Human Health Knowledge of the health effects of wildfire smoke emissions is limited. A recent study of effects of smoke exposure of prescribed burning workers recommended a health risk assessment to evaluate the likelihood of acute and chronic health effects of exposure (Reinhardt et al. 1994). These researchers conclude that the most significant pollutants for firefighter health include carbon monoxide, aldehydes, benzene, and respirable particulate. However, smoke exposure at large, intense wildfires is likely different than at prescribed fires, and different yet than the general public's exposure to smoke some distance from the fire itself. In terms of general public health considerations, respirable particulate matter appears to be the pollutant of greatest import.

Most of the particulate matter produced in wildland fire is respirable; that is, it is small enough to pass through the upper respiratory system and enter the lungs. Acute smoke impacts include eye, mucous membrane, and respiratory tract irritation, aggravation of chronic respiratory and cardiac disease, and reduced lung function (Reinhardt et al. 1994, RERI 1994). Although placed in a fairly innocuous category by OSHA, studies have shown wood smoke to have a high mutagenic and carcinogenic potential, and epidemiological studies have connected disease and adverse respiratory symptoms with particulate laden atmospheres (Reinhardt et al. 1984). However, the effects of chronic exposure to wood smoke over the long term remain uncertain.

Economic value of health impacts is most often measured by medical expenditures and lost wages. However, since this does not account for pain and suffering, such estimates represent at best a low bound economic estimate of health impacts (RERI 1994). These authors established a table of estimates for the economic value of health impacts (Table 4).

Table 4. Estimated Economic Impact of Health Effects (1995 dollars)

	Estimated Range of Impacts		
Impact	Low	Medium	High
Cough	$3.14	$7.32	$14.64
Headache	3.14	7.32	14.64
Eye Irritation	3.14	7.32	14.64
Chest Discomfort	3.14	7.32	14.64
ARD	3.14	7.32	14.64
TRRAD	23.54	48.64	73.74
MRAD	14.64	23.54	40.27
Asthma Attack	11.51	33.47	55.44

ARD = any respiratory disease days
TRRAD = total respiratory related restricted activity days
MRAD = minor restricted activity days
Source: RERI 1994.

Where air pollution causes death, placing an economic value on that loss is generally done through a "value of a statistical life" approach. RERI (1994), based on a comprehensive review of the literature and considerations of various factors, accepted a mid-range value of $4.2 million dollars for the value of a statistical life.

While these health and associated economic impact data are enlightening, they are of limited use since there are no functional relationship data available to link wildfire occurrence to the resulting levels of health impacts. Thus, we have no ability to calculate overall economic impacts.

Materials. Damage to materials from exposure to the smoke of wildland fires is related to the effects of particulate matter in soiling and discoloring structural metals, fabrics, and building materials (RERI 1994). Dose-response estimates for materials damage have been fraught with much uncertainty, making it difficult to estimate the economic impacts of smoke from wildfire. However, RERI (1994) has estimated that a one-unit reduction in PM10 (in micrograms per cubic meter) results in $3.13 (1995 dollars) benefit in saved cleaning costs per household. This estimate cannot be conveniently translated into the wildfire situation, however, since it is a measure of the benefits resulting from a change in average annual PM10 levels, not the acute, short term changes that might be associated with a wildfire.

Vegetation. Air pollution damage to vegetation, including timber, is primarily related to ozone and sulfur dioxide exposure (RERI 1994). Since these are not major components in the smoke of wildland fires, it appears that vegetation is little affected by the smoke of such fires and need be considered no further in this analysis.

Pollution Rights. In recent years, air quality regulators have moved in part to use market approaches to allocating among industrial polluters the atmosphere's limited capacity to absorb air pollutants. As a part of this approach, regulators in some air basins now allow polluters to buy and sell rights to emit specified quantities of pollutants within a given airshed. These approaches can achieve more economically efficient pollution control results than systems based on technological controls alone (Tietenberg 1985).

The Air Resources Board monitors the prices paid in exchanges of pollution rights in California air basins. Among the pollution rights traded, particulate matter is the one most relevant for wildfire. In 1993, rights for emission of approximately 45 tons per year of PM were exchanged, with prices ranging from $10,000 to $25,000 per ton per year and averaging $19,123 per ton per year (Air Resources Board 1994). PM had the highest average ton/year value of the four criteria pollutants examined in the report.

These pollution rights represent a perpetual right to emit the given quantity of pollution each year. If we annualize this value, using a 7.5 percent real discount rate, the average $19,123 per ton per year perpetual pollution emission value has an annualized value of $1,434 per ton per year.

Referring to the emission factor information presented in Table 2, grass and woodland fires emit 23 pounds of particulate matter per acre burned and timber and brush fires emit 630 pounds. Thus, if we assume that a change in wildfire emissions creates a similar value as PM pollution rights, we can estimate the economic impacts of a marginal increase or reduction in a given year's wildfire PM emissions, based on the change in number of acres burned. For grass and woodland, the value would be $16 per acre per year and for timber and brush, the value would be $452 per acre per year. Since one generally would not burn the same piece of ground more than once in a year, we can functionally cancel out the per-year unit of these variables and assume that the air pollution right cost of burning an acre is $16 for grass and woodland and $452 for timber and brush.

These values must be used carefully, however. First, not all air basins have a market in PM pollution rights, thus there would be no pollution right value for PM in such basins. In 1993, there were PM rights transactions in only three air basins, the San Francisco Bay Area, Sacramento Metropolitan, and the South Coast. However, the fact that most air basins are nonattainment for PM suggests that there may be other areas where a pollution rights value could be ascribed to wildfire PM emissions.

Looking at the Bay Area air basin, in 1992, 4,121 acres of grass and woodland and 320 acres of timber and brush burned on CDF-DPA. Using the data above, these fires emitted an estimated 148 tons of PM, with a value of approximately $211,000. In the South Coast air basin in 1992, 3,782 acres of grass and woodland and 9,601 acres of timber and brush burned on CDF-DPA. Thus, these fires emitted an estimated 3,068 tons of PM with a value of approximately $4.4 million. Totaling for these two air basins with active PM pollution rights markets, the value of wildfire smoke emissions in 1992 was approximately $4.6 million.

Greenhouse Gases. Carbon is an important contributor to the greenhouse effect. The California Energy Commission (1995) estimates an externality impact of $36 per ton (1995 dollars) for carbon emissions. Converting this value to CO emissions yields an externality impact of $15.43 per ton of CO. One could use the emission factors in Table 2 to calculate a carbon impact value for wildland fire (the results would be $1.56 per acre of grass or woodland burned and $30.09 per acre of timber or brush burned). However, the impact value for carbon is calculated on the basis of fossil fuel combustion and assumes that the carbon released to the atmosphere will not be directly re-sequestered. Since the carbon released in a wildland fire will eventually be re-sequestered in vegetative regrowth on the same site, it seems more appropriate to view the release of carbon from wildland fire as a short-term impact that does not contribute to long-term accumulation of greenhouse gasses. Therefore, it is the recommendation of this plan that carbon impact values not be calculated for wildland fire, whether the fire is prescribed or not.

Table 5. Overall Marginal Pollution Impact Values for PM10 (1995 dollars)

				Including Pollution Right Value	
Air Basin	Marginal Emission Value ($/ton)	Grass and Woodland ($/acre)	Timber and Brush ($/acre)	Grass and Woodland ($/acre)	Timber and Brush ($/acre)
San Francisco Bay Area	24,258	279	7,641	295	8,093
South Central Coast	6,441	74	2,029	74*	2,029*
South Coast	46,458	534	14,634	550	15,086
San Diego	24,593	283	7,747	283*	7,747*
Sacramento Valley	2,935	34	925	50	1,377
Southeast Desert	708	8	223	88*	223*
San Joaquin Valley	5,184	60	1,633	60*	1,633*
North Central Coast	6,441	74	2,029	74*	2,029*
North Coast	1,703	20	536	20*	536*
Great Basin Valley	125	1	39	1*	39*
Northeast Plateau	395	5	124	5*	124*
Lake Tahoe	924	11	291	11*	291*
Lake County	908	10	286	10*	286*

Unweighted Average	9,313	107	2,934	111	3,038

* indicates assumed PM10 pollution right value is zero.
Sources: California Energy Commission 1993, 1995; Air Resources Board 1994.

Rangeland

Introduction

California's 82,470,000 acres of rangeland are a critical part of the productive base of the range livestock industry in the state (CH2MHILL 1989). This rangeland crosses a wide spectrum of vegetation covertypes, from desert, to annual grasslands, to chaparral, to oak woodlands, to conifer forest. Of this area, an estimated 30,000,000 acres are actually grazed. Total annual revenue produced by the range livestock industry is in the vicinity of $1 billion (Tippet,pers. comm., 1995).

This report examines the value of the forage provided by rangelands and the loss to the rangeland owner or lessee when grazed lands burn in wildfires. When rangeland burns, assets other than forage may be affected as well, such as wildlife habitat, water quality, and air quality. These impacts are addressed in other asset sections.

Value of Forage Production from Grazed Lands

Using a market value approach, the value of forage production from grazed lands in the state can be measured by the fees paid by the livestock industry to graze these lands. CH2MHILL (1989) presents data on grazed acreage, carrying capacity, and grazing fees. Table 6, below, presents the annual value of grazing in the state, based on the data in CH2MHILL, with adjustment of grazing fees to 1995 dollars. Table 7 presents a key to the abbreviations for the covertype and ownership categories found in Table 6.

As indicated in Table 6, the annual value of grazing in the state is approximately $138 million per year. Thus, forage value represents about 13 percent of the total value of the range livestock industry's annual output. Regionally, the highest grazing value is found in the San Joaquin Valley ($54.1 million per year) and the lowest on the East Side ($1.9 million per year).

Table 6. Annual Value of Grazing in California (in dollars)

Cover Type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Total
CHP.BLM	$287	$2,851	$861	$837	$8,530	$3,230	$0	$10,269	$26,864
CHP.OP	118	1,994	1,827	130	357,576	1,788	26	7,861	371,320
CHP.PVTL	40,271	105,477	46,598	10,625	42,920	2,890	0	1,661	250,442
CHP.PVT	375,189	272,996	362,239	327,373	4,434,287	317,815	3,190	1,556,428	7,649,517
CHP.FS	120	10,663	7,749	4,143	59,668	8,457	4,243	27,408	122,451
WET.BLM	0	1,848	0	0	0	0	25,694	122	27,664
WET.OP	2,082	11,841	567	572	19,988	4,202	1,002	390	40,644
WET.PVTL	15,573	37,817	0	16,955	0	0	0	0	70,345
WET.PVT	109,043	425,525	993,443	67,792	238,308	2,494,474	450,983	36,660	4,816,227
WET.FS	0	23,226	6,393	2,902	0	5,691	2,772	1,009	41,994
OAK.BLM	2,630	4,914	3,193	3,542	17,196	55,466	0	385	87,326
OAK.OP	37	1,073	46,276	92	342,343	19,284	0	385	409,491
OAK.PVTL	464,668	44,794	43,610	0	146,090	116,821	0	0	815,983
OAK.PVT	1,972,610	2,305,505	4,129,931	2,668,246	11,786,387	15,706,696	0	87,515	38,656,891
OAK.FS	7,110	18,966	14,622	22,534	7,382	118,562	0	13,089	202,264
AGR.BLM	3,708	3,695	2,027	1,877	24,540	58,304	0	33,238	127,390
AGR.OP	1,397	3,934	167,751	350	796,479	11,454	0	5,709	987,075
AGR.PVTL	486,071	117,787	36,167	33,004	109,961	36,820	0	4,643	824,453
AGR.PVT	5,910,289	1,523,383	6,184,303	3,867,689	16,908,744	33,474,897	0	1,799,509	69,668,816
AGR.FS	1,370	43,226	1,155	585	0	15,565	0	2,757	64,658
PGR.OP	813	0	0	0	0	0	0	0	813
PGR.PVTL	0	0	0	0	0	0	0	0	0
PGR.PVT	301,093	0	0	0	0	0	0	0	301,093
PGR.FS	$0	$2,985	$4,788	$231	$0	$0	$674	$0	$8,677
CON.BLM	1,476	6,573	312	694	363	2,313	220	410	12,361
CON.OP	64	3,489	306	141	13,146	3,512	1,026	220	21,904
CON.PVTL	784,982	997,955	297,415	190,882	43,652	21,387	0	1,531	2,337,805
CON.PVT	866,705	457,732	205,487	289,489	385,166	317,253	12,976	47,508	2,582,316
CON.FS	6,798	142,115	68,172	44,199	19,638	43,361	45,552	12,450	382,287
SAG.BLM	0	176,071	358	15	0	11,697	56,819	4,486	249,444
SAG.OP	0	24,833	100	0	0	717	207,344	772	233,766
SAG.PVTL	0	162,014	7,601	0	0	3,375	0	0	172,991
SAG.PVT	0	3,021,696	184,965	6,206	13,263	759,413	611,959	3,764	4,601,266
SAG.FS	0	75,699	8,160	147	0	5,719	47,053	0	136,778
JUN.BLM	0	21,723	525	0	0	6,024	9,788	11,344	49,404
JUN.OP	0	1,968	118	0	0	71	16,095	55	18,308
JUN.PVTL	0	48,580	0	0	0	0	0	1,544	50,123
JUN.PVT	0	378,667	25,746	0	4,636	128,636	56,476	92,185	686,347
JUN.FS	0	49,560	801	0	29	2,546	18,294	1,169	72,399
DES.BLM	0	0	0	0	0	14,455	12,344	139,475	166,275
DES.OP	0	0	0	0	0	86	121,771	13,869	135,727
DES.PVTL	0	0	0	0	0	0	0	424	424
DES.PVT	0	0	0	0	0	303,166	186,472	355,694	845,333
DES.FS	0	0	0	0	0	205	102	202	508
Total	11,354,503	10,533,175	12,853,568	7,561,250	35,780,292	54,076,354	1,892,875	4,276,143	138,328,161

Table 7. Key to Abbreviations in Table 6

Abbreviation	Definition
*.BLM	land managed by the Bureau of Land Management
*.FS	land managed by the USDA Forest Service
*.OP	land managed by a public agency other than the above two
*.PVT	privately owned land
*.PVTL	privately owned land under lease
CHP.*	chaparral
WET.*	wetlands
OAK.*	oak woodland
AGR.*	annual grasslands
PGR.*	perennial grasslands
CON.*	conifer lands
SAG.*	sagebrush
JUN.*	juniper lands
DES.*	desert

Impact of Wildland Fire on Grazing Value

Wildland fire impacts rangeland by burning up the forage present on the land at the time of the fire, as well as by reducing forage production for the next two years. In some cases, however, fire can result in a net increase in forage production over time. The actual magnitude of the economic impact to the landowner depends upon the land's carrying capacity, whether the land is being grazed, the time of year at which the fire occurs, the amount of the year's forage which has already been grazed, and the intensity of the fire. When grazed lands are burned, lost forage must generally be replaced through feeding oat hay or alfalfa to the livestock (McDougald, pers. comm., 1995).

Replacement feeding costs were calculated using statewide averages for oat hay and alfalfa prices; regional data were not available (USDA Statistical Reporting Service). Prices reported for January 1995 were $85/ ton for oat hay and $123/ton for alfalfa. Transportation costs and feeding costs were each assumed to be $15/ton (McDougald, pers. comm., 1995). One animal unit month of feeding was assumed to be 800 pounds of a 60/40 mix of oat hay and alfalfa (McDougald, pers. comm., 1995).

It was assumed that the burning of rangelands would affect forage productivity for the current year plus two additional seasons (McDougald,pers. comm., 1995). We assumed that although all the standing forage would be destroyed by the fire, only half of the year's forage production would be lost because, on average, half of the forage would be consumed by livestock before the fire occurrence. The first year after the fire, forage production was assumed to be 50 percent of normal. The second year after the fire, production is assumed to be 80 percent of normal. We assumed productivity would be back to normal by the third year after the fire. These assumptions may overstate losses since fire in many cases can increase forage production over time.

Based on these assumptions, we compared the discounted three-year stream of costs of forage provision without fire to the three-year stream of costs with fire (including the costs of providing supplemental hay and alfalfa feeding). A 5 percent real discount rate was used. The difference between these two cost streams represents the loss to grazers due to fire.

We calculated these losses on a per-acre basis at the disaggregated level of region, cover type, and ownership. Table 8 presents the results when the fire affects grazed lands specifically. Table 9 presents the results for rangeland as a whole — whether grazed or not — based on the assumption that the probability of fire affecting an acre of grazed rangeland versus an acre of ungrazed rangeland is proportional to the relative fraction of all rangeland that these two categories represent. Since one does not know ahead of time whether the rangeland that will burn is grazed or not, the values presented in Table 8 are the most appropriate ones to use for fire planning. It should also be noted that grazed acres are more likely to receive fire prevention treatments than ungrazed acres, and thus may actually be at somewhat lower risk to fire than ungrazed acres.

Table 8 shows that the weighted statewide average loss when grazed rangeland burns is $24/acre. Average costs range from $4 per acre on the South Coast to $52 per acre on the North Coast.

Table 9 shows that the weighted statewide average loss when rangelands in general burn is $8 per acre. Average costs range from $1 per acre on the South Coast to $25 per acre in the San Joaquin Valley.

Recreation, Cultural and Historic Resources

Introduction

This report discusses wildland recreation and unique assets in California and how their values are affected by wildfire. Part one identifies recreation assets; part two assesses their commodity and non-commodity market values and how they are affected by wildfire.

California’s 18 national forests, 17 national park units, nearly 300 state park units, and numerous county and local parks are a major recreation draw for state residents, people from other states, and citizens of other nations. Unique natural places, such as Yosemite National Park, often exert a powerful force on the imagination, and contribute to the world perception of California as the place that "has it all," not just beautiful beaches, shimmering deserts, snow-capped mountains, and fertile valleys, but some of the world's most spectacular hunting, fishing, hiking, and camping country as well. Recreation visits to California’s state parks, national forests, and national parks exceed all other states in the nation (U.S. Department of Commerce, 1986). Visitation figures are important as a means of gauging just how many people visit California's wildlands and forests, and just how much money those facilities generate themselves. But this is only a part of the picture, for many tourists attracted by recreation opportunities make a significant contribution to the state economy which is not reflected in the identification of actual recreation market values. Visitors get to California by purchasing airline tickets, they stay in hotels, purchase meals and gasoline, and often do many other things besides outdoor

Table 8. Cost impact of Burning One Acre of Grazed Rangeland (in dollars)

Cover Type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Weighted Average
CHP.BLM	$3.08	$12.34	$12.96	$8.02	$17.53	$5.43	$3.61	$8.41	$9.61
CHP.OP	35.76	29.13	13.12	7.71	15.98	6.81	41.46	16.88	15.90
CHP.PVTL	33.10	27.56	13.62	8.00	16.12	6.44	48.85	15.98	19.25
CHP.PVT	33.10	27.56	13.62	8.00	16.12	6.44	39.23	15.98	14.98
CHP.FS	40.77	9.02	19.88	13.05	19.53	12.11	9.89	1.16	4.13
WET.BLM	0.00	77.94	0.00	0.00	0.00	0.00	71.69	25.56	71.50
WET.OP	80.54	102.35	65.82	66.36	65.14	80.56	501.15	87.37	76.97
WET.PVTL	76.20	96.83	77.55	62.79	75.88	94.91	590.44	102.94	81.33
WET.PVT	76.20	96.83	62.28	62.79	60.93	76.22	474.15	82.66	79.85
WET.FS	0.00	37.67	68.66	32.98	0.00	51.92	19.03	12.00	36.93
OAK.BLM	59.43	97.85	83.02	73.16	81.97	80.57	0.00	26.95	79.83
OAK.OP	80.59	122.36	49.21	35.32	30.97	54.90	0.00	18.26	33.07
OAK.PVTL	76.25	115.77	46.65	41.61	29.30	51.94	0.00	21.51	55.70
OAK.PVT	76.25	112.50	46.65	33.42	29.30	51.94	0.00	17.27	41.62
OAK.FS	124.83	64.58	58.97	49.38	155.69	47.98	0.00	1.17	27.12
AGR.BLM	173.26	97.67	80.24	108.42	117.69	93.66	0.00	60.05	85.71
AGR.OP	135.80	132.39	36.24	45.60	48.29	63.15	0.00	56.65	46.46
AGR.PVTL	117.83	121.43	37.61	46.49	49.40	59.74	0.00	53.60	85.04
AGR.PVT	117.83	121.43	37.61	46.49	49.40	59.74	0.00	53.60	55.89
AGR.FS	243.99	98.09	114.66	108.37	131.86	102.25	0.00	61.43	98.13
PGR.OP	105.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	105.67
PGR.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGR.PVT	99.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.98
PGR.FS	0.00	11.56	32.57	7.10	0.00	0.00	22.95	0.00	18.58
CON.BLM	6.19	5.99	8.99	7.17	15.65	11.29	7.37	9.01	6.98
CON.OP	15.97	10.31	3.55	4.24	7.91	12.68	43.29	13.02	9.31
CON.PVTL	15.11	10.70	3.34	4.40	8.21	11.99	51.00	12.32	8.21
CON.PVT	15.11	10.70	3.34	4.40	8.21	11.99	40.95	12.32	8.47
CON.FS	14.54	6.28	6.30	5.62	10.25	3.91	5.40	10.31	5.93
SAG.BLM	0.00	20.23	15.21	9.35	0.00	12.54	6.66	0.87	10.69
SAG.OP	0.00	25.97	6.99	9.78	13.83	11.57	22.24	1.37	21.41
SAG.PVTL	0.00	24.58	6.33	9.78	13.83	10.95	26.21	1.62	22.48
SAG.PVT	0.00	24.58	6.33	7.86	11.11	10.95	21.04	1.30	18.67
SAG.FS	0.00	20.57	16.28	10.34	0.00	13.02	10.49	0.00	15.00
JUN.BLM	0.00	9.68	11.22	0.00	0.00	7.35	5.75	3.20	5.91
JUN.OP	0.00	25.84	8.02	0.00	8.05	9.42	42.82	12.33	38.24
JUN.PVTL	0.00	24.45	9.45	0.00	8.05	11.09	50.45	11.66	23.65
JUN.PVT	0.00	24.45	7.59	0.00	6.47	8.91	40.51	11.66	15.84
JUN.FS	0.00	10.90	8.88	0.00	2.64	7.43	6.31	4.29	8.87
DES.BLM	0.00	0.00	0.00	0.00	0.00	3.35	2.21	1.12	1.23
DES.OP	0.00	0.00	0.00	0.00	0.00	2.31	8.25	1.11	4.98
DES.PVTL	0.00	0.00	0.00	0.00	0.00	2.73	9.72	1.05	1.05
DES.PVT	0.00	0.00	0.00	0.00	0.00	2.19	7.81	1.05	1.69
DES.FS	0.00	0.00	0.00	0.00	0.00	3.11	0.81	0.89	1.22
Wtd. Ave.	$52.45	$21.04	$23.95	$21.21	$30.93	$41.25	$10.64	$3.52	$23.59

This table measures the loss to the owner/grazer when an acre of grazed land burns. It is based on the difference between feeding the livestock forage vs. feeding them hay/alfalfa.

Table 9. Cost impact of Burning One Acre of Rangeland (in dollars)

Cover type and Ownership	North Coast	Northern Interior	Sacramento Valley	Central Sierra	Central Coast	San Joaquin Valley	East Side	South Coast	Weighted Average
CHP.BLM	$0.21	$1.69	$0.41	$0.29	$0.99	$1.64	$0.00	$1.24	$0.99
CHP.OP	0.04	0.26	0.24	0.01	5.29	0.12	0.00	0.13	1.74
CHP.PVTL	10.01	4.19	4.15	3.14	9.21	3.41	0.00	3.92	5.03
CHP.PVT	10.01	4.19	4.15	3.14	9.21	3.41	3.01	3.92	6.04
CHP.FS	0.06	1.88	1.39	2.14	1.49	0.92	1.14	0.84	1.21
WET.BLM	0.00	19.74	0.00	0.00	0.00	0.00	13.08	3.91	13.24
WET.OP	2.26	1.83	0.08	0.46	14.04	0.61	1.30	0.21	1.58
WET.PVTL	36.77	44.64	0.00	26.68	0.00	0.00	0.00	0.00	36.90
WET.PVT	36.78	44.65	23.93	26.67	60.93	64.01	40.18	15.74	42.23
WET.FS	0.00	10.79	17.08	6.20	0.00	7.02	3.42	2.49	8.26
OAK.BLM	3.24	10.50	2.23	2.99	3.70	13.27	0.00	4.11	6.81
OAK.OP	0.01	6.97	8.03	0.02	11.30	2.32	0.00	0.19	7.55
OAK.PVTL	41.40	35.25	20.59	0.00	24.64	50.15	0.00	0.00	35.67
OAK.PVT	41.40	34.25	20.59	21.43	24.64	50.14	0.00	8.26	31.10
OAK.FS	113.97	7.51	9.57	6.69	78.88	12.88	0.00	1.17	9.51
AGR.BLM	7.43	14.81	3.61	3.76	8.65	22.25	0.00	21.75	14.48
AGR.OP	0.77	2.91	12.07	0.19	26.51	0.97	0.00	0.67	11.69
AGR.PVTL	52.16	37.08	21.35	31.17	39.94	57.95	0.00	21.92	43.74
AGR.PVT	52.16	37.08	21.35	31.16	39.94	57.96	0.00	21.90	42.19
AGR.FS	2.93	22.72	2.85	3.75	0.00	19.96	0.00	17.68	15.82
PGR.OP	5.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.64
PGR.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PGR.PVT	74.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71.08
PGR.FS	0.00	2.81	9.59	1.06	0.00	0.00	5.40	0.00	4.28
CON.BLM	0.35	1.14	0.30	0.21	0.31	4.12	0.64	1.64	0.74
CON.OP	0.00	0.09	0.11	0.00	0.47	0.06	1.33	0.06	0.08
CON.PVTL	3.24	2.93	2.55	2.14	3.03	8.42	0.00	3.62	2.90
CON.PVT	3.24	2.93	2.55	2.14	3.03	8.42	1.86	3.62	3.13
CON.FS	0.27	0.96	1.10	0.94	1.06	0.81	1.79	1.06	0.98
SAG.BLM	0.00	5.41	1.91	0.47	0.00	3.35	1.21	0.64	2.77
SAG.OP	0.00	1.15	0.10	0.00	0.00	0.10	1.13	0.03	0.96
SAG.PVTL	0.00	12.14	6.33	0.00	0.00	7.97	0.00	0.00	11.76
SAG.PVT	0.00	12.14	6.33	1.83	8.95	7.97	9.26	0.56	10.32
SAG.FS	0.00	5.40	4.76	0.67	0.00	2.44	2.32	0.00	3.54
JUN.BLM	0.00	2.48	2.40	0.00	0.00	1.61	1.10	2.13	1.83
JUN.OP	0.00	0.46	0.77	0.00	0.00	0.46	1.08	0.02	0.84
JUN.PVTL	0.00	5.88	0.00	0.00	0.00	0.00	0.00	2.43	5.63
JUN.PVT	0.00	5.88	7.15	0.00	2.43	4.37	8.89	2.43	4.78
JUN.FS	0.00	2.93	2.14	0.00	0.02	1.22	1.32	0.43	1.93
DES.BLM	0.00	0.00	0.00	0.00	0.00	1.03	0.27	0.48	0.48
DES.OP	0.00	0.00	0.00	0.00	0.00	0.00	0.73	0.03	0.18
DES.PVTL	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.40
DES.PVT	0.00	0.00	0.00	0.00	0.00	2.05	5.54	0.40	0.79
DES.FS	0.00	0.00	0.00	0.00	0.00	0.82	0.07	0.14	0.16
Wtd. Ave.	$10.94	$4.93	$9.44	$7.26	$16.35	$24.64	$1.86	$1.19	$8.49

This table measures the loss to the owner/grazer when an acre of rangeland burns. It is assumed that the amount of such rangeland that is grazed is directly proportional to the amount of all such rangeland that is grazed.

recreation. Non-residents constitute a significant portion of recreational use of the state's wildlands. The California Department of Tourism estimates that non-residents accounted for 46 percent of the 48 million trips takenin California during 1983-84. Nearly 3 million non-resident trips are estimated to have had outdoor recreation as the primary purpose and consisted of visits to the state's parks and forests (Keye, Donna and Pearlstein Inc., 1985).

Recreation and Unique Areas in California

General Wildland Recreation. Outdoor recreation is typically defined in terms of Recreation Visitor Days (RVDs). One RVD represents 12 hours of participation in any recreation activity. According to information obtained from the relevant agencies, annual forest and rangeland recreation on state and federal lands has averaged over 112 million RVDs in recent years according to data collected from the relevant agencies (Table 9). National forest use amounted to 71.5 million RVDs, national parks 19.8 million RVDs, state parks 12.8 million RVDs, and Bureau of Land Management lands about 8 million RVDs.

National forest recreation in the state is estimated to represent one quarter of all national forest recreational use throughout the U.S., although the 20 million acres of national forest land represent only 11 percent of the national total. Recreation on national forests is distributed among the 18 national forest units administered in the state.

The National Park Service administers 22 units in California, although not all of these provide wildland recreation opportunities. Yosemite National Park is the most visited national park in the state and one of the top national park destinations in the nation. Internationally renowned, it draws thousands of visitors from outside the United States each year.

The Bureau of Land Management manages 17 million acres of California lands. Off-highway driving and camping are the most popular activities.

The state park system contains nearly 300 units and covers almost 1.3 million acres. Anza-Borrego Desert State Park in San Diego County accounts for 553,000 acres, or nearly half of the total state park system acreage. Average size of the other parks is 5,000 acres. About one-half of the 300 units, or 1.2 million acres, support some form of wildland recreation.

The central Sierra region is the most heavily used recreation area in the state. This is a function of the large number of recreation opportunities on national forests and parks (including Lake Tahoe) and the close proximity of major population centers. Southern California also supports a high number of RVDs, particularly on national forests. Southern California has less national forest acreage (about 1.8 million acres) than any other region except the North Coast Region (0.9 million acres). Yet the amount of national forest use is higher than anywhere else in the state and 30 times greater than the North Coast.

Recreation on lands other than those owned by the state or federal government is more difficult to assess because there is little coordinated record-keeping and few available records. These other lands include private recreation facilities, such as campgrounds, hunting clubs, public utility lands, and county, city and regional parks.

Wildlife-Oriented Recreation. Wildlife-oriented recreation is a significant and high-value portion of wildland recreation. As indicated below in the section on effects of wildland fire on wildlife, fire effects are generally negative for fisheries, but can be positive, negative, or neutral with respect to other wildlife. The next few paragraphs illustrate the importance and value of wildlife-oriented recreation in California.

One partial measure of the value of wildlife-oriented recreation is expenditures for fishing and hunting licenses. In 1994, almost 2.4 million sportfishing licenses were issued in California, along with close to 900,000 sportfishing stamps. In total, these generated almost $4 million in license and stamp revenues. Hunting is also a popular recreational activity. More than 354,000 hunting licenses and 828,000 tags and permits were sold in the state in 1994. These sales generated about $14.6 million in revenues to the state. In total, fishing and hunting generated $18.6 million in licensing revenues.

Wildlife-oriented recreation generates some of the highest user values of any recreation form, according to the USDA Forest Service (1990). Based on this source, a wildlife and fish user day (WFUD) in California is valued at $77 for fishing, $40 for hunting, and $88 for non-consumptive wildlife use (all figures in 1995 dollars).

A survey sponsored in the mid-1980s by the Department of Parks and Recreation indicated that more people may participate in non-consumptive types of wildlife recreation than do actual hunting and fishing, such as bird watching or wildlife photography (California State University 1987). Out of the survey sample of 2,526 people statewide, nearly 34 percent said that they spent some or most of their leisure time outdoors and participated in at least one non-consumptive wildlife activity. Another 32.5 percent indicated they spent some or most of their leisure time outdoors and participated in at least one non-consumptive wildlife activity and also fished and/or hunted. Only about 3 percent stated they spent some or most of their leisure time outdoors, and hunted and/or fished, but did not participate in non-consumptive wildlife activities.

Archaeological and Historical Sites. Archaeological and historical sites represent another type of unique resource found in California. These include prehistoric Indian village sites, petroglyphs, pictographs (rock paintings), midden deposits, human burial grounds, caves, hunting blinds, and bedrock milling sites. Historic sites include buildings and structures of historical significance (such as Fort Ross, Bodie, etc.), Gold-Rush-era mining sites, wagon roads and trails, and cemeteries. Many of these historic resources contain irreplaceable assets which are at risk from wildfire. Some of these are situated on national and state park lands and directly contribute to the recreational use of a park. Most sites, however, have little recreation value as the public is often discouraged from unsupervised visitation due to relic hunting, site vandalism and other impacts. These sites have unique values in addition to contributing to recreation use of forest and range lands.

As of 1995, there are over 100,000 recorded archaeological sites in California; 59,000 of these are on federal lands, 33,000 are on private or other lands, 6,000 on state lands, and 12,000 are located on county, city or special district properties (California Office of Historic Preservation 1995). The California Office of Historic Preservation (1995) has estimated that approximately 100,000 additional unrecorded (undiscovered) archaeological sites exist within the state. This latter group is most at risk from wildfires since their locations are not known, and consequently difficult to protect during fire suppression activities. Additionally, California has 85,000 recorded historic buildings, most of which are situated in wildlands. This figure does not include historic districts in cities, which are excluded from this assessment. It is primarily the 85,000 structures in rural (wildland) locations that are at risk from escaped wildfires in California.

Value of Recreation and Unique Areas in California

USDA Forest Service economists have estimated a market value for each RVD within various recreation categories (USDA Forest Service 1990). The 1995 market value of one RVD is as follows: winter sports $49.86; resorts $20.52; wilderness $16.46; camping, picnicking, swimming $10.10; mechanized travel and viewing scenery $10.31; hiking, horseback riding, and water travel $13.60; and other recreation activities except wildlife and fishing $65.89. These figures were derived from 1989 data (USDA Forest Service 1990:18-19) and converted to 1995 dollars using the GNP deflator. A weighted average 1995 market value of $13.26 per RVD was estimated for this assessment. This value is only a partial measure of the value of recreation to the state.

Table 10 applies this value to recreation on California public lands to estimate the total and per-acre annual value of the recreation on these lands. Total annual recreation values are estimated at almost $1.5 billion for the four ownership categories. The value ranges from $6 per acre on BLM lands to $141 per acre on state park system lands. Again, it should be emphasized that these are low-bound estimates of the value of public lands recreation in the state. For example, Goldman and Gates (1986) calculated the total spending by wildland recreationists in California to be $4.9 billion, which resulted in $17.3 billion in gross output, $8.2 billion in regional income, and accounted for approximately 207,000 full-time jobs. There is no question that recreation users in California make a significant contribution to the state's economy.

We also estimated the average recreation values lost when an acre of wildland burns. Wildfire does not totally destroy the recreation value of lands that are burned. For example, consider the interest that was generated after the huge Yellowstone fires of 1988. Also, if a person avoids recreating on a given area because it has burned, he or she may be able to enjoy a similar recreation experience on another, unburned area. Of course, once an area burns in a severe fire, it may take years for it to return to its former condition. To what degree these assets are affected by wildfire is a complicated issue. For some recreation use, such as winter sports (e.g., skiing), wildfires do not seem to cause a significant decrease in recreation use of an area. The recreation use is sometimes improved by opening

Table 10. Estimated Forest and Rangeland Recreation Values in California (1993-94 average)

Landowner	Acres (millions)	RVDs (millions)	Dollars per RVD*	Total recreation value in dollars (millions)	Recreation values (/acre)	Recreation value lost per acre burned
National Park Service	4.7	19.8	13.26	263	56	42
USDA Forest Service	20.4	71.5	13.26	948	46	35
Bureau of Land Management	17.1	8	13.26	106	6	5
State Park System	1.2	12.8	13.26	170	141	107
Total in California	43.4	112.1		1,486	34	26

*$13.26 figure is a weighted average calculated in 1995 dollars.
Source: Listed agencies.

up new areas for expanded skiing opportunities. However, overall, statewide recreation use is significantly degraded by wildfires, particularly due to the direct cost of replacing recreation facilities and lost revenues during time of closure, and this effect is realized in millions of lost recreation dollars annually.

We estimated the recreation use value lost when an area burns by assuming that 15 percent of its recreation value is lost during the first year after the fire and that the percentage of value lost decreases to zero in a straight line over a 10-year period. Discounting this stream of losses to the present yields an average value loss of $10.04 per RVD for a burned area. Applying this value to Table 9 yields an average statewide loss of $26 of recreation use value per burned acre of public lands. The loss per acre varies from $5 on BLM lands to $107 for state park system lands.

We also wish to illustrate the damage wildland fire can cause to recreation facilities. The 1993 Green Meadow Fire burned 38,000 acres in the Santa Monica Mountains National Recreation Area (NRA). This NRA is composed of National Park Service lands, four state parks, and privately owned lands. The fire burned numerous bridges along trails, signs, recreation structures, and a pumphouse which provided water to the five campground sites. The total cost of repairing or replacing these facilities, removing hazard trees, and cleaning up campground facilities and recreation trails was $458,549. An additional $33,614 in lost campground revenues resulted from closure of recreation facilities.

Certain unique areas in California, such as significant scenic areas and major sites of archaeological or historical interest, also attract tourism and contribute to recreation values. These too are extremely difficult to quantify, but they contribute a sizable portion of the recreation value generated at state, local and national parks, and national and state forests. Examples where historical features represent a primary attraction to recreation use include the reconstructed Coast Miwok Village at Point Reyes National Seashore, Patrick's Point State Park with its reconstructed Yurok Village, Indian Grinding Rock State Park, the reconstructed, early-19th-century Russian fortress at Fort Ross, Vikingsholm at Emerald Bay in Lake Tahoe, and the standing ruins of a historic mining town at Bodie. There are numerous other examples where California's significant cultural sites contribute to its recreation markets.

The 1987 Case Fire provides an example of how unique assets are at risk to wildland fire. This fire resulted in significant damage to a prehistoric archaeological site, an ancient Indian village on a ridgetop. The site was bulldozed by firefighters during the construction of a fuelbreak on the ridgetop. The bulldozer crew knew of the site's location and attempted to avoid it but a change in the fire behavior put the lives of the crew in jeopardy. The dozer operators were forced to make a wide clearing to escape from the flames. In doing so, the archaeological site was badly damaged. CDF was required to conduct a rehabilitation and data recovery project at the site which cost a total of $12,310. While the direct cost of this damage is relatively low, it is important to emphasize that these costs do not adequately express the social value of the damage done to this cultural resource. These types of losses are incalculable.

Structures

Loss of structures is one of the more emotionally gripping and economically significant impacts of wildland fire in California. Statewide, there are an estimated one million housing units within California's wildlands or the wildland/urban interface. Approximately 500,000 of these housing units are owner-occupied, single-family homes with an average replacement cost of $140,000. Taken as a whole, these housing units have an estimated replacement cost of approximately $107 billion.

Based on fire records for 1985-94, an average 703 homes are lost per year to wildland fire in California. It should be noted, however, that the number of homes lost varies significantly from year to year. Housing values typically range from $15,000 on up, with the median, owner-occupied single-family home valued at $140,000 (excluding land value). Since the value of the homesite is little affected by wildfire, only the value of structures and contents should be considered. Discussions with insurance and fire officials indicate that the average market value of a home's contents is 20-25 percent of the replacement value, or about $35,000 per home. Thus, as a first approximation, the median house and contents are valued at an estimated $175,000.

When insurance claims are filed for homes lost to wildland fire, insurance companies face costs to process claims. The overall cost of operating insurance programs is estimated to be 45 cents per dollar of premium. However, this represents the average of all operating costs for an insurance company, not the marginal cost of handling a claim. As a rough approximation, it is estimated here that the transaction cost to insurance companies to settle a claim is 1 percent of the claim amount, on average.

In addition to insured property loss, homeowners also face a significant loss of intangibles in a house fire. While these losses are difficult to quantify and value, they should be considered in the evaluation of the effects of wildland fire on homeowners. As an approximation, we will assume that the average homeowner faces an uninsured loss of $10,000 when his or her home is lost to wildfire.

Additional costs associated with the loss of homes to wildland fire include disruption of utilities, transportation, and other public services. In addition, there are lost wages, costs of temporary shelter, and other costs that cannot be captured easily. We will assume that these costs average $10,500 per house lost to wildland fire.

Table 11 summarizes and totals the above-described costs. Total average annual costs statewide associated with loss of homes to wildfire is $163,271,750, or $232,250 per home.

Table 11. Estimated Average Annual Losses Due to Destruction of Homes by Wildland Fire

Category	Loss Amount
Dwellings and contents lost: 703/year @ $140,000 each	$ 98,420,000
Contents valued at 25 percent of dwelling	24,605,000
Total home and contents loss (equals insurance claim amount)	123,025,000
Insurance company transaction cost	
1 percent of claim cost or 1 percent of $123,025,000	1,230,250
Uninsured losses	
Intangibles: 703 dwellings/year @ $10,000 each	7,030,000
Other improvements on site: 25 percent of home loss or 25 percent x $98,420,000	24,605,000
Total uninsured losses	31,635,000
Disruption costs: 703 dwellings/year @ $10,500 each	7,381,500
Total loss to homeowner and others	$163,271,750

Timber

Introduction

This section estimates the effects of stand-replacing fires on the value of sawtimber in California. The data available allowed quantifying only direct, near-term effects of fire in economic terms. The indirect, long-term effects of stand replacing fires such as altered soil characteristics and forest successional patterns were not considered in this analysis. Indirect effects of non-stand replacing fires such as reduced health and disease susceptibility were not considered in this analysis of stand replacing fires. The analysis considered timberlands[2] available for harvest, excluding reserved lands and lands that did not meet the definition of timberland.

Four ownership categories, five inventory regions, and two forest types within one of the inventory regions, formed the basis for quantifying fire losses on timberlands

[2] *Timberlands as used here denotes land capable of growing at least 20 cubic feet of commercial timber species per acre per year.*

with different legal and biological characteristics. Ownership categories consisted of:

- National forests
- Other public lands owned by the Bureau of Land Management, individual counties and the state
- Forest industry (private holdings 5,000 or more acres)
- Non-industrial private (private holdings less than 5,000 acres)

The five relevant inventory regions, as defined by the Forest Inventory and Analysis (FIA) project of the USDA Forest Service, are:

- North Coast (Del Norte, Humboldt, Mendocino, and Sonoma counties)
- Northern Interior (Siskiyou, Modoc, Trinity, Shasta, and Lassen counties)
- Sacramento (Butte, Colusa, El Dorado, Glenn, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Sierra, Sutter, Tehama, Yolo, and Yuba counties)
- San Joaquin and Southern California (Alpine, Amador, Calaveras, Fresno, Imperial, Inyo, Kern, Kings, Los Angeles, Madera, Mariposa, Merced, Mono, Orange, Riverside, San Bernardino, San Diego, San Joaquin, Stanislaus, Tulare, and Tuolumne counties)
- Central Coast (Alameda, Contra Costa, Marin, Monterey, San Benito, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Solano, and Ventura counties)

The statistical limitations of the non-spatial timber inventories used in this analysis precluded estimating meaningful distinctions between forest cover types in most cases. The North Coast region was the exception: the presence or absence of redwood trees was used to distinguish between the coastal and interior forest types within this inventory region. Table 12 summarizes timberland acreage by cover type/region and ownership category.

Table 12. Acres of Timberland by Ownership and Inventory Region/Forest Cover Type

	Ownership				
Region/Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast/ Redwood+ Douglas-fir		114,000	566,000	622,000	1,302,000
North Coast/ Interior Mixed Conifer	619,000	149,000	735,000	808,000	2,311,000
Northern Interior	3,190,000	126,000	1,757,000	580,000	5,653,000
Sacramento	2,526,000	70,000	935,000	708,000	4,239,000
San Joaquin and Southern California	1,898,000	50,000	167,000	303,000	2,418,000
Central Coast	53,000	8,000	24,000	255,000	340,000
All Regions	8,286,000	517,000	4,184,000	3,276,000	16,263,000

Using the FIA inventory data and national forest inventory data, Table 13 presents the average timber volume per acre in each ownership and cover type category. In the next step of the analysis, multiplying current timber market prices from the state Board of Equalization with average volume estimates from Table 13 and timberland acreage from Table 12 resulted in an estimate of total standing timber value, in dollars (Table 14). Table 15 presents standing timber values on a per-acre average basis. Finally, historical records of fire damage provided estimates of the financial loss in timber values per acre resulting from a stand replacing fire (Table 16), based on an estimated loss of 65 percent of value from standing timber value.

The sections below further explain the methodology used to derive the data presented in Tables 12-16.

Table 13. Average Volume of Sawtimber (board feet, Scribner rule) Per Acre, by Ownership and Inventory Region/Forest Cover Type

	Ownership				
Region/Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All Ownerships
North Coast Redwood/ Douglas-fir		22,918	23,053	21,365	22,235
North Coast/ Interior Mixed Conifer	21,550	17,002	8,788	6,457	11,921
Northern Interior	11,670	9,821	8,255	7,405	10,130
Sacramento	22,200	14,411	14,576	11,279	18,566
San Joaquin and Southern California	20,120	9,410	17,872	3,913	17,712
Central Coast	10,500	11,626	26,976	24,008	21,821

Table 14. Total Value of Timber (millions of dollars), by Ownership and Inventory Region/Forest Cover Type

	Ownership				
Region/Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast/ Redwood+Douglas-fir		$1,371	$7,773	$7,391	$16,535
North Coast/Interior Mixed Conifer	5,998	1,330	3,848	2,902	14,078
Northern Interior	14,513	495	5,423	1,638	22,069
Sacramento	24,237	502	5,921	3,698	34,358
San Joaquin and Southern California	11,469	165	984	415	13,033
Central Coast	326	47	409	3,833	4,615
All Regions	$56,543	$3,910	$24,358	$19,877	$104,688

Table 15. Per-acre Value of Timber (dollars per acre), by Ownership and Inventory Region / Forest Cover Type

	Ownership				
Region / Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast / Redwood+ Douglas-fir		$12,028	$13,733	$11,883	$12,700
North Coast / Interior Mixed Conifer	9,690	8,923	5,235	3,591	6,092
Northern Interior	4,549	3,932	3,086	2,825	3,904
Sacramento	9,595	7,178	6,333	5,223	8,105
San Joaquin and So. California	6,043	3,306	5,894	1,369	5,390
Central Coast	$6,158	$5,813	$17,035	$15,030	$13,574

Table 16. Estimated Loss, in dollars per acre, of Timber Resulting from a Stand-replacing Fire, by Ownership and Inventory Region / Forest Cover Type

	Ownership				
Region / Forest Cover Type	USDA Forest Service	Other Public	Industrial Private	Non-industrial Private	All ownerships
North Coast / Redwood+ Douglas-fir		$7,818	$8,926	$7,724	$8,255
North Coast / nterior Mixed Conifer	6,299	5,800	3,403	2,334	3,960
Northern Interior	2,957	2,556	2,006	1,836	2,538
Sacramento	6,237	4,666	4,116	3,395	5,268
San Joaquin and Southern California	3,928	2,149	3,831	890	3,504
Central Coast	$4,003	$3,778	$11,073	$9,770	$8,823

Timber Volume

The most recent FIA inventory data, 1,150 plots measured in 1985, formed the basis for the standing volume estimates in this analysis, except for the national forests. The standing volume estimates were derived by adding the per-acre expansion of individual tree volume estimates on each plot, and adding all plots and their acreage expansion factors. National forest timber volume data is based on individual forest inventory data, as compiled inUSDA Forest Service publications.

Timber Value

Timber values in dollars came from the State Board of Equalization's market price schedules for the major commercial timber species in the state, by regions. Weighting the timber volume estimates by tree species with their respective estimated acreages provided an accurate current market value of the estimated standing inventory. Table 14 shows the value of the estimated total volume of standing timber in each region and ownership category. These values are valid only to the extent that sellers are price takers; the analysis did not consider the price-depressing effect of releasing large amounts of timber on the market. Table

15 shows the per-acre value of the standing timber in each region and ownership category. It resulted from dividing the total value estimates in Table 15 by the estimated acreage in each region and ownership category in Table 13.

Value Loss after Fire

The impact of fire on timber value was expressed in terms of the dollar value destroyed on the average acre in a stand replacing fire. The analysis included the following assumptions about timber value loss:

- A stand replacing fire will result in a total loss of 30 percent of the standing merchantable board foot volume. Although immediate salvage can theoretically recover close to 100 percent of the green volume, a delay of 6 months or more before salvage can be undertaken is common. The 30 percent value loss is an applicable figure for both the 1987 Stanislaus fire and the 1991 Fountain fire. The remaining 70 percent of the merchantable volume, although reduced in value, will be fully recovered through salvage harvests.
- Harvest values of salvaged timber are approximately 50 percent of green tree values. This overall estimate came from the state Board of Equalization's green harvest and salvage harvest value schedules.

Based on these assumptions, only 35 percent of the prefire timber value (70 percent of volume times 50 percent of value) can be captured after a stand replacing fire. Thus, 65 percent of the value is lost. Table 16 shows the estimated dollar value per acre lost as a result of a stand replacing fire. The figures in Table 16 were derived by calculating 65 percent of the per acre value estimates in Table 15.

Water and Watersheds[3]

Introduction

Water is both an element of the environment and a commodity. Water rights and the facilities to harness water are real property. The value of water is expressed in terms of its beneficial uses. But how much water supply does California have, what is it used for, and what is its overall value to the state? And given that water is a valuable resource, how does wildfire threaten the beneficial uses of the state's waters?

Pacific storms in the winter months and mountains tall enough to make them release their moisture bless California with an ample, if maldistributed, water supply in most years. Average statewide precipitation is about 23 inches and most of it (about 60 percent) is used by native vegetation or lost by evaporation. Estimated average annual runoff amounts to about 71 million acre-feet. This water is first used to maintain healthy riparian ecosystems in California's rivers, and eventually much of it is also used for urban and agricultural supply. The available

[3]The department is working with the State Water Resources Control Board staff, Department of Water Resources, USDA Forest Service, Los Angeles Flood Control District, Pacific Gas & Electric Co. and East Bay Municipal Utility District to refine our approaches to water and watersheds.

surface water supply totals 78 million acre-feet when out-of-state supplies from the Colorado and Klamath Rivers are added.

California uses 6 million acre-feet annually to supply urban users with residential, commercial and industrial water to support a population of over 30 million and the eighth largest economy in the world. After capture, storage, treatment, and distribution, retail customers pay on average $465 an acre-foot for this water — an annual retail value approaching $3 billion. California uses an additional 24 million acre-feet annually to support irrigated agriculture. At an average, unsubsidized value of $60 an acre-foot at the farm, this water has a value of about $1.5 billion. California also dedicates 24 million acre-feet to environmental uses. Most of this water runs its natural course through the state's river systems. Some of it is stored and released during the dry season to improve water quality in the Delta and other similarly environmentally sensitive areas. Assigning a value to this mix of wet and dry season water is problematic, but a value of $40 an acre-foot for this water would equate to about a billion dollars.

Water has many other non-consumptive values to Californians as well. For example, falling water is used to generate large amounts of hydroelectric power. In an average year, California produces about 40,000 gigawatt-hours of hydroelectric power with a value of approximately $1.6 billion. Additionally, water provides recreational opportunities and scenic beauty throughout much of the state. Conversely, excessive amounts of water can cause serious problems in many areas of the state. Floods may lead to fatalities and damage extensive amounts of personal property. A multitude of flood control structures and other measures are used to mitigate this threat. Large, intense wildfires that significantly alter hydrologic regimes and increased erosion and sediment loads can adversely affect the value of surface runoff water. Smaller, lower intensity fires that do not produce these impacts are generally not a problem. Indeed, frequent, low intensity fires are a natural part of many ecosystems. They reduce the incidence and severity of large, intense wildfires and produce the most stable watershed conditions in the long run.

California's watersheds are fire-adapted, but fire suppression is still critical to protect life and property. Total fire suppression, however, can be detrimental in the long-term to fire-adapted environments. Aggressive fire suppression without an equally aggressive program of fuels and fire hazard reduction leads to larger, more intense fires, which is ultimately detrimental to both environmental and commodity uses of water.

Since the work presented in this section was completed, we have initiated a cooperative process with the State Water Resources Control Board staff and others to refine the methods and data utilized here. An updated water and watersheds assets report will be issued upon completion of this process.

Types and Magnitudes of Impacts

Large, intense wildfires often have a negative effect on water quality and beneficial uses as a result of increased erosion and, consequently, sedimentation. Sediment increases are measured in terms of additional cubic yards of material delivered to streams and transported to places of deposition. Additional sediment storage can alter a stream's form and function in a deleterious manner. Water quality effects of wildfires are usually measured as increases in total dissolved solids (TDS) and total suspended solids. Large, intense wildfires may also increase runoff and peak flows. Increases in runoff are expressed in additional acre-feet of water.

The magnitude of these impacts in a given watershed can vary greatly with a number of factors, including type and condition of the vegetation, type of soil and its moisture content at the time of the fire, level of heat generated by the fire, slope, aspect, proximity to the nearest watercourse, and the timing and intensity of post-fire storms (USFS 1979a). Without the detail of specific cases, fire related watershed impacts can only be described in general terms.

Accelerated erosion usually leads to accelerated sedimentation. Experience on the Stanislaus National Forest, for example, indicates large, intense wildfires produce an average of 20 to 50 tons per acreper year of erosion for the first two years following burning (J. Frazier and A.Janicki, Stanislaus National Forest, pers. communication). Of this amount, about half, or 10 to 25 cubic yards per acreper year of the eroded material, reaches a stream and becomes sediment. In contrast, unburned forest lands have erosion rates of less than one ton per acre per year and less than a fifth reaches a stream to become sediment. Similarly, estimates of hillslope erosion on the Shasta-Trinity National Forest following extreme wildfire events in 1987 on 50 percent slopes with no remaining ground cover ranged from 10 to almost 40 cubic yards per acre, depending on the soil type present (Miles and others 1989). Monitoring with silt fences installed in swales on burned areas of the Shasta-Trinity with granitic soils having very little ground cover and steep slopes produced sedimentation rates up to 12.2 cubic yards per acre (Miles and others 1992).

Experience in chaparral is somewhat different (DeBano 1989). Erosion and sediment production in chaparral is more variable than in forest lands for both unburned and burned conditions. In unburned watersheds, sediment was found to collect in debris basins at rates ranging from 0 to 109 tons per acre per year[4] The range is great due to the tendency for sediment mobilization only during infrequent large storms. In burned chaparral watersheds, sediment has been collected at rates from 0 to 312 tons per acre per year (McIlvride 1984). Recently burned chaparral watersheds generally yield 6-35 times more sediment than their unburned counterparts and average a 10-fold increase (Davis 1980). Hillslope erosion rates following burning have been found to range from less than one ton per acre per year to more than 200 tons per acre per year, with slope being a critical factor in determining the amount of erosion that occurs. As with forest lands, erosion rates are high immediately after burning, but generally return to prefire levels within a few years. This is not the case, however, for steep areas where shallow-seated landsliding is the dominant erosional process. For these chaparral covered areas, the dominant window of susceptibility is 6 to 10 years

[4] *Various studies have reported erosion in different units; a ton can be assumed to be approximately one cubic yard.*

following fire when total root biomass is lowest (Rice and others 1982). In contrast, burned grasslands develop a vegetative cover so quickly that increases in erosion and sedimentation rate are generally negligible.

Large, intense fires can also have an adverse impact on water quality (USFS 1979b). Forested watersheds generally produce water with very low TDS (<50 mg/l) and low turbidity (<1 NTU). The quality of water produced from undisturbed chaparral lands is generally lower and more variable. Intense burns can cause large increases in TDS and turbidity on forest and chaparral covered areas, particularly during storm periods. For instance, Cohen (1982) found increased concentrations of nitrogen and suspended sediment in Milliken Reservoir (Napa County) resulting from the first large storm following the Atlas Peak wildfire. Nitrate concentrations were elevated above background levels during the first winter, but did not reach levels detrimental to domestic water usage. Cohen concluded that watersheds with higher nitrate background levels and similar influxes of nutrients as occurred in Milliken Creek could cause nitrate levels to approach the recommended health limit.

Increased water yield is another potential impact of large, intense wildfires. Where 75 percent to 100 percent of the vegetative cover is removed, runoff increases average from 0.1 acre-foot per acre of burned watershed for basins receiving 15 inches of mean annual precipitation to 0.8 acre-foot per acre burned for watersheds receiving 40 inches of mean annual precipitation (based on Turner 1991). Studies of shrub recovery after prescribed burning have found that the canopy reaches the 75 percent cover or 100 percent maximum evapotranspiration level in about 8 years after burning, and that the season of burning significantly affects canopy recovery (Lampinen 1982). By extension, the wildfire-caused increase in runoff might be expected to decline to near zero over a similar period of time. In forested areas, water yield increases are minimal until basal area loss to fire exceeds 50 percent (Potts and others 1989).

The additional water yields that result from catastrophic wildfires, however, are generally considered to have little value for water supply and hydroelectric energy generation. Almost all of the additional runoff occurs during the wet season and must be regulated for dry season use by surface reservoir storage (Ziemer 1987). Typically flows increase during large storm events when water is often passed through reservoir catchment systems because of flood management concerns. Additionally, the added water yield does not contribute to a dependable water supply or firm energy capacity, since the additional water is only a very temporary supply.

Peak flows, or maximum instantaneous discharges, are also increased by large, intense wildfires. In Central and Southern California watersheds, it is estimated that peak flows will often increase about 2.5 times over pre-burn conditions with intense burning conditions (R. Blecker, Los Padres National Forest, pers. comm.). Sinclair and Hamilton (1955) found that stormflow increased threefold to fivefold on a burned California chaparral watershed during the first rainy season following wildfire. Rowe and others (1954) reported increases in peak discharge that varied from 2 to 45 times normal, depending on storm size, in the first year following wildfire. Nasseri (1989) used the Stanford Watershed Model to predict the impact of wildfire on a Southern California chaparral covered watershed. This simulation indicated that a moderate storm would produce a 200percent increase in runoff and the frequency of flooding increased dramatically. Peak flow increases in intensely burned forested watersheds may be less dramatic, particularly in basins that are wholly or partially snow-dominated (B. McGurk, USFS Pacific Southwest Research Station, Albany, pers. comm.).

Water Uses at Risk and Their Value

The beneficial uses of water as a commodity include: agriculture, urban (including residential, commercial and industrial), hydroelectric power generation, recreation, and rearing habitat for commercial and sport fisheries (see Table 17). Water also has many non-commodity beneficial uses, including aquatic and riparian habitat for non-commercial species of plants and animals, and aesthetics or scenic beauty.

Water prices vary widely in California based on the source of the water and the region and type of use. The value of the water yield that can be readily converted to water supply ranges from zero in water rich areas of the state to about $2,500 per acre-foot in critically water short locations that remove salt from brackish or sea water, such as the City of Morro Bay[5]. Water values north of the Tehachapi Mountains range from $40 to $120 an acre-foot, while south of the Tehachapis values range from $300 to $600 an acre-foot. These are current values, based on estimates that assume available water can be delivered to willing customers.

Table 17. Water Values in California

Beneficial Use	Unit	Market Value	Value (Non-Market)
Urban - Northern 2/3 of California	Acre-feet	$40-120	
Urban - Southern 1/3 of California	Acre-feet	$300-600	
Agriculture	Acre-feet	$3-252	
Hydropower generation	Acre-feet	$0-320	
Fisheries: Commercial Sport	 $/lb Rec-visitor days	 $1.30 $75	
Recreation	Rec-visitor days	>$12	
Aquatic habitat for non-commercial species			X
Aesthetics			X

On average, California uses about 30 million acre-feet (maf) per year of surface water for agricultural and urban purposes. About 5 maf derived from the Colorado River is fed by watersheds outside the state. The remaining 25 maf represents the total average annual consumption of water derived from watersheds within California. Based on regional averages found in the California Department of Water Resources' updated Water Plan (CADWR 1994), this water has a statewide unit

[5] *Despite the high cost of facilities and energy for delivery, imported water would likely cost less, but is not yet available.*

value ranging from $3 to $252 per acre-foot[6], with an average of $60 per acre-foot. The total annual value of this water is $1.36 billion.

Water often has a high value for hydropower production. For example, in 1987 Romm and Ewing estimated the power generation value of water from national forests in California to range between zero and $320 an acre-foot. Water that cannot be run through a hydropower generation facility due to timing or location is worth zero from a hydropower perspective. Water with the highest possible usable head that can be run through one or a sequence of generation facilities is the most valuable. California hydropower generates an average of 40,000 gigawatt-hours annually. The value of this power at 4 cents per kilowatt-hour (M. Johanas, CA Energy Commission, pers. comm. is about $1.6 billion. This represents a minimum value and does not include the premium paid for peaking power.

Floods, like fire, are a major problem in California. Billions of dollars have been invested over the past several decades, and millions are spent annually on flood control. Fire related increases in flood magnitude can add substantially to flood damage and repair costs. Large, intense burns make local flooding worse by elevating peak flows and adding large amounts of damage-causing debris to flood torrents.

In Northern California, intense wildfires commonly burn in watersheds with tributaries containing important spawning and rearing habitat for anadromous fish. The value of these fisheries must be considered in terms of both commercial and sport fishing. Decreasing trends in the number of salmon observed in Northern California over the last several years have caused widespread concern about the long-term viability of several species. For example, the California Department of Fish and Game recently asked the State Board of Forestry to list coho salmon as a sensitive species. The number of salmon commercially caught in Northern California from 1989 to 1991 averaged only 1,156,000, with a value of approximately $1.5 million (USFS 1993). In terms of the value of sport fishing, the USDA Forest Service (1990) reported that the value of a fisherman day in California is $74.07 (adjusted to 1995 dollars).

Water-related recreation has become an integral part of society's needs. Reservoirs, natural lakes, and streams can be adversely impacted by large, intense wildfires. Water rafting is estimated to generate just over one million visitor days annually statewide (CADWR 1994). Rugged natural beauty and some of the most renowned fishing streams in North America attract over 10 million people annually to the state's North Coast region alone. The recreational opportunities provided by reservoirs generate enormous benefits to California's economy. In 1985, an estimated $500 million was spent on water-related activities in the Delta and major reservoirs. The estimated 7 million visitors to the Sacramento-San Joaquin Delta generated an estimated $125 million; the 6.6 million visitors to the 12 State Water Project (SWP) reservoirs and the California Aqueduct brought in an

[6] *Regional values of agricultural water include: North Coast-$3 per acre-foot, Sacramento-$12, Colorado River-$12, Central Coast-$14, San Joaquin-$19, Tulare Lake-$86, South Lahontan-$150, South Coast-$252.*

estimated $170 million; and benefits of the 11.6 million visitors to 10 of the 22 federal Central Valley Project (CVP) reservoirs totaled $208 million. In addition to the half-billion dollars described above, a similar amount may have been spent at the many local and regional reservoirs and streams (CADWR 1994). These estimates put the total annual value of water-related recreation statewide at $1 billion or more.

Estimates of Net Value Loss Per Acre for Large, Intense Wildfires

Large, intense wildfires can both harm and benefit consumptive uses of water. As previously stated, fire often produces a short-term increase in water yield. If this water can be captured and stored, it can be put to agricultural and urban (including residential, commercial and industrial) uses. Unfortunately, this benefit is usually associated with increased sedimentation and water quality degradation. The type of water use involved plays a major role in determining whether the outcome is positive or negative, but the overall net effect is almost always negative.

As mentioned earlier, large, intense wildfires might produce 0.1 to 0.8 acre-feet of additional runoff per acre annually for the first few years. In the best situations about half of this might be captured and stored for consumption. Depending upon location, the value of the additional water would be between zero and $1,600 an acre-foot. At $60 an acre-foot[7], this increased water yield would be worth from $3 to $12 per acre burned on an annual basis.

Most surface water consumed in California must be stored for later use. Reservoirs trap sediment, resulting in decreased capacity. Large, intense wildfires accelerate sedimentation rates, thereby reducing reservoir storage capacity and the expected life of the impoundment. Replacement capacity is very expensive to construct. For example, the proposed Los Vaqueros Reservoir Project would store 100,000 acre-feet of water at an estimated cost of $450 million (CADWR 1994) or about $4,500 per acre-foot of storage capacity. Enlargement of Shasta Reservoir could increase storage 9.7 million acre-feet at a cost of $4.5 billion or about $464 per acre-foot of storage space. An acre-foot equals about 1,613 cubic yards. Therefore, an intensely burned acre producing an extra 25 cubic yards of sediment the first year after burning would remove about 0.015 acre-feet of reservoir storage capacity. This would be a loss per acre burned of about $7 at an expanded Shasta Lake and $70 at the newly constructed Los Vaqueros Reservoir. Excavation and removal of the sediment generally costs between $4 and $40 per cubic yard, depending on factors such as end hauling distance to disposal sites (M. Bollander, Los Angeles Dept. of Public Works; C. Mitchell, El Dorado National Forest, pers. comm.). This translates to a cost that ranges from $6,452 to $64,520 per acre-foot of removed sediment, which is why it is not often adopted as a practical solution in the case of large reservoirs.

Consumptive use of water, particularly urban uses, suffer most acutely from: (1) direct fire damage to waterworks, and (2) the increased turbidity produced by large, intense wildfires. Neither is quantifiable in the abstract. Water purveyors look for the least expensive and most expeditious ways to cope with the advent or increased frequency in episodes of highly turbid raw water. There are many ways that this type of problem can be addressed. Water purveyors can, in some cases, change their water sources (e.g., drill a well or move the diversion point further upstream). They may be able to increase the storage of raw water, so they can shut

[7] *The assumed statewide average, as discussed earlier.*

off the diversion during periods of high turbidity in the supply. Likewise, they can increase the storage capacity of treated water, so they can suspend water treatment during periods of high turbidity. They can add pretreatment, like sedimentation basins or flocculation, to remove most of the suspended sediment prior to filtration. Alternately, they can install filtration systems that can handle higher turbidity levels efficiently. The costs of these solutions vary widely. Prudent operators will choose the method(s) that best meet their needs at the least cost. Such costs are so dependent on circumstances that no average or typical expenditure can be assigned.

Water conveyance structures such as penstocks and flumes are also at risk to damage from large, intense wildfires. Damage to these must be calculated on a case-by-case basis, given the variability in structure type, accessibility for repair, and degree of damage.

Flood control suffers twice from the effects of large, intense wildfires. First, as we saw in the previous discussion of chaparral lands, the frequency of large floods can be dramatically increased. For example, precipitation that would normally produce a moderate flood may suddenly be capable of producing a much larger runoff event. In a hypothetical case, a community might have to spend ten times as much for facilities capable of providing increased flood protection. Second, increased sediment and debris in flood basins costs between $4 and $40 per cubic yard to remove and dispose. Where increased sedimentation rates from intense fires are 1 to 200 tons/acre/year, annual costs can range from $0 to $8,000 per burned acre for the first few post-burn years, and this does not include the cost of potential flood damage.

Hydropower generation can be both benefited and adversely impacted by large, intense wildfires. As previously stated, fire often produces a short-term increase in water yield which can sometimes benefit hydropower production, but this benefit is often associated with increased sedimentation and water quality degradation. Assuming a water value of $70 per acre-foot[8] for hydroelectric generation, an increase of 0.5 acre-feet of water per acre intensely burned, and a utilization rate of 50 percent, the value of an acre intensely burned would be about $17.50 for the first year. This value would decline to near-zero over an 8-year period. If the increased sedimentation rate is 25 cubic yards/acre/year and the cost of removing sediment from forebays is $4 per cubic yard, the cost of the increased sedimentation would be about $100 per acre burned per year. Furthermore, there would be increased costs associated with additional wear and tear on mechanical equipment, which cannot be quantified readily. The net quantifiable effect of intense wildfire on hydropower generation is estimated to be a loss of $82.50 per acre burned per year for the first 2 to 3 years following wildfire (i.e., $17.50 per acre - $100 per acre = -$82.50 per acre).

Fisheries assets are influenced by the quality of stream habitat that can be impacted by wildfire. Potential impacts from fire include increased sedimentation,

[7] *Value given by Romm and Ewing (1987) for the Upper Feather River.*

water temperature, and nutrient loading (Kaczynski 1994). It is not possible, however, to quantify the impact a large wildfire will have on the value of commercial and sport fishing. For instance, the amount of sedimentation that occurs will depend on the soil type and slopes present. Even though it is not possible to produce a general relationship between hillslope impacts and reduced number of fish on a statewide basis, it is clear that the impacts from intense wildfire can be severe.

Wildfires reduce recreational assets in watersheds primarily through diminished aesthetic values. While it is still possible to white-water raft down a canyon that has been severely burned, most people would agree that the lowered aesthetics reduce the value of the experience. This type of phenomenon is not readily quantifiable on a dollar per acre basis. By extension, most water-related recreation losses, including reservoir recreation, produced by severe wildfire are not readily quantifiable. In specific cases where the effects of a fire were so severe that the number of visitor days for a particular use significantly dropped, the effects might be quantified. Relating that value to the number of acres burned would not produce reliable results, however, since most outdoor recreation is concentrated on a few scattered, small sites. For example, of the 12 major white-water rafting rivers in the state, more than half the use is concentrated on two relatively short reaches of one river, the American.

Watershed rehabilitation is a real and quantifiable cost of large, intense wildfires. To reduce the adverse impacts previously described, emergency watershed rehabilitation plans are implemented on severely burned watersheds with valuable downstream beneficial uses. It is common to aerial seed the most intensely burned areas with native and non-invasive species of grasses. Ordinarily, only 10 to 25 percent of the burn area is seeded in chaparral areas and less in forested areas (B. Parker, CDF, San Luis Obispo, pers. comm.). Costs range from $30 per acre to $200 per acre and average approximately $60 per acre.

Conclusion

Large intense wildfires negatively impact both water as a commodity and water as an element of the environment. The occasional, short-term positive gains from increased water yield are more than offset by the frequent short and long-term negative impacts of increased peak flows, increased sedimentation and decreased water quality (see Table 18). Dollar estimates for these impacts are elusive, notoriously unreliable, and there is great variability from one site to another in the averages presented here.

Table 18. Impacts Associated with Intense Wildfire

Beneficial Use	Benefit (+) or Cost (-) Per Acre Burned ($)	Comments
Water Yield	+$3 to +$12	1st two years
Hydropower generation	+$17.50	1st two years
Reservoir Storage Capacity	-$9 to -$90	1st two years
Reservoir Sedimentation	-$40 to -$100	1st two years
Debris Basin Cleanout	0 to -$8000	Southern CA
Watershed Rehab	-$30 to -$200	1st year only
Water Quality	negative, unquantifiable	Increased turbidity, suspended sediment
Flooding	negative, unquantifiable	Increased peak flow, debris
Fisheries	negative, unquantifiable	Increased sediment, water temperature
Recreation	negative, unquantifiable	Degraded aesthetics

Wildlife, Habitat, Plants, and Ecological Health[9]

Fire Effects on Wildlife

Fire can have two markedly different effects on wildlife habitats. Large fires do not burn evenly and as a result produce a mosaic of vegetation and post fire plant community succession. Alternatively, at a smaller scale, an intense stand-replacing fire can reduce habitat heterogeneity and foster a uniformity of food and cover value particularly in areas of similar slope, aspect, and soil type. Both outcomes may either be positive, negative, or exhibit no particular effect depending on the degree of habitat patchiness, the wildlife species of concern, and other topographic, climatic, and biological variables influencing fire effects. Similarly, the size, number, distribution, shape of unburned areas, and fire history of adjacent areas can markedly influence the population response of a particular wildlife species. Consistent generalization of the effects of post fire habitat conditions and their implications for wildlife species is not possible. Species may be favored, negatively affected, or exhibit no particular response to the post fire environment.

The general societal and frequently institutional view that fire in all its forms and potential locations results in a wholly negative effect on wildlife is mistaken. California's landscapes are dynamic expressions of climate, topography, soils, and vegetation that are continually changing at a variety of spatial and temporal scales as a result of both natural and human-caused disturbance and subsequent plant community succession. A disturbance regime characteristic of the physical environment of California was present before influence by European man and created habitats in which plants and animals had to adapt and perpetuate their kind. More recent and widespread influences by society on the structure and composition of vegetation brought about by various types of disturbance or the lack of disturbance (e.g., development, timber harvest, fire control policies, and

---

[9]We are working closely with the Department of Fish and Game to further strengthen our analysis for this asset at risk. The discussion will be broadened to better incorporate plant communities, ecosystem health, and a more complete treatment of both game and nongame wildlife species.

public attitudes toward fire) have influenced the distribution and abundance of many if not most wildlife species.

Evaluating the effects of change in fire regimes on wildlife in terms of economic gain or loss to society requires consideration of several factors. These include variation in fire attributes and location, population response of the species to the post fire environment separate from other influences, temporal response of the plant and wildlife community to the fire event, adaptation of species across taxonomic groups that occupy environments subject to repeated fire, and value society places on wildlife in either a generic or species-specific sense. Most of these variables have not been examined or remain unquantifiable.

Direct Effects. The direct effects of fire on wildlife populations vary depending on body size, mobility of the species in question, and the intensity and rate of fire spread. Most vertebrate species move away from fire although some (insectivorous birds, raptors) may be attracted, ostensibly to take advantage of available prey. Although some evidence of vertebrate mortality has been reported, the most common opinion is that these losses are negligible, particularly over the long term for those species of high reproductive potential (Lyon and others 1978). The effects of fire on invertebrate populations vary with habitats used and fire intensity. Populations of surface and soil inhabiting insects are generally significantly reduced although other species are attracted to the burned area. Reinvasion and recovery of pre burn insect populations and species diversity likely parallel recovery of the vegetation (Lyon and others 1978).

Indirect Effects. Fire sets the stage for significant and, depending on habitat type, long-term alteration of habitats. Plant succession is set back, and vegetation structure is significantly and immediately altered. Additional changes occur through the process of plant and animal community succession over time. The net positive or negative effect on habitat capability for all species potentially encountered along the successional continuum is uncertain. The immediate post fire environment presents all terrestrial and aquatic species with significant levels of habitat modification and microclimates that have both positive and negative effects. Long-lasting negative effects of a wildfire in present day fire regimes are likely limited to (1) localized stream habitats, late seral or climax forest habitats sensitive to fire effects and requiring long periods before reestablishment, (2) some seral habitats that through direct and indirect fire effects do not effectively regenerate, and (3) areas occupied specifically by species with unstable populations that are negatively affected by fire occurrence.

The number of species occupying an area may change little in response to fire in adjacent habitats. Bendell (1974) (fide Lyon and others 1978) summarized 22 studies of breeding birds and mammals in burned and adjacent unburned habitat. Overall, fire resulted in a slightly richer avifauna and stable mammalian fauna. Although some change in population density and trend of species was noted, 80 percent of bird and mammal populations remained about the same in density and population trends.

Examples

Late seral forest habitats may be increasingly fragmented or eliminated by fire of high intensity. Consequently, species exhibiting a preference or dependence on certain forest structural attributes characteristic of these plant communities may be directly and indirectly lost through habitat modification or displacement.

> Fire patterns in the Sierra mixed-conifer zone have changed radically in the twentieth century. The annual acreage burned may have declined by two orders of magnitude when compared with historic levels. This in turn has led to historically unprecedented buildups in fuels and to stand structures that are prone to crown fires. Because of these conditions, fires that escape initial suppression efforts — usually those occurring during extreme weather conditions — tend to become large, stand-replacing events. (McKelvey and Weatherspoon 1992 p.261).

> Prehistoric fire regimes have changed over time, and probably considerably for any given climate and vegetation groups, due to human influence. Modern fire control has attempted to remove fires from wildlands. Instead of removing fires, the result has been a gross distortion in the fire regimes, removing most fires of low and intermediate severity and size and increasing the proportion of large, high severity fires (Martin and Sapsis 1992 p.150).

It is axiomatic that fire suppression cannot remove fire from the landscape in perpetuity. Modern fire control, principally as a result of its own success and resultant buildup in fuels, has been required to become increasingly effective. Technological and fire management improvements have markedly influenced the effects and behavior of fire on the landscape. Other factors have also influenced vegetation development and fire regimes and include: wetter than normal weather patterns early in this century, decrease in Native American ignitions, and increase in fire prevention through public education (W. Laudenslayer, USDA Forest Service, pers. comm.).

Fire influence on plant community succession depends on the fire regime and the plant and wildlife species present. Fire occurrence in some shrub steppe habitat types (e.g., some forms of bitterbrush and sage), given present day plant community composition, negatively affects the productivity of the landscape for certain uses. The capability of shrub steppe habitat in the post fire environment of the Cascades and eastern Sierra Nevada to support a socially valued species, (mule deer), is compromised by the influence of a competing and disturbance-tolerant introduced plant species such as cheatgrass. However, in the relatively more mesic habitats of western Sierra Nevada mixed-conifer, where fire suppression has promoted plant community maturation and contributed to a reduction in deer habitat quality, fire occurrence can have a very positive effect (K. Mayer, California Department of Fish and Game,pers. comm.). Finally, unnaturally frequent patterns of fire can overwhelm the inherent ability of many fire adapted species of plants to sustain themselves. This results in type conversion to habitats adapted to a more frequent or intense fire regime (e.g., coastal sage scrub is converted to annual grassland).

California's Mediterranean plant communities, composed of many fire adapted species, depends on fire disturbance to perpetuate the type. It follows that resource use by plant and wildlife species that make up these dynamic communities would exhibit adaptations consistent with periodic habitat disturbance. These adaptations include lack of specialization in conifer habitats, enhanced dispersal capabilities, and high and variable birth rates (Udvardy 1969).

The potential negative effects of present day wildfire behavior on specific fire-sensitive species are clear. Habitat alteration that results in negative effects of any duration or the direct loss of individuals in a small population that is demographically tenuous may result in local extinction and increased risk to the species across the remainder of its range. For example, a major concern is fire risk to preferred habitat of the California spotted owl in the Sierra Nevada (USDA Forest Service 1995).

Assigning Value Lost or Gained

Several factors must be considered when determining the scope of the economic value of wildland fire's impact on wildlife. For example, Althaus and Mills (1982) suggest that:

> Resource output that cannot be readily measured in dollars should not be forced into the economic analysis. Fireeffects on rare and endangered species are examples of this class of outputs. Intended resource use plays an important role in determining fire effects. A resource loss takes place only if the resource output would have occurred in the absence of the fire

Wildlife values are generally expressed in terms of the value of a consumptive use (e.g., hunting) or non-consumptive use (viewing, bird watching, etc.). However other values also exist and include existence value (e.g., the value assigned to the knowledge that a species exists in a particular place) or bequest value (e.g., the value assigned to the knowledge that a resource will exist for the enjoyment of one's heirs). It is likely that existence and bequest values are significantly greater than the more direct forms of value assigned to wildlife (N. Dennis, Jones and Stokes Associates, pers. comm.). A major tool for determining wildlife value lost or gained for use of natural resources that are not traded in markets is contingent valuation. The contingent valuation method (CVM) is a survey technique that constructs a hypothetical market to measure individuals' "willingness to pay" or to accept compensation for different levels of non marketed natural and environmental resources. The CVM is the only method available to measure other resource values, such as the benefits the public receivesin existence and bequest values, at various levels of certainty, of unique natural environments or species (Loomis 1993).

CVM has been employed to assess the value of deer, spotted owls, gray whales, goose hunting, wildlife viewing, waterfowl in the San Joaquin Valley, salmon as a product of water quality, and several other species or area specific examples. However, the technique has not been applied to fire effects or other large scale (e.g., a statewide assessment area) habitat perturbations on wildlife (J. Loomis, Colorado State University, pers. comm.).

Determining the effects of fire on populations of all species of wildlife at a statewide scale is not feasible. Similarly, assessing the economic implications of fire on wildlife without the benefit of recognized valuation techniques makes quantitative value judgments more than problematic. Given these observations, it is only possible to make a qualitative judgment concerning the potential impact of fire on all wildlife species, in the aggregate, at a spatial scale represented by the state of California.

Fire was a common influence on the structure and function of California's ecosystems in prehistoric times with as much as 5.5 to 13 million acres burning annually on the average (Martin and Sapsis 1992). Fire regimes varied in period between fires, seasonality, dimension, and other characteristics. The fire regime exhibited under present day fire suppression policies, and as influenced by other historic variables, is one of many small low intensity fires and one of markedly more severe, less frequent, and large size fires. Nevertheless, when one considers qualitatively the economic effect of wildfires on wildlife value for all species, fire regimes, and wildland habitats at the scale of the state, it is likely that fire, at least over the short term, has had a net neutral if not beneficial effect (R. Barrett, UC Berkeley, pers. comm.; W. Laudenslayer, USDA Forest Service, pers. comm.).

Since the work presented in this section was completed, we have initiated a cooperative process with the Department of Fish and Game to refine the methods and data utilized here. An updated wildlife and ecosystem health assets report will be issued upon completion of this process.

Aggregating Values of Assets at Risk Statewide and at Ranger Units

The Fire Plan Process

As part of the fire plan, a methodology has been developed for a coarse-level aggregation of individual assets at risk into a single value measure for a given geographic area. Through this process, geographic areas will be ranked based on the potential impacts ("total cost") of a large fire event, and the likelihood of a large fire event. The objective is to identify high-risk/high- value areas. This coarse statewide analysis will provide a better understanding of the spatial distribution of the assets protected and their risks of fire damage. The statewide analysis serves as a "pointer" to where prefire projects might be needed, and aids in the identification of the "state interest" in terms of where investment of state resources is appropriate.

The process of designing and ranking prefire projects, discussed below, will involve a more detailed and quantitative analysis of assets at risk. This process, which will involve asset stakeholders, will allow the department to rank potential projects based on costs and benefits, and quantify the appropriate state contribution to cost-sharing efforts.

Mapping and Ranking Values of Assets at Risk

The previous portions of this appendix have detailed the methods used for estimating the values of assets. In addition, since the fire plan process involves identifying high value areas based on total cost of a potential large fire event, suppression costs and rehabilitation costs must also be included in the asset analysis.

For the coarse, statewide analysis, each asset at risk is represented within the GIS using the best available statewide digital data sources. For a given asset, geographic areas will be ranked as high, medium or low based on potential impacts from a large fire event, if one were to occur. A large fire event can be thought of as a high intensity fire of at least 5,000 acres. Rankings are developed based on the potential physical fire effects as well as the human valuation of those effects. For example, for air quality the physical effects of a large fire in timberlands is higher than grasslands due to production of a larger volume of smoke. The valuation of this effect will differ based on the additional factor of how many people are affected within specific air basins. For example, a timberland fire affecting the Northeast Plateau air basin will have a lower ranking than one that affects the Sacramento Valley air basin. The specific methodologies for mapping and ranking each asset follows this general discussion.

For the purpose of ranking potential impacts for a given asset, a common statewide geographic unit is required. To link the analysis to a common map source used by department field units, the seven minute quad (1:24,000 scale) boundaries were selected as a base. Since they cover large areas (about 35,000 acres), quads are divided into ninths (about 4,000 acres). The size of these units roughly corresponds to a “large fire event” The significance of this is that it can be assumed that if an asset occurs in the unit, even as a point location (e.g., a nest site or historic building), it will be affected by a large fire event.

By ranking all assets for common geographic units, the results can be displayed in a matrix similar to Table 19. Table entries, potential impact of a large fire event, are either 0 (asset not present), 1 (Low), 2 (Medium), or 3 (High).

Table 19. Example Asset at Risk Ranking Matrix

Quad	9th	Popu-la-tion	Flood	Fire Sfty	Air Qlty	H2O Qlty	Non-Game Wild-life	Ecol Hlth	Game	Rec-rea-tion	H2O Stor-age	Hydro Power	Hist-oric Bldgs	Scenic Areas	Range	Timber	Struc-tures	Suppr-ession Costs	Rehab Costs
Colfax	1	3	0	2	2	1	1	1	1	1	2	3	0	1	1	0	3	2	1
	2	3	0	2	2	1	2	2	1	1	3	3	0	1	1	0	3	2	1
	3	2	0	2	2	1	2	2	1	1	2	3	0	1	2	0	2	1	1
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	9	1	0	1	2	1	2	1	1	2	3	3	0	1	2	0	1	1	1
Westville	1	1	0	1	1	1	1	1	1	1	2	0	0	2	2	0	1	1	1
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	

Identification of High-Value Areas

The asset rankings in the above matrix must be combined into an overall ranking based on the entire spectrum of assets the department protects. The result of this process is a designation of high-value areas. By including all impacts of a large fire event, both economic and non-economic, high-value areas represent places where the total cost plus damage of a large fire event would be greatest.

Given the ranking approach used, a scheme for weighting assets at risk, or assigning relative values, must be developed in order to aggregate values across asset categories. Obviously, assigning weights that explicitly quantify the relative importance of the various assets to the state interest will be controversial. However, it cannot be avoided if high-value areas are to be identified. It is not the role of the department to attempt to single-handedly determine these weightings. Rather, this task will be done through the stakeholder process at the ranger unit level.

The State Constitution provides “direction” in terms of the priority ranking various public issues: (1) public safety; (2) public health; (3) the environment; and (4) public welfare. Using these categories as an organizing framework, Table 19 suggests how assets might be grouped.

While the Constitution suggests a higher priority of weighting as you move from left to right in Table 19, it provides no specific weights. While the magnitude of impacts is potentially more severe on the left, the frequency with which impacts occur is far greater on the right. For example, while a large fire event that takes human life is tragic, it is less frequent than the event that has major impacts on public welfare.

Map Production and Distribution

For each asset at risk, two maps will be produced. First, the ranking map displays quad ninths shaded as white (asset not present), light gray (Low), gray (Medium), or black (High). Second, the asset map shows the actual data used to generate the rankings, for example recreation areas, watersheds prone to fire-flood, historic buildings, or range vegetation types. Both of the maps are produced in black and white in 8.5" by 11" format. This will allow stakeholders with standard printers to access the files electronically. It also will allow the department to easily reproduce the maps for distribution.

Field Validation of Assets at Risk

The initial coarse asset analysis for the state will be “fine-tuned” by successive ranger units. For each asset, GIS data will be provided to the ranger unit for the actual location of the assets. The data included may be finer-scale (e.g., from county GIS programs) than that used for the statewide analysis. A ranking matrix (Table 20) generated from the asset data will be provided to ranger units as the database file associated with a GIS data set of quad ninths.

Table 20. Assignment of Assets at Risk to Public Issue Categories

Public Safety	Public Health	The Environment	Public Welfare
Population	Air quality	Non-game wildlife (2) (3)	Game wildlife (3)
Fire-flood watersheds	Water supply	Ecosystem health (3)	Recreation
Firefighter safety (1)			Water storage
			Hydroelectric power
			Historic buildings
			Scenic areas
			Range
			Timber
			Structures
			Fire suppression costs (1)
			Rehabilitation costs(1)

(1) Methodology for mapping and ranking not yet developed.
(2) Includes numerous assets at risk for different rare species, plant communities, and habitats.
(3) Methodology for mapping and ranking under development in cooperation with Department of Fish and Game.

Field validation involves three possible refinements of the statewide analysis. First, the scale of the asset data, changes since mapping occurred, or mapping errors could lead to improper ranking of some quad ninths. For example, a new subdivision may not appear in the population asset data, leading to the associated quad ninth being erroneously ranked aslow.

Second, the ranking procedure used at the state level foran asset at risk may be inadequate to capture all instances of high value. For example, the ranking procedure for air quality is based on fuel type and population within air basins. At the local level, even though the larger air basin is sparsely populated there could be a small inversion-prone valley containing settlement especially sensitive to smoke, for example a retirement community. This could merit a higher ranking, even though other areas in the air basin are ranked low.

Finally, there may be assets that have local importance that were not included in the statewide analysis. For example, a timber mill that is an important component of a local economy would not appear in the statewide framework. As a general guide to identifying assets at risk, important qualities to consider include, but are not limited to, uniqueness, economic value, public investment, and any special legal status.

There could be three processes for field validation, depending on the asset at risk (Table 21). Complete validation is used for assets that typically occur as a relatively small number of point or area locations. Actual location and fire susceptibility of all occurrences of these assets can be verified and re-mapped if necessary. For example, all state designated historic landmarks that are buildings (as opposed to plaques) can be visited, evaluated for fire susceptibility, mapped within the GIS, and ranked in the quad ninth matrix. Stream channels that feed hydroelectric power plants can probably be verified without site visits based on field knowledge of local power plants.

Table 21. Assets at Risk for Three Different Validation Procedure Classes

Complete Validation	Spot Validation	Cooperative Validation
Water quality	Population, structures	Wildlife assets at risk
Recreation	Fire-flood watersheds	Ecosystem health
Water storage	Air quality	Range
Hydroelectric power	Timber	
Historic buildings	Suppression, rehab costs	
Scenic areas		

Spot validation will be used for assets that typically cover the entire ranger unit in complex spatial arrangements, where complete validation is not feasible. The ranking map can be scanned for obvious omissions, inconsistencies, or gross errors. For these problem areas, better information will be needed through field experience or actual site visits. The procedure will be to change the quad ninth ranking in the matrix and document the reason for the change. For most of these assets, it will not be feasible to change the actual base data since it will typically involve a significant mapping effort. For example, mapping the actual boundaries of timber stands is probably not an efficient use of departmental resources (and could meet landowner resistance).

For assets that require a specific expertise, it may not be possible for the department to independently validate the data, thus requiring a cooperative validation process. For these assets, the department will need to engage local expertise, such as Fish and Game biologists or extension agents. Further, the stakeholder process at the ranger unit level will help to validate the assets analysis, as well.

Since this is the department's first attempt at the considerable task of ranking and validating all assets susceptible to fire, it is impossible to initially design a framework that captures all important asset values. The asset framework and validation process will be refined as the fire plan process progresses through the ranger units based on direction from the Board of Forestry, department field staff, and stakeholders.

Prefire Management Project Selection and Cost Sharing

Following the aggregation of assets at risk, as described above, and the overlaying of the high fire hazard data layer, the ranger units will be able to identify the high-risk/high value areas that are most in need of prefire management projects. Once these areas are identified, the department can begin to design potential prefire projects (such as fuels management, forest health, land use planning, and fire prevention) to reduce suppression costs and impacts to assets at risk. The next step in the fire plan process is to determine how limited funds should be allocated among these potential projects. Given that department funds for prefire projects are limited, the department must carefully and systematically select the projects that provide the greatest benefit for a given investment.

The primary goal of the department in implementing prefire projects is the reduction of fire suppression costs and subsequent disaster relief to the state; reduction of losses to assets is of secondary importance. Thus, in selecting among prefire projects to be applied in high risk/high value areas, the department will look first at a project's potential to reduce state suppression and disaster relief costs should an ignition occur during a severe fire weather period. Those projects that provide the greatest potential suppression cost savings for a given project cost will be highest on the department's list for implementation.

Another key factor that must be identified is who is receiving the benefits of the prefire projects and who, accordingly, should be responsible for paying for them (i.e., private landowners, local, state, or federal government, or interest groups). Thus, another step in the project selection and funding process is to determine these factors and to approach the benefiting parties to request that they share in project funding. The department will not be able to implement projects for which other benefiting parties do not provide an adequate amount of cost-share funding, particularly where these projects do not offer a significant potential reduction in fire suppression costs. The process of working out cost-sharing of prefire projects will be carried out through the stakeholder processes conducted at the ranger unit level.

For each potential prefire project considered by a ranger unit, a framework such as that presented in Table 22 will need to be completed. The table shows, for a hypothetical prefire project, which stakeholders — state, local, federal, or private — would benefit. Beyond this simple identification of values and beneficiaries, determinations could be made, to the degree possible, of the relative extent of benefit and, thus, the relative shares of the project costs that each stakeholder should be considered to be responsible to support. For example, assuming that each cell with an X in Table 22 represents an equal benefit value, then the state would be expected to support 1/2 of project cost (split among the Air Resource Board, Department of Water Resources, Department of Fish and Game, and the Department of Forestry and Fire Protection), local government would be expected to support 3/8ths, and private parties 1/8th of project costs.

Table 22. Identifying Assets Affected and Stakeholders for a Hypothetical Prefire Project

	Stakeholders			
Assets at Risk	State	Local	Federal	Private
Air Quality	X (ARB)	X		
Range				
Recreation				
Structures		X		X
Timber				
Watersheds	X (DWR/DFG)	X		
Wildlife and Plants	X (DFG)			
Other Assets				
Suppression and Rehabilitation Costs	X (CDF)			

Summary

The fire plan assets at risk assessment results in the identification of prefire management projects, within ranger units and across the state, that offer the greatest net benefits to the state, local government, federal government, and the private sector. The first step of this process, the statewide identification, quantification, and valuation of assets at risk to large, damaging fires, has been largely completed, although work is ongoing with the Department of Fish and Game, the State Water Resources Control Board staff, and other stakeholders to refine our approaches to wildlife, plants, ecosystem health, water, and watersheds. The second step of aggregating assets across the state on a geographically is under way. Work to refine the statewide data has commenced with the first pilot ranger unit. Once this is completed, and the fire hazard overlay added to the analysis, the ranger unit will be able to identify those areas that have the highest fire hazard and risk, and thus merit consideration for the application of prefire projects. Once potential prefire projects are identified, the beneficiary identification and cost-sharing analysis procedures can be initiated. Finally, project selection and implementation decisions can be made on the basis of which projects provide the highest benefits and have received an adequate level of funding from the various benefiting parties.

Literature Cited

Althaus, I.A. and T.J. Mills. 1982. Resource values in analyzing fire management programs for economic efficiency. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. GTR-PSW-57 Berkeley, CA. 9p.

Bendell, J.F. 1974. Effects of fire on birds and mammals. In: Fire and Ecosystems, p. 73-138. T.T. Kozlowski and C.E. Ahlgren (eds.) Academic Press, New York.

Air Resources Board. 1994. Emission Reduction Offsets Transaction Cost Summary Report for 1993. Stationary Source Division, Air Resources Board, California Environmental Protection Agency. Sacramento. 18p.

California Department of Water Resources. 1994. California Water Plan Update, Bulletin 160- 93. Sacramento, CA. 3 volumes.

California Energy Commission. 1995. 1994 Electricity Report. Preliminary approved draft. California Energy Commission, Sacramento.

California Energy Commission. 1993. 1992 Electricity Report. California Energy Commission, Sacramento.

California State Office of Historic Preservation. 1995. pers. comm. between Dan Foster (CDF) and Bill Seidel (Coordinator of the California Archaeological Inventory) on January 23, 1995 concerning the number of archaeological and historical sites in California.

California State University. 1987. Attitudes Concerning the Use of Fish and Wildlife Resources in the state of California. Survey Research Center report to the California Department of Fish and Game, Sacramento. California State University, Chico.

CH2MHILL. 1989. California Livestock Industry Economic Model. Final report, prepared for California Department of Forestry and Fire Protection. CH2MHILL, Sacramento.

Chestnut, L.G., R.L. Dennis, and D.A. Latimer. 1994. Economic benefits of improvements in visibility: Acid rain provisions of the 1990 Clean Air Act Amendments. Paper presented at International Specialty Conference, Snowbird Utah, September 26-30, 1994. 13p.

Cohen, W.L. 1982. Effects of the Atlas Peak fire on surface water quality in Upper Milliken Creek Watershed, Napa County, California. Unpubl. Master of Science thesis. Univ. of California, Davis. 66 p.

Davis, D.J. 1980. Rare and unusual postfire flood events experienced in Los Angeles County during 1978 and 1980. In: California Institute of Technology Environmental Quality Laboratory Symposium on Storms, Floods, and Debris Flows in Southern California and Arizona, 1978 and 1980. p. 243-256.

DeBano, L.F. 1989. Effects of fire on chaparral soils in Arizona and California and postfire management implications. Proceedings of the Symposium on Fire and Watershed Management. October 26-28, 1988, Sacramento, CA, General Technical Report PSW-109, USDA Forest Service, p. 55-62.

Goldman, George and Ellen Gates. 1986. Estimates of the Economic Value of California's Wildlands: Recreation and Grazing, 1983. Cooperative Extension, University of California, Berkeley.

Kaczynski, V. 1994. Wildfire impacts on stream habitats. Prescribed Burning Issues and Notes, Oregon Department of Forestry, November 1994, v. 4 no. 1.

Keye, Donna and Pearlstein Inc. 1985. State of California Tourism research: a Quantitative Study of Travel Patterns, behaviors, and attitudes. Keye, Donna, and Pearlstein Inc., Los Angeles.

Lampinen, B.D. 1982. Regeneration of chaparral shrubs after prescribed burning. Unpubl. Master of Science thesis in ecology. Univ. of California, Davis. 36 p.

Loomis, J.B. 1993. Integrated Public Lands Management: principles and applications to National Forests, Parks, Wildlife Refuges, and BLM Lands. Columbia University Press, New York. 470p.

Lyon, J.L., H.S. Crawford, E. Czuhai, R.L. Fredriksen, R.F. Harlow, L.J. Metz, and H.A. Pearson. 1978. Effects of fire on fauna: a state of knowledge review. USDA Forest Service National Fire Effects Workshop, Denver, Co., April 10-14, 1978. USDA Forest Service, Gen. Tech. Rept. WO-6.

Martin, R.E. and D.B. Sapsis. 1992. Fires as agents of biodiversity: pyrodiversity promotes biodiversity. p. 150-157. In: Harris, R.R. and D.E. Erman (tech. coords.) and H.M. Kerner (ed.). Proceeding of the symposium on biodiversity of northwestern California, October 28-30, 1991, Santa Rosa, CA. University of California, Wildland Resources Center Report No. 29, Berkeley, CA. 316p.

McDougald, N. 1995. pers. comm.. Extension Advisor, Madera County, Madera, CA. March 15, 1995.

McKelvey, K.S. and C.P. Weatherspoon. 1992. Projecting trends in owl habitat In: Verner, J., K.S. McKelvey, B.R. Noon, R.J. Gutierrez, G.I. Gould, and T.W. Beck (tech. coords.). The California spotted owl: a technical assessment of its current status. Gen. Tech. Rept. PSW-GTR-133. Albany, Ca: Pacific Southwest Research Station, USDA Forest Service, U.S. Department of Agriculture; 285p.

McIlvride, W.A. 1984. An assessment of the effects on prescribed burning on soil erosion in chaparral. USDA Soil Conservation Service. Davis, CA. 102 p.

Miles, S.R., D.M. Haskins and D.W. Ranken. 1989. Emergency burn rehabilitation: cost, risk, effectiveness. Proceedings of the Symposium on Fire and Watershed Management. October 26- 28, 1988, Sacramento, CA, General Technical Report PSW-109, USDA forest Service, p. 97- 102.

Miles, S.R., D.M. Haskins, and C. Lukacic. 1992. Erosion monitoring and its implications for management. Proceedings of the Conference on Decomposed Granitic Soils: Problems and Solutions. Oct. 21-23, 1992, Redding, CA. Univ. Extension, UC-Davis. p. 92-97.

Nasseri, I. 1989. Frequency of floods from a burned chaparral watershed. Proceedings of a symposium on Watershed management. USDA Forest Service General Technical Report PSW- 109. p. 68-71.

Potts, D.F., D.L. Peterson, and H.R. Zuuring. 1989. Estimating postfire water production in the Pacific Northwest. Res. Paper PSW-197. Berkeley, CA., 9 p.

Reinhardt, T.E., A. Hanneman, and R. Ottmar. 1994. Smoke Exposure at Prescribed Burns — Final Report. Report prepared for USDA Forest Service, Pacific Northwest Research Station, and University of Washington, Department of Environmental Health. USDA Forest Service, Pacific Northwest Research Station, Seattle, WA.

RERI. 1994. The Air Quality Valuation Model. Draft report prepared by Regional Economic Research, Inc., April 21, 1994, for California Energy Commission, Sacramento, CA.

Rice, R.M., R.R. Ziemer, and S.C. Hankin. 1982. Slope stability effects of fuel management strategies — inferences from Monte Carlo simulations. Gen. Tech. Rep. PSW-58. Berkeley, CA. Pacific Southwest Research Station.USDA Forest Service. p. 365-371.

Romm, J.M. and A. Ewing with S. Yen and R. Haberman. 1987. The economic value of water in National Forest management. Proceedings of the California Watershed Management Conference (West Sacramento, CA, November 18-20, 1986), published by Wildland Resources Center, University of California as Report No. 11, pp. 89-102.

Rowe, P.B., C.M. Countryman, and H.C. Storey. 1954. Hydrologic analysis used to determine effects of fire on peak discharge and erosion rates in southern California watersheds. California Forest and Range Experiment Station, Berkeley, CA. USDA Forest Service. 49 p.

Sinclair, J.D. and E.L. Hamilton. 1955. Streamflow reactions to a fire-damaged watershed. Proceedings of the hydraulic division of the American Society of Civil Engineers. 15 p.

Tietenberg, T.H. 1985. Emissions Trading — An Exercise in Reforming Pollution Policy. Resources for the Future, Washington, D.C. 222p.

Tippet, D. pers. comm.. California Department of Food and Agriculture, Sacramento. March 1995.

Turner, K.M. 1991. Water salvage from Mediterranean-type ecosystems. In: Water Supply and Water Reuse: 1991 and Beyond. Proceedings of the American Water Resources Association annual symposium. p. 83-90.

Udvardy, M.D.F. 1969. Dynamic Zoogeography with special reference to land animals. Van Nostrand Reinholt, Princeton, New Jersey.

US Department of Commerce. 1986. Statistical Abstract of the United States. US Department of Commerce, Bureau of Census, Washington D.C.

USDA Forest Service. 1995. Managing California spotted owl habitat in the Sierra Nevada National Forests of California: an ecosystem approach. Draft Environmental Impact Statement. USDA Forest Service, Pacific Southwest Region, San Francisco, CA.

USDA Forest Service. 1995. Draft Environmental Impact Statement — Managing California Spotted Owl Habitat in the Sierra Nevada National Forests of California. 2 volumes. Pacific Southwest Region, San Francisco, CA.

USDA Forest Service. 1993. Forest ecosystem management: an ecological, economic, and social assessment. Rept. of the Forest Ecosystem Management Assessment Team.

USDA Forest Service. 1990. Resource pricing and valuation procedures for the recommended 1990 Resource Planning Act (RPA) Program. USFS Washington Office. 33 p.

USDA Forest Service. 1979a. Effects of fire on soil. General Technical Report WO-7. 34 p.

USDA Forest Service. 1979b. Effects of fire on water. General Technical Report W0-10. 28 p.

Ziemer, R.R. 1987. Water yields from forests: an agnostic view. Proceedings of the California Watershed Management Conference (West Sacramento, CA, November 18-20, 1986). Report No. 11, Wildland Resources Center, University of California, Davis. p. 74-78.

Appendix D. Prefire Management Process: For Pilot Ranger Units and the Postfire Component

Summary

"If you always do what you always did, you will always get what you always got." That adage, cited in the Strategic Fire and Resource Protection Plan for the Stanislaus National Forest, presents a solid if colloquial argument for prefire management with a strong postfire element.

Prefire management addresses fuel loading, fuel arrangement, land-use patterns and ignition management to reduce the costs and losses of wildland fires. The postfire element seeks and applies lessons to be learned after each large, damaging wildfire to break the cycle of disastrous fires.

The importance of successful prefire management is evident in the increasing intensity of wildland fires, high damage levels and suppression costs; population increases and movement into wildland areas; and limited fire-protection budgets at private, local, state and federal levels.

Increased development in traditional wildland areas has varied throughout the state, but three fairly distinct categories have evolved: highly developed land; development intermixed with wildland; and solely wildland areas (undeveloped). Add in the changes in the natural fire regime, with accompanying increase in fuel loading, and the result is a complex challenge for wildland fire protection agencies. It should be addressed in planning and implementing prefire, suppression and postfire programs.

All three phases of fire management must be targeted at areas with high-value assets at high risk of loss to large, high-intensity wildfires. This priority acknowledges the limited federal, state and local budgets for fire-protection agencies. It will require inventories of assets to be protected, comparison with the hazards they face, and factoring in the probability a large fire will occur. It is where these areas overlap that additional investment is warranted to reduce losses.

One traditionally narrow aspect of fire protection is postfire treatment. Generally, it has meant rehabilitation efforts to reduce soil erosion after a large intense fire. Little attention has been paid to the future conditions of the landscape and corresponding development, but long-term results dictate the conditions and fuels available in the next large wildfire.

It is time to expand postfire treatment from watershed rehabilitation into broader prefire management that will break the cycle of large damaging wildfire. Postfire management must include postfire assessments, watershed rehabilitation, prefire management analyses and a collaborative planning process. In turn, it must be part of a balanced approach addressing fire prevention, forest health, land-use planning, and fuel and ecosystem management. To be successful, these programs will require:

- Comprehensive planning and increased coordination — not just by the traditional fire and land management agencies but also by private landowners, private industry, the education system and other resource-related organizations.
- A greater level of investment by those who benefit the most from fire protection at private, local, state and federal levels. The costs and benefits of each planning and implementation project will require more attention.

Postfire Assessment

Wildfires affect both natural resources and those developed by society. All these resources were the assets at risk before the fire and the same assets will be at risk when the area burns again. There are the basic steps to postfire assessment.

Identify resources. Nine basic classifications of assets at risk were identified in the wildland fire protection planning effort undertaken by the Board of Forestry. They are life and safety, air quality, range, recreation on public wildlands, structures, timber, water and watershed, wildlife and habitat for listed species, and other resource assets (such as unique scenic areas and cultural and historic resources). These eight provide a starting point; other assets to protect from wildfire can be identified locally.

Take prefire inventory of the area. This would first include such natural conditions as soils, vegetation, topography, watercourses and wildlife habitat conditions. Second is an inventory of prefire development; it would include conditions of the transportation system, types of structures and building materials used, water sources, landscaping near structures, and any presuppression activities that were used.

Note damage to both natural and development resources. An effort should be made to include factors that could have reduced the damage. For example, where structures had wood-shingle roofs, it should be noted that a change in building materials could have reduced the chance of loss. Where a plantation burned, any opportunity to provide prefire treatment of the plantation or surrounding area should be noted.

A Planning Approach for Postfire Hazard Reduction

The information gathered from the postfire assessment supports a planning process that can reduce losses of valued assets when the next large fire burns all or part of the same area. It provides the base for watershed rehabilitation and managing the area overall to avoid re-creating the conditions that supported the first fire. This is prefire management.

It addresses the components of fuel loading, fuel arrangement, land-use patterns and ignition management through a prefire management *plan*. Its tools include traditional fire prevention, vegetation (fuels) management, forest health and land-use planning programs that are more aggressively emphasized in a focused effort. Prefire management does address the protection of high-value, high-risk, high-hazard areas which are likely to burn under optimum fire weather conditions.

Management options include:

- ❍ Ignition reduction (education and arson programs)
- ❍ Hazard mitigation (prescribed burning or mechanical fuels reduction treatments)
- ❍ Exposure mitigation (fire-safe building standards, land-use planning, insurance policy conditions, and application of near home fire-safe guides)
- ❍ Fire suppression planning
- ❍ Silvicultural treatments for improving forest health
- ❍ Forest management to achieve fire-resistant forest structure
- ❍ Research and technology development
- ❍ Development of cooperative agreements and mechanisms

The implementation and execution of the prefire strategy (postfire hazard mitigation) must be part of a larger process. That provides a comprehensive plan involving all institutions and stakeholders in the planning and implementation of a strategic fire management plan for a given fire environment.

Prefire Planning Process for Pilot Ranger Units

Using the prefire planning process results in guides to postfire hazard reduction. It will yield the most efficient blend of the prefire tools and the ratio of cost vs. losses most acceptable to the local community.

The Board of Forestry 1995 Fire Plan is moving to implement a process for the development of prefire management in three of CDF's ranger units: Nevada-Yuba-Placer, Tuolumne-Calaveras and Riverside. The process will be refined and set an example of how to develop a plan that will reduce the cost of suppression together with a reduction in losses of assets at risk.

The process employs 13 steps that can be followed by any interested community, watershed group, resource conservation district or other locally organized group. This will likely require the participation and assistance of the wildland fire protection and land management agencies within the planning area.

1. CDF staff produces maps of the local area showing:
    - Success rate of initial attack fire protection agencies

- Fuel hazards
- Commodity and non-commodity assets protected
- Severe fire weather days per year.

All four criteria are to be summarized in high, medium and low risk categories. The results are to be shown on geographic information system (GIS) maps.

2. A separate GIS map is generated that identifies the high-risk areas where prefire management is to be applied.
3. CDF FRAP unit provides the ranger unit with an assets at risk GIS map for each asset in the area.
4. Separate community level meetings are scheduled with respective stakeholders for each asset at risk. The meeting is to acquaint the stakeholders with the process and bring their expertise and knowledge to bear on the asset maps that identify high-, medium- and low-risk areas.
5. Ranger unit personnel provide ground review and validation of the high-risk prefire management areas. Validation will be used to make any identified corrections in GIS maps.
6. Ranger units correct the maps with assistance, as needed, from CDF headquarters staff. Headquarters produces final GIS maps for developing prefire management projects.
7. The ranger unit forms a group with local expertise to define alternative prescriptions for prefire management projects that will reduce total costs and losses of a future major fire burning through the area in severe fire weather.
8. Ranger unit staff, with assistance from headquarters staff and from stakeholders with expertise, identify economic and non-economic assets protected and estimated reductions in costs and losses if prefire management projects are implemented.
9. Ranger unit staff identifies the mix of local, state or federal government or private funding needed for prefire management projects based upon the levels of interest and stockholder values.
10. Prefire management projects are ranked based on cost effectiveness and local community and stakeholder values.
11. The ranger unit holds a second set of meetings with the stakeholders who are to provide funding.
12. The results are presented at a public meeting in the community to review the assessments, results and proposed prefire management projects.
13. The pilot prefire management projects are aggregated for use in approaching the defined funding organizations.

The process not only should address local fire protection needs but also should result in projects to address ecosystem needs. Involving all organizations and the private sector provides greater potential of overcoming the institutional and funding barriers that have killed similar plans in the past.

Annual (or more frequent) monitoring should be included when prefire management plans are implemented. It helps determine effectiveness of the projects in reducing costs and losses to the wildland fire protection system. Monitoring should be tested against pre-project conditions and should allow for adjustments for initial attack fires. Results should be used to adjust project design and priorities over time.

A prefire management plan will remain a living document as long as it is guided by the local community needs.

Appendix E. Blue Book Allocation and Staffing Standards

Introduction

An analysis of the current Blue Book Staffing and Allocation Standards indicates that they are not meeting current fire protection needs. Existing standards are tied to the 1985 Fire Plan and have not been updated since that time. During this period the value of the funding for the currently authorized positions have been impacted due to various budget decisions. Additionally the funding and authority required to staff the budgeted fire season does not match the operational definition of fire season.

The analysis of fire season length and staffing allocations was conducted using actual ranger unit fire history and damage based on 10-13 years of actual fire occurrence data and 34 years of initial attack success based on the current Board of Forestry policy of suppressing all fires at 10 acres or less. The Department will make a recommendation prior to the 1996 fires season in regard to the current three allocation levels for Board consideration to more accurately reflect the severe fire periods when resources need to be staffed at the highest level of readiness.

The Blue Book is associated with the Temporary Help Blanket positions. These temporary positions are funded for staffing during "an average bad fire season." The staffing and allocation staffing levels are spread over three periods — 1 - Spring; 2 - Peak; 3 - Fall. The continuing goal of these three periods for initial attack engines are as follows:

- During the spring and fall periods, staffing will be consistent with the fuels, weather, and expected fire severity.
- During the peak period, every action must be made to provide 3.0 staffing for all initial attack engines during the daylight period with some planned overnight uncovering of second engines at two-engine stations.

During severe seasonal conditions when fire severity is expected to exceed the "average bad fire season,"[10] additional funding, staffing and/or augmentations will be requested.

---

[10] *The “average bad fire season” is an average of the past 10-15 years of fire season activity described in duration of months and weeks, broken out as (“transition” in or out of “peak”) and “peak” periods. This is known as the budgeted fire season.*

With regard to contract counties and the Gray Book, any changes to the Blue Book should be studied for applicability.

The current Blue Book fire season periods and staffing standards are included in the appendix for reference.

Action

- ❍ The department will be recommending to the Resource Protection Committee changes to the current three allocations levels that more accurately reflect severe periods and a higher level of readiness.
- ❍ An analysis of the Gray Book in regard to action #1 needs to be completed within time limits recommended by the Resource Protection Committee.

E Fund

Emergency fund expenditures are being analyzed by the department. The main focus for now is statewide trends. This issue should be brought back for further fire plan analysis when department analysis is complete.

Crew or Station Type	Civil Service Class and Category	Number of Personnel	Allocation Level I	II	III
Detection					
lookout	flo - seas pm	2	9	11	0
Dispatch					
ecc - r.o.	clerk	3	3	3	3
ecc - r.u.	capt - coded	3	3	3	3
Ground attack					
1 engine station	capt - coded	2	2	2	2
	capt - perm pm	0.5	8.334	8.486	8.654
	fae - seas pm	1	4.2	4.2	6
	ff-i - seas pm	3.5	16.28	18.78	21.28
2 engine station	capt - coded	2	2	2	2
	capt - seas pm				
	fae - coded	1	1	1	1
	fae - seas pm	1	8.4	9.1	13.6
	ff-i - seas pm	7	32.55	37.55	42.55
dt standard	hfeo coded	2	2	2	2
dt w/1 camp hfeo	hfeo coded	1	1	1	1
Air Attack					
air base	capt - seas pm	2	12	12	12
	fae - seas pm	1	4.25	4.25	4.25
	ff-i - seas pm	3.5	14	14	14
Helitack					
Light copter	capt - coded	1	1	1	1
	capt - seas pm	1	4	4	4
	fae - seas pm	2	7	7	7
	ff-i - seas pm	6	24	24	24
Medium copter	capt - coded	1	1	1	1
	capt - seas pm	3	16	16	18
	fae - seas pm	2	7	7	8.4
	ff-i - seas pm	6	36	36	58.5
	pilot - coded	1	1	1	1
	pilot - seas pm	1	4.5	4	6.5

Allocation Levels: (in months)	Current	Season Length (in months)	Peak Length (in months)
I	May 15 - Nov 15	6	4
II	May 1 - Dec 1	7	5
III	Apr 15 - Dec 15	8	6

Glossary

CEQA

California Environmental Quality Act

climax forest

See *late seral forest.*

CFES-IAM

California Fire Economics Simulator-Initial Attack Module, a software program for modeling the initial attack system and simulating changes in the fire protection system.

contract counties

In California, the six counties that provide fire-protection services in state responsibility areas under contract with the state. These counties are Marin, Kern, Santa Barbara, Ventura, Los Angeles, and Orange.

defensible space

Adequate space (free from flammable vegetation) between structures and flammable vegetation, which allows firefighters a safe working area within which to attack an oncoming wildfire.

FMAZ

Fire management analysis zone, the basic planning unit for fire protection planning.

ICS

Incident Command System.

ignition management

Includes fire prevention program activities that are aimed at preventing the ignition of wildland fires and/or reducing damage from fires. Components include law enforcement, public education, engineering, fuels modification, and fire-safe planning.

initial attack

The wildfire control efforts taken by resources that are first to arrive at a wildfire.

interface, or wildland interface

The geographical meeting point of two diverse systems, wildland and structures. At this interface, structures and vegetation are sufficiently close that a wildland fire could spread to structures or a structure fire ignite vegetation. See *intermix*.

intermix, or wildland intermix

Interspersing of developed land with wildland, where there are no easily discernible boundaries between the two systems. An example would be what real estate brochures describe as “ranchettes” or “weekend farmer” homes. Poses more problems in wildland fire management than*interface*.

I-zone

Casual reference to wildland interface and/or intermix.

late seral forest

A forest that has evolved, through successional processes, near to the end of the successional line, or climax forest. Only through disturbance (fire or clear-cutting, for example) will the forest return to an earlier seral (successional) stage.

pollution rights

In some areas, industries can buy and sell rights to emit specified amounts of pollutants.

ranger unit

Administrative unit of the CDF.

silviculture

The art of cultivating a forest; forestry.

stakeholder

Any person, agency or organization with a particular interest — a stake — in fire safety and protection of assets from wildland fires.

stand-replacing fire

A fire that kills most or all of the trees in a section of forest.

uncontrolled fire

Any fire that threatens to destroy life, property or natural resources, and either is not burning within the confines of firebreaks, or is burning with such intensity that it could not be readily extinguished with ordinary tools commonly available. See *wildfire*.

wildland fire

Any fire occurring on undeveloped land. See*wildfire*.

wildfire

A fire occurring on wildland that is not meeting management objectives and thus requires a suppression response.

Sources include the Glossary of Wildland Fire Terminology, produced by the Incident Command System Working Team; published by the National Wildfire Coordinating Group