## INTRODUCTION

Fire, erosion, plant succession, and surface and ground water flow are upper watershed processes that contribute to the water supply and water quality of the Bay-Delta. Major factors that effect these processes are fire suppression, wildfire, road building and maintenance, water diversions, livestock grazing, timber harvest, and forest management practices.

The vision for upper watershed health and function is to reduce the adverse effects of stressors sucha as wildfire, erosion, sedimentation, timber harvest, road construction, and water diversions in order to maintain watershed health and the ability to contribute to the health of the Bay-Delta ecosystem. Water supply and water quality in the Central Valley require healthy watershed processes in the upper portions of the tributary watersheds. Land and resource management in the upper portions of tributary watersheds have substantially modified watershed processes and affected the reliability of inflows of high-quality water to the Sacramento-San Joaquin Delta and San Francisco Bay. Management activities have also affected the available capacity of reservoirs that store water for water supply and provide flood control to downstream residents. Upper watershed stressors include wildfire, road construction and maintenance, water diversions, timber harvesting, and livestock grazing.

## BACKGROUND

### WILDFIRE

Prehistorically, fire was a principal mechanism by which the nutrients contained in forest material were recycled. With fire frequency reduced since the late 1800s recycling of forest nutrients has been reduced, which in turn has lessened forest and watershed health. The Native American practice of setting fires to enhance their environment has stopped and fire suppression policies and large-scale livestock grazing has been introduced (Vankat 1977, Kilgore and Taylor 1979, Swetnam et al. 1992). In response, rates of biomass decomposition have dramatically declined and fuels have accumulated throughout most upper-watershed wildlands. Because wildfires are less frequent, they now burn larger areas with higher intensity and with greater environmental damage than occurred during the presettlement period (McKelvey et al. 1996).

Wildfires can have devastating effects on watershed health that, in turn, affects the quantity, timing, and quality of inflows to the Delta and San Francisco Bay from the upper watersheds. Catastrophic wildfire can produce more intensive and extensive changes in watershed conditions than any other form of disturbance (Kattelmann 1996).

Over the past century, fire suppression and logging of large conifers have resulted in forests dominated by dense stands of tree species that are relatively small, shade tolerant, and fire sensitive, such as white firs and incense-cedars (Parsons and

DeBendeetti 1979). Consequently, there has been a large increase in the volume and continuity of live and dead wood fuels near the forest floor that provide a fuel "ladder" that connects surface fuels with the forest canopy (McKelvey et al. 1996). Risks of large, severe fires have increased accordingly. Such changes have been greatest in the lower and middle elevations of the Sierra Nevada, which is also where human development has been most rapid. With the increase in hazardous fuel conditions, human populations and property potentially endangered by fire have also increased. On a regional scale, Sierran forest ecosystems are believed to be outside the range of variability that was present in the historical ecosystem regarding fire frequency and severity, forest structure, and landscape mosaic (distribution of vegetation patches) (Skinner and Chang 1996).

Nonthinned conifer stands are widespread in the Sierra Nevada. These stands have dense understories that provide the horizontal and vertical continuity of fuels that fires need to move from the ground surface to the forest canopy. Excessive competition for water and sunlight in nonthinned stands often weakens or kills trees, resulting in increased fuel loads, potential fire severity, and the rate of spread (Weatherspoon 1996). Present fuel conditions in much of the Sierra Nevada support the potential for large, severe fires (Sapsis et al. 1996).

Timber harvesting substantially increases fire hazards unless postharvest slash treatments (e.g, piling and burning) are implemented (Stephens 1995, Weatherspoon 1996, van Wagtendonk 1996, Elliott-Fisk et al. 1996). Forest-practice regulations, which apply on all private timberland in California, require only minimal slash treatments (e.g., lopping branches and tops) and only in a highly limited area (within 50-100 feet of publicly accessible roads and 100-200 feet of structures maintained for human habitation) (14 CCR 917.2).

Catastrophic fire is detrimental to watershed function and water quality. By killing vegetation, burning the organic matter in litter and soil, and forming impervious soil layers, severe fires accelerate runoff from the watershed. More water is discharged over a shorter period of time, peak flows are greater (contributing to increased flood hazards), and summer and fall streamflows are lower than those in less disturbed watersheds. Bare soils and increased runoff cause greater detachment and transport of soil particles. With reduced infiltration, saturated soil conditions and mudslides become more prevalent. Sediment carried to streams increases markedly, particularly where riparian vegetation is burned (Kattelmann 1996). In addition to the direct effects of catastrophic fires, ground disturbance related to fire suppression and postfire activities (e.g., salvage logging) adversely affects water quality. Although total annual water yield from a watershed may increase for several years following a fire, the value of the increased yield is limited because it occurs during peak flows.

## ROADS

Roads are probably the most important cause of accelerated erosion in western montane forests (Kattelmann 1996). They reduce rainfall infiltration, oversteepen adjacent cut-and-fill slopes, and, by intercepting subsurface flows, divert runoff across compact surfaces. Stream crossings are particularly important sources of sediment because of their direct disturbance to the channel. The failure of an individual culvert, for example, can cause gullies and landslides, resulting in hundreds of tons of sediment entering streams and storage reservoirs (Weaver and Hagans 1994). Landslides and surface erosion can often be traced to haphazard road design, location, and construction; carefully planned road systems disturb less ground and produce less sediment than poorly planned systems.

Road instability is often increased by inadequate maintenance. Funding for maintenance of forest roads in the State is inadequate and continues to decline. In addition to removing unneeded roads or closing them seasonally, reshaping roadcuts, pulling back side-cast material, "ripping" compact surfaces, and removing stream crossings can be

effective means of rehabilitating watersheds (Kattelmann 1996).

### Timber Harvest

Although soil disturbance associated with felling trees and skidding logs expose forest soils to rainfall, which causes some soil compaction, timber harvesting has less of an effect on soil erosion than road construction (Kattelmann 1996). Clearcut areas are relatively susceptible to erosion until vegetative ground cover becomes reestablished. After harvest, the ability of the remaining tree roots to inhibit erosion gradually declines until new trees become well established. Using tractor skidders on highly erodible or unstable areas can lead to accelerated erosion or landslides. Timber harvesting and using heavy equipment adjacent to streams increases streamside erosion. Best management practices implemented by the U.S. Forest Service (USFS) on national forest lands and required on private forest lands by the California Forest Practice Rules limit the extent of clearcuts and the use of heavy equipment on erodible or unstable lands.

Timber harvesting affects peak flows by reducing transpiration (i.e., the amount of water used within a specific period by plants to build tissue) and by accelerating snowmelt by exposing snow-covered areas to the sun. Excessive vegetation removal can increase flooding, particularly during small and moderate storms and in small basins (Kattelmann 1996); however, increased thinning and selective harvesting has the potential to increase usable water yield by reducing transpiration.

### Grazing

Like road construction and timber harvest, past grazing practices have left a legacy of watershed degradation in California. Livestock grazing has probably affected more land in the Sierra Nevada than any other management activity (Menke et al. 1996). Although livestock density on forest lands has generally declined since the late 1800s, grazing continues to affect watershed health and function.

The hydrologic effects of grazing are primarily related to livestock behavior and management. Loss of streamside vegetation from grazing promotes soil compaction and erosion. Trampling of streambanks causes erosion and sedimentation in many montane meadow streams. Removal of riparian vegetation by livestock in headwater valleys of the North Fork Feather River, for example, has led to rapid channel widening and massive sediment loads (Kattelmann 1996). Impacts of grazing on watersheds can be substantially reduced by removing livestock before residual forage becomes deficient.

## Restoration Needs

Current land uses in the upper watersheds make it infeasible to return to the prehistoric fire regime, where fires occurred every 8-26 years depending on vegetation type and climate (McKelvey et al. 1996). Not only are structures, infrastructure, and managed forests at too great a risk of fire damage to permit burning at the pre-European average rate of at least 1 million acres annually, but regulatory constraints and the social costs of fire and its effects (e.g., low air quality) prohibit burning at pre-European scales. Although fire will remain an essential element of these wildland ecosystems, it must be controlled and used in conjunction with other techniques to reduce fuel loads to levels consistent with maintaining watershed and forest health.

Prescribed fire is an effective tool for managing forest fuels (McKelvey et al. 1996). It includes prescribed ignited fires (fires intentionally set to burn a planned area at a planned intensity) and prescribed natural fires. Prescribed natural fires are those resulting from unplanned ignitions (caused by lightning or humans) but for which plans have been adopted that specify conditions and areas under which such fires will be allowed to burn. Prescribed natural-fire planning represents an important opportunity for wildfire

help to meet management objectives, rather than be in conflict with them. Mechanical fuel-management techniques (e.g., thinning) can also reduce fire hazard (Elliott-Fisk et al. 1996).

From a practical perspective, perhaps the most important requirement for successful fuel management programs is a viable market for small trees and other biomass materials removed from wildlands. Products made from these materials include pulp chips, panel products (e.g., particle board), biomass energy fuel (e.g., for production of electricity), ethanol, and lumber. A major limitation on the marketability of biomass materials is their high handling costs. Recent innovations in logging equipment could substantially increase the feasibility of marketing such materials, which, in turn, would enable more extensive fuel treatments.

Unless resource commitments are made to implement fuel management on an unprecedented scale, catastrophic wildfires will have increasingly detrimental environmental and socioeconomic consequences, among the most important of which are impaired watershed functions and nonsustainable yields of high-quality water.

Except for spur roads that are needed to access local areas, the forest road systems that provide access to the montane regions of California are largely complete. Although thousands of miles of existing roads are obsolete or in disrepair, they continue to supply large volumes of sediment to streams, similar to toxic waste dumps that remain ongoing sources of water pollution (Kattelmann 1996). Substituting modern cable yarding systems for tractor log skidding could provide opportunities to replace many streamside roads with midslope or ridgetop roads to reduce sedimentation. Road realignment and installation of adequate drainage in poorly designed and drained segments could reduce erosion and sedimentation throughout the upper watersheds.

Effective implementation of best management practices for silviculture are likely to minimize the adverse effects of timber harvesting on watershed health and function. For example, compliance with streamside zone protection measures, restrictions on use of tractors on highly erodible and unstable areas, and limits on the size and density of clearcuts will minimize accelerated sedimentation associated with logging. Expanded thinning of dense forest stands could increase water yields.

Increased management of livestock herds to avoid depletion of residual vegetation, removal of riparian vegetation, and trampling of streambanks will reduce the effect of grazing on stream sedimentation.

The short-term objective to manage fuel loads in the upper watershed is to develop a comprehensive strategy, and establish treatment priorities to achieve fuel levels of pre-European-settlement conditions in selected areas. Because of the infeasibility of treating all wildlands within a reasonable time period, a strategy should be developed that identifies treatments that not only reduce hazards of treated areas, but also increase the defenses of adjacent areas against catastrophic fire. The strategy should also identify areas where such treatments should first be applied. For example, an extensive system of fuel breaks along ridgetops and roads could enhance the ability of fire suppression forces to protect surrounding areas. Similarly, a system of fuel profile zones (broad areas treated to reduce fuel loads and ladders, thus reducing fire severity and spotting potential) could be installed around forest communities to protect human life and property. The following actions would help to achieve these short-term objectives:

- Prepare fuel management plans at the county or subcounty level that identify treatments, priorities and schedules for their application, and means to ensure the availability of adequate resources to implement the treatments.

- Expand the application of prescribed natural fire, particularly on relatively remote federal forest lands.

- Increase resource allocations for fuel management without decreasing fire suppression resources to dangerous levels.

- Provide increased training in fuel management, including cross training fire suppression specialists.

- Identify means to expand markets for biomass materials removed from wildlands.

- Adopt more stringent requirements for slash disposal following timber harvesting.

- Refine analytical tools (e.g., landscape-level models of fire behavior) to facilitate identification of effective fuel management regimes and cost-effective strategies to implement them.

The short-term objective for controlling road-related erosion and sedimentation is to identify and prioritize watershed hazards that could be reduced through reconstruction or installation of drainage improvements on all major public and private timberland in the upper watersheds. The following action would help to achieve this objective:

- Conduct comprehensive road inventories on all major timberlands to identify hazardous conditions, assess the feasibility and cost-effectiveness of projects to reduce the hazards and prioritize feasible projects for implementation.

The long-term objective for fuel management in the upper watersheds is to achieve fire fuel levels comparable to prehistoric conditions in sufficient areas so that, based on the projected availability of fire suppression resources, when large, intensive fires do occur they can, with a high degree of assurance, be contained within a single fourth-order watershed (an area of 3,000-10,000 acres). The following long-term actions would help to achieve this objective:

- Implement fuel management treatments on a scale and schedule consistent with standards specified in county-level fuel management plans.

- Implement actions to expand markets for biomass materials.

The long-term objective for controlling road-related erosion and sedimentation is to replace poorly designed segments of existing forest road systems with well-designed and adequately drained roads. The following actions would help to achieve this objective:

- Decommission or obliterate obsolete roads.

- Replace streamside roads designed to facilitate tractor skidding that are sources of large volumes of sediment yield with midslope or ridgetop roads to be used in conjunction with cable yarding systems.

- Reconstruct poorly designed road segments and install adequate drainage structures in poorly drained road segments.

## IMPLEMENTATION OBJECTIVE AND INDICATORS

The implementation objective for upper watershed health and function is to restore ecological processes in the upper watersheds in order to maintain and improve the quality and quantity of water flowing into the tributaries and rivers of the Sacramento-San Joaquin Delta and San Francisco Bay.

Indicators of the health of upper watersheds are the extent of forest fuel loads, timber stand conditions, extent of roads, the potential and extent of erosion, and streamflow regimes.

# LINKAGE TO OTHER PROGRAMS

## FUEL MANAGEMENT

Recognition of the critical need to increase wildland fuel management has increased substantially in recent years. Several land management and wildfire suppression agencies have implemented or expanded programs to increase the application of fuel treatments. ERPP's goals will be advanced by coordinating with and supporting the following programs.

**California Department of Forestry and Fire Protection's Vegetation Management Program.** The Vegetation Management Program (VMP) was initiated in 1981 to reduce wildfire damage and enhance resource values by reducing wildland fuel hazards. For several years, VMP focused primarily on prescribed burning of private rangelands. Following a series of catastrophic wildfires in southern California in fall of 1993, the California Department of Forestry and Fire Protection (CDF) convened the VMP Working Group to review the program's purpose and performance. As a result of that review, VMP's focus has expanded to encompass all major ecosystems in the State and a wide range of fuel management techniques. Its focus has shifted to reducing hazards at the urban interface, where most assets are at risk. In addition, the acreage targeted for annual treatment is substantially greater than the average acreage that has been treated in the past. CDF is preparing a program environmental impact report to facilitate environmental compliance for a wide variety of fuel treatment projects.

**California Department of Forestry and Fire Protection's Prefire Management Initiative.** As part of the California Fire Plan, CDF is implementing a prefire management initiative to conduct prefire planning at the ranger-unit (i.e., county or multicounty) level throughout the portions of the State for which CDF has fire suppression responsibility (California Board of Forestry 1996). Three ranger units (Nevada-Yuba-Placer, Tuolumne-Calaveras, and Riverside) initiated this planning process in 1996; the 19 remaining ranger units and six contract counties are expected to initiate it in 1997. The process is scheduled to be completed in 1999.

The prefire planning process will be based on developing geographic information system (GIS) maps depicting assets at risk, levels of fire suppression service, and fire weather severity. Community-level public meetings will be held to review the maps for accuracy and to solicit input regarding acceptable levels of service by area. Ranger unit staff will validate high-risk locations, which will provide the focus for developing prefire management prescriptions, and prioritize projects based on cost-effectiveness. Additional stakeholder meetings will then be held to review project priorities.

**California State Water Resources Control Board's Delta Tributary Watershed Program.** As part of the California Safe, Clean, Reliable Water Supply Act (Proposition 204), the State Water Resources Control Board (SWRCB) is administering the Delta Tributary Watershed Program. This is a $15 million grant program to enable rehabilitation projects in watersheds tributary to the Sacramento-San Joaquin Delta or the Trinity River. Eligible projects will reduce contamination of drinking water, increase water yield or watershed retention capability, enhance fish habitat, control sedimentation, or improve overall forest health.

**U.S. Department of Agriculture Forest Service's Forest Health Initiative.** A 1995 report recommended that the U.S. Forest Service shift from its traditional focus on fire suppression and control to comprehensive fire management, taking into consideration the essential role of fire in forest ecosystems (U.S. Department of Agriculture 1995). The agency subsequently announced a commitment to improve forest health throughout the national forests in the western United States, including expanded application of fuel management in densely stocked stands with excessive fuel loads (U.S. Department of the Interior and U.S. Department of Agriculture 1995). Underlying this initiative is the goal of

maximizing the amount of national forest land periodically receiving fuel management treatment.

**The Quincy Library Group's Community Stability Proposal.** The Quincy Library Group (QLG) is a coalition of diverse stakeholders from Lassen, Plumas, and Sierra Counties who have organized to obtain consensus on forest management policies to promote forest health, ecological integrity, adequate timber supply, and local economic stability. Because most of the land in these counties is in national forests, QLG is focused primarily on strategies for managing federal forest land. Portions of the budgets of the Lassen, Plumas, and Tahoe National Forests have been allocated for projects developed by QLG. QLG is the most highly developed example of local consensus-building to influence national forest management policies and programs including those for watershed restoration and fuel hazard reduction.

### Road-Related Watershed Hazards

**Watershed Assessments for Programmatic Environmental Compliance Documents.** Many private timberland owners are conducting watershed assessments as part of their preparation of environmental compliance documents to meet federal or State regulatory requirements. The federal Endangered Species Act, for example, enables landowners to obtain permits authorizing take of listed species incidental to otherwise lawful activities pursuant to preparation and approval of a habitat conservation plan (HCP). HCPs addressing listed or candidate fish species typically include a watershed assessment to address cumulative watershed effects, including road-related erosion and sedimentation hazards. Similarly, several private landowners are preparing either sustained yield plans (SYPs) or program timberland environmental impact reports (PTEIRs) to meet the requirements of the California Forest Practice Act regarding the maximum sustained production of high-quality forest products and minimization of significant environmental impacts. These State-level programmatic environmental compliance documents also require watershed assessments addressing cumulative watershed effects. Watershed assessments being prepared for HCPs, SYPs, and PTEIRs provide important opportunities to identify and remediate road-related watershed hazards.

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